



Massachusetts Bay Transportation Authority

Green Line Extension Design Build Project

Cambridge, Somerville, and Medford Massachusetts

Execution Version

VOLUME 2

Exhibit 2A – Technical Specifications

MBTA Contract No. E22CN07

December 11, 2017

Exhibit 2A.1

Mandatory Specifications

Exhibit 2A.1

MANDATORY SPECIFICATIONS PREFACE

Section references within these [Mandatory] Specifications in the form of “Section XXXXX” are references to specifications, by such number, in Exhibit 2A and Exhibit 2I. Except as otherwise noted, all other section references are references to Volume 2 Technical Provisions.

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SECTION 02224

REMOVAL, PRESERVATION, AND REUSE OF HISTORIC ELEMENTS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies removal, preservation, and reuse of historic elements as indicated on the Project Definition Plans, including, but not limited to, the following:
1. Historic Steel Elements: Steel bents cut from the existing historic viaduct at Lechmere, for reinstallation in their existing location after the new viaduct has been constructed. Work includes cutting out portions of the existing structure so that the new viaduct structure can pass over it. Historic Steel Elements shall be stored in a safe, secure and enclosed area provided by the DB Entity.
 2. Historic Concrete Elements: Concrete demolition work for the bridge seat and on the parapet of the historic Lechmere Viaduct, the demolition the Homans building (See Section 7.1), which are to be removed, labeled, protected and stored at the Somerville DPW, Pier 13.
- B. Related Work:
1. Section 03300 – CAST IN PLACE CONCRETE
- C. Historical Conservator: The DB Entity will engage a Historical Conservator that meets the National Park Service's (NPS) standards set forth at 36 CFR Part 61 regarding qualifications for preservation/conservation professionals at http://www.nps.gov/history/local-law/gis/html/table_of_contents.html. The Historical Conservator will meet the NPS professional standards and have demonstrated experience performing conservation work within the guidelines of the American Institute for Conservation Code of Ethics and Guidelines for Practice at https://www.nps.gov/training/tel/Guides/HPS1022_AIC_Code_of_Ethics.pdf. The MBTA will review and approve the qualification requirements for the DB Entity's proposed Historical Conservator. The duties of the DB Entity's Historical Conservator will include, but not be limited to the following:
1. Approving proposed methods for removal, preservation and handling.
 2. Documenting existing conditions by still photographs (Article 1.2.D) and preparing a report to be submitted to the MBTA prior to beginning the Work of this Section.
 3. The review of submittals described in this section.
 4. The review of specialist qualifications.
 5. On site review of the work described in Part 3 – EXECUTION of this specification section.
 6. Coordinate with the MBTA and other members of the project team.

1.2 SUBMITTALS

- A. Removal Specialist: Qualifications of the proposed qualified Historical Conservator and Historic Metalwork, Masonry, Concrete and Steel Removal and Dismantling, and Refinishing Specialist's for review by MBTA.
- B. Shop Drawings: Fabrication and installation details for historic elements to be reinstalled for review by MBTA. Include structural analysis data signed and sealed by the qualified professional engineer licensed in the Commonwealth of Massachusetts responsible for their preparation
 - 1. Include plans, elevations, sections, and details of connections.
 - 2. Show anchorage and accessory items.
 - 3. Provide information and specifications for cutting, paint removal/stabilization, coatings, and finishes of historic steel sections.
 - 4. Provide copies of all information to the Historical Conservator to review and coordinate with the MBTA.
- C. Construction schedule for Historic Elements: Submit a construction schedule to the MBTA for review and acceptance. Include detailed sequence of Historic Element work with start and end dates, coordinated with the MBTA's continuing operations and with any other related work planned by the MBTA or in progress at other locations that is likely to be affected by the Work of this Project.
- D. Preconstruction Documentation: Prepared by or in coordination with the Historical Conservator, showing pre-existing conditions of adjoining construction, including finish surfaces, that might be misconstrued as damage caused by the DB Entity's historic element operations. Documentation shall include a record of measurements, materials, and construction details of the Historic Elements.
- E. Construction approach for Historic Elements: Submit procedures for the scope of this Section to demonstrate the means, methods and materials to ensure that the following guidelines are applied:
 - 1. Retain as much existing material as possible.
 - 2. Use additional material or structure to reinforce, strengthen, prop, tie, and support existing material or structure.
 - 3. Record existing work before each procedure (preconstruction) and during the course of the Work with digital documentation such as video recordings and still photographs.
 - 4. If missing features are indicated to be repaired or replaced by the Historical Conservator or the MBTA, the DB Entity shall provide features whose designs are based on accurate duplications of the existing structure rather than on conjectural designs.
 - 5. Where the Work requires existing features to be removed or dismantled, perform these operations without damage to the material itself, to adjacent materials, or to the substrate.
 - 6. Exposed concrete surfaces resulting from the cutting of the historic concrete Lechmere Viaduct shall be treated to protect from environmental degradation.
- F. Structural Procedures Report: The DB Entity shall engage a professional engineer, licensed to stamp and seal drawings in the Commonwealth of Massachusetts, to survey existing conditions of the scope

of Work and to evaluate demolition and reconstruction impacts on the existing structure based on the DB Entity's means and methods. The evaluation shall be submitted as a Structural Procedures Report and shall include, but not be limited to, the following.

1. Adherence to notes specified on the Project Definition Plans.
 2. Requirements for the structural integrity of the system during construction activities.
 3. Protection of the structure to remain against any and all damage.
 4. Recommendations against compromising the structural integrity and capacity of the system.
 5. Requirements for temporary supports, bracing, shoring and underpinning.
- G. Cleaning and Protection: Submit for review cleaning materials product data sheets, application means, methods and environmental condition requirements and disposal procedures.

1.3 QUALITY ASSURANCE

- A. Historical Conservator: The DB Entity shall engage the services of a qualified Historical Conservator who shall work cooperatively with the MBTA. The DB Entity shall make all task related information available to the Historical Conservator and shall make all arrangements necessary for site visits.
1. The Historical Conservator shall visit the Project site daily when work of this Section is in progress. The Historical Conservator shall not be changed or replaced during the term of the Work on the historic Viaduct structure except for a cause judged by the MBTA to be beyond the control of the Historical Conservator specialist or firm.
- B. Removal and Refinishing: Removal, dismantling and refinishing work shall be performed by a qualified Historic Metalwork Specialist or Historic Masonry and Concrete Removal and Dismantling specialist, as appropriate, with the following qualifications:
1. Experience in historic metal or concrete removal work as partial demolition of a historic building or historic landmark structure in the last two years. Qualifications shall be submitted for review by the Historical Conservator and the MBTA.
 2. Two letters of reference for previous experience, completed by previous facility owners and submitted to the Historical Conservator and the MBTA.
- C. Historic Element Preconstruction Conference: The Historical Conservator and the MBTA shall be present at this meeting. Review methods and procedures related to historic element including, but not limited to, the following:
1. Review and finalize the construction schedule for Historic Elements; verify availability of materials, equipment, and facilities needed to continue the Work and avoid delays.
 2. Review qualifications of personnel assigned to the Work and their duties.
 3. Review material application, work sequencing, tolerances, and required clearances.
 4. Review areas where existing historic construction is to remain and requires protection.

PART 2 - PRODUCTS

Not Used

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Preparation for Removal and Dismantling: Examine all Historic Elements construction items to be removed or dismantled in order to determine best methods for safely and effectively performing removal and dismantling work. Examine adjacent work to determine what protective measures will be necessary. Make explorations, probes, and inquiries as necessary to determine the condition of all construction to be removed or dismantled and location of utilities and utility services to remain that may be hidden by construction that is to be removed or dismantled.
1. Verify that affected utilities have been disconnected and capped.
 2. Inventory and record the condition of items to be removed and dismantled for reinstallation or salvage.
 3. Before removal or dismantling of existing Historical Elements that will be reproduced or duplicated in final Work, make a permanent record of measurements, materials, and construction details that will be required to make exact reproductions of these elements.

3.2 HISTORIC REMOVAL AND DISMANTLING EQUIPMENT

- A. Removal Equipment: Use only hand-held tools except as follows or unless otherwise approved by the Historical Conservator, on a case-by-case basis:
1. Light jackhammers are allowed
 2. Large air hammers are not permitted.
- B. Dismantling Equipment: Use manual, hand-held tools, except as follows or otherwise approved by the Historical Conservator, on a case-by-case basis:
1. Hand-held power tools and cutting torches are permitted only as submitted for review and following approval by the Historical Conservator. All such tools must be adjustable so as to penetrate or cut only the thickness of material being removed.
 2. Pry bars more than 18" long and hammers weighing more than 2 lbs. are not permitted for dismantling work.
- C. Cleaning Equipment: Use only passive, non-chemical cleaning methods for cleaning concrete surfaces unless otherwise approved by the Historical Conservator.

3.3 GENERAL PROTECTION

- A. Ensure that the Historical Conservator is on-site and on duty when Historic Element Work begins and throughout the progress of the Work.
- B. Protect persons, motor vehicles, adjacent surfaces, the work-site in general, plants, and surrounding buildings from harm resulting from historic element procedures.
 - 1. Use only proven protection methods, appropriate to each area, material and surface being protected.
 - 2. Contain dust and debris generated by removal and dismantling work on historic Viaduct and prevent it from reaching the public and adjacent or nearby surfaces.
 - 3. Provide shoring, bracing, and supports as necessary.
 - 4. Protect the site and abutters from debris due to demolition activities.
- C. Temporary Protection of Historic Materials: Protect existing historic materials with temporary protections and construction. Do not deface or remove existing materials outside the limits shown for removal and dismantling. Do not attach temporary protection elements to historic surfaces except as where indicated to be part of the construction approach for Historic Elements and as approved by the Historical Conservator.

3.4 HISTORIC REMOVAL AND DISMANTLING

- A. Ensure that Historic Metalwork or Historic Masonry and Concrete Removal and Dismantling Specialist's field supervisors are present when removal and dismantling work begins and at all times during the performance of this work. The Historical Conservator shall be present at all times that this work is underway and shall observe the progress of Work. Historical Conservator shall offer comments and recommendations regarding the performance of this Work prior to its initiation and during its performance.
- B. Perform Work according to the detailed sequence of shop drawings, the Construction approach for Historic Elements and other accepted submittals.
- C. Use water-mist sprinkling and other wet methods to control dust only with adequate, accepted procedures and equipment that ensure that such water will not create a hazard or adversely affect other building areas or materials.
- D. Keep equipment that is not permitted for historic removal or dismantling work away from the vicinity where such work is being performed.
- E. Protect historic surfaces from damage by tools and machinery. Support each Historic Element as it becomes loosened to prevent stress and damage to the historic surfaces. Dismantle anchorages.

3.5 STORAGE AND PROTECTION

- A. Storage and Protection: When taken from their existing locations, catalog and store Historic Elements within a weathertight enclosure where they are protected from wetting by rain, snow, condensation, or ground water, and from freezing temperatures.

1. Identify each item with a non-permanent mark to document its original location. Indicate original location of each item on plans, elevations, sections, and/or photographs by annotating the documents with these identifying marks.
2. Secure stored materials to protect from theft and vandalism.

3.6 REINSTALLATION

- A. Comply with recommendations of the Historical Conservator and the MBTA. Install materials in accordance with accepted submittals.

END OF SECTION

SECTION 02450

SECONDARY CONTAINMENT SYSTEMS - GEOSYNTHETIC BARRIER

PART 1- GENERAL

1.1 DESCRIPTION OF WORK

- A. Design, furnish and install a prefabricated and complete geosynthetic barrier oil containment system including all accessory materials including excavation of soil materials, installation of backfill to form a secondary containment system around oil-filled electrical equipment.
- B. The DB Entity shall propose a suitable secondary oil containment system to be placed under/around each oil filled transformer. The system shall comprise of a buried geosynthetic barrier that will allow the passage of rain water but impede the flow of oil.
- C. DB Entity shall size the containment system meeting the necessary oil containment requirements, i.e. volume of oil, based on the specifics at each site and shall propose the required crushed stone to meet the necessary void ratio as recommended by the manufacturer. It is expected that one containment area will be constructed at each traction power substation and that the containment area will encompass all the transformers at that location.
- D. Geosynthetic barriers typically installed as a "Passive" secondary containment measure also used in "Active Containment" situations to impede or block the flow of oil from reaching drainage structures or waterways.
- E. Excavation and backfilling shall be performed to prevent damage to adjacent properties, buildings, structures, utilities, underground piping, electric cable, cable trays, grounding systems, and other facilities.

1.2 RELATED SECTIONS

- A. Section 02300- EARTHWORK
- B. Section 02240- DEWATERING

1.3 APPLICABLE CODES, STANDARDS AND REFERENCES

- A. IEEE Std 980-1994 R2001 (The Institute of Electrical and Electronics Engineers) Guide for Containment and Control of Oil Spills in Substations.
- B. Code of Federal Regulations (CFR) 40 CFR Protection of the Environment; PART 112- Oil Pollution Prevention.
- C. AASHTO No. 57 (American Association of State Highway and Transportation Officials)

1.4 QUALITY ASSURANCE

- A. Design geosynthetic barrier under direct supervision of a Professional Engineer experienced in the design of such Work and to accommodate site conditions.
- B. Excavations shall comply with the local Building Code and published standards.
- C. Manufacturer shall be company(s) specializing in manufacturing geosynthetic barrier systems with minimum three years of documented experience.
- D. Installer shall be company(s) specializing in installation of geosynthetic barrier or similar systems with minimum three years of documented experience.
- E. Engage the services of a trained manufacturer's representative to be on Project site during geosynthetic barrier installation.

1.5 SUBMITTALS

- A. See Sections 2.7 and 2.8
- B. Submit qualification and experience record for designers.
- C. Product Data: Provide containment system dimensions & materials (including geotextile fabric, barriers, partition barriers, etc.); describe components within assembly and anchorage of fasteners.
- D. Design drawings for each location, including, if necessary, the method of installing the fabric around pipes or conduits and at perimeter supports.
- E. Design Data: Provide physical characteristics and engineering calculations and identify dimensional requirements/limitations.
- F. Shop Drawings: Indicate geosynthetic barrier dimensions, affected related Work and details including overlap at joints.
- G. Samples: Submit two samples 6 by 6 inches in size illustrating barrier materials.
- H. Warranty: Submit manufacturer warranty and ensure forms have been completed in MBTA's name and registered with manufacturer.

1.6 DELIVERY, STORAGE AND PROTECTION

- A. Handle products of this section in accordance with manufacturer's requirements.
- B. Protect geosynthetic barrier materials during transport and on Project site storage prior to installation.

1.7 WARRANTY

- A. Provide manufacturer warranty against failure of barrier material when installed properly including provision for replacement of failed units.

- B. Warranty shall be in effect for the Service Life of installed product.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Geosynthetic barrier shall be designed to prevent flow of hydrocarbons from a site by becoming an impervious barrier in the event of an oil release and allow unrestricted water flow during normal rainfall or snow melt events.
- B. Barrier shall be suitable to be laid horizontally at the bottom of the containment area.
- C. Materials to adjoin to adjacent concrete walls shall be proposed. Refer to the Design Documents for details.

2.2 PERFORMANCE

- A. The geosynthetic barrier shall have a hydrocarbon flow rate: 0 gpm.
- B. The secondary containment system must be able to contain 110% of the oil volume in the equipment or have a freeboard of 3.5” for 100% of oil volume, whichever yields the largest storage volume.
- C. Geosynthetic barrier must be able to flow a minimum of 3 GPM per square foot of material with one foot of head pressure
- D. Shall meet Spill Prevention Control and Countermeasures (SPCC) requirements in accordance with 40 CFR 112.

2.3 FABRICATION

- A. Fabricate components with minimum clearances around perimeter of assembly, yet enabling installation and dynamic movement of perimeter seal.
- B. Accurately fit and secure joints and corners. Make joints flush.
- C. Prepare components to receive anchor devices.
- D. Arrange fasteners and attachments to conceal from view.

2.4 MATERIAL FOR COVER

- A. Gradation requirements shall be determined in accordance with AASHTO No. 57.
- B. For fills categorized as "crushed stone" or equivalent clean stone comply with the following:

Coarse Aggregate

Sieve Size		AASHTO No. 57 (percent passing)
50 mm	2 inch	-
37.5 mm	1.5 inch	100 min
25 mm	1 inch	95 - 100
19.0 mm	0.75 inch	-
12.5 mm	0.5 inch	25 - 60
9.5 mm	0.375 inch	-
4.75 mm	No. 4	10 max
2.36 mm	No. 8	5 max
1.18 mm	No. 16	-

PART 3 – EXECUTION

3.1 EXAMINATION

- A. Verify dimensions, tolerances, and method of attachment.
- B. Verify that anchorage devices have been properly installed and located.

3.2 INSTALLATION

- A. Avoid damage wherever excavation is being done. The width of such excavation shall not exceed the width necessary for the proper prosecution of the work.
- B. Install geosynthetic barrier in accordance with manufacturer's instructions.
- C. Overlap and splice barrier sections, as necessary, according to the shop drawings and the manufacturer's recommendations.
- D. Barrier should not be cut or trimmed without the approval of the manufacturer or their representative.
- E. Attach to grade to permit sufficient adjustment to accommodate construction tolerances and other irregularities allowing expeditious progress of the work.
- F. Comply with site MBTA and operator's safety practices particularly in close proximity to active electrical equipment.
- G. Stage the work in accordance with the manufacturer's recommendations.

3.3 FIELD QUALITY CONTROL

- A. Verify barrier is firmly attached to supports before placing cover material.

3.4 CLEANING AND PROTECTION

- A. Remove any protective material.
- B. Repair minor damage to surfaces to the satisfaction of the manufacturer prior to cover material being installed.
- C. Protect barrier during installation of cover material.

END OF SECTION

SECTION 02850

LIGHT RAIL TRACK CONSTRUCTION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies Ballasted Transit Track Construction on the Project.
- B. Ballasted transit track construction shall include:
 - 1. Constructing new ballasted transit track.
 - 2. Placing and compacting ballast.
 - 3. Placing and compacting subballast.
 - 4. Placing and aligning wood ties.
 - 5. Thermal adjustment of existing Continuous Welded Rail (CWR).
 - 6. Aligning and clamping rail.
 - 7. Installing welded rail joints.
 - 8. Initial tamping, gauging, lining and surfacing track.
 - 9. Testing and corrections/adjustments to completed track.
 - 10. Other operations as specified.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Delivery, unloading and handling of 115 RE rail and procedures for creating CWR strings is in Section 02851 - RAILROAD RUNNING RAIL.
- B. Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- C. Section 02854 – TRACK SURFACING AND ALIGNMENT.
- D. Turnout procurement and installation is in Section 02855 – SPECIAL TRACKWORK.
- E. Section 02865 – TRACK APPURTENANCES.
- F. Section 02867 – RESTRAINING RAILS.
- G. Section 02877 – THERMITE WELDING.

1.3 GENERAL DESCRIPTION OF NEW TRACK CONSTRUCTION

- A. New Green Line Track, for mainline and yard lead tracks, shall be new 115 RE head hardened rail, electric flash butt welded rail on 7" x 9" x 8' 6" treated timber ties with resilient fastener tie plates, spring clips and screw spikes. New yard track shall be jointed.
 - 1. Head hardened rail shall be used for all new track.
 - 2. Curves less than 1,000 feet radius shall require restraining rail.
 - 3. Electric flash butt welds may be by a fixed plant or by an in-track mobile unit as specified in Section 02851 – RAILROAD RUNNING RAIL.
 - 4. The use of thermite welds shall be limited to locations where electric flash butt welding is not possible and as permitted by the MBTA.

1.4 APPLICABLE STANDARDS

- A. The following Codes, Regulations, Reference Standards and Specifications apply to work included in this Section:
 - 1. MBTA Track Maintenance Standards.
 - 2. MBTA Book of Standard Trackwork Drawings
 - 3. American Railway Engineering and Maintenance of Way Association, AREMA:
 - a. Manual for Railway Engineering
 - b. Portfolio of Trackwork Plans

1.5 SUBMITTALS

- A. Submit a prepared CPM Construction Plan in accordance with Section 2.7. The CPM Construction Plan shall include descriptions of the following:
 - 1. Construction sequences
 - 2. Construction activities including but not limited to:
 - a. Rail distribution and installation
 - b. Track removal
 - c. timber crosstie unloading and installation
 - d. ballast distribution
 - e. surface and alignment
 - f. thermal adjustment of CWR
 - g. final ultrasonic inspection and rail grinding

- h. turnout installation
- 3. Production Equipment
- B. Submit identity and location of licensed incinerator and land fill facilities proposed for crosstie and switch timber disposal.
- C. Submit a detailed trackwork installation plan.

1.6 QUALITY CONTROL

A. Tolerances From Design

- 1. Final established gauge, cross level, superelevation, vertical and horizontal alignment of tracks are indicated on Design Documents, and shall be within tolerances from design specified below:
 - a. Horizontal Track Alignment:
 - Maximum permissible variation from design shall not exceed
 - Plus or minus 1/2"

 - Rate of change of permissible variation from design shall not exceed
 - Plus or minus 3/16" middle ordinate to a 31' chord on curves, and 1/16" middle ordinate to a 31' chord on tangent
 - b. Vertical Track Profile:
 - Maximum permissible variation from design shall not exceed
 - Plus or minus 1/2" .

 - Rate of change of permissible variation shall not exceed
 - Plus or minus 1/16" middle ordinate to a 31' chord
 - c. Track Centers:
 - Maximum permissible variation from design not to exceed
 - Plus 1/2", minus zero
 - d. Cross Level:
 - Maximum permissible variation from design at any point
 - Plus or minus 1/16"
 - e. Gauge variation: +/- 1/16"

2. No tolerances from design shall be allowed at locations where vertical and horizontal clearances are restricted by the MBTA and Contract Documents such as platforms, abutments, and overhead bridges.
- B. Welds, in track after final acceptance will be warranted by the DB Entity as specified in Section 02851 – RAILROAD RUNNING RAIL

PART 2 – PRODUCTS

Not Used.

PART 3 - EXECUTION

3.1 TRACK CONSTRUCTION

- A. Construct ballasted transit track construction as shown on the Design Documents.

3.2 SUBGRADE PREPARATION IN NEW TRACKBED LOCATIONS

- A. Remove existing track structure and fouled ballast.
- B. Smooth and compact subgrade areas, with cross slope as shown on the Design Documents, to receive subballast.

3.3 PLACEMENT OF NEW SUBBALLAST

- A. Subballast shall be distributed over subgrade unless otherwise specified on the Design Documents.
- B. Distribute and compact eight inch layers of subballast, uniformly over the finished subgrade.
- C. Deliver subballast at a rate no faster than can be satisfactorily incorporated into the work, maintaining a proper interval of operations, and at such times as to permit proper inspection by the MBTA.
- D. To the extent practicable, unload subballast in position for use with a minimum of redistribution and dressing.
- E. Self-spreading vehicles may be used as accepted by the MBTA. When subballast is initially spread by a self-spreading vehicle, a power grader may be used to assist spreading operations.
- F. Thoroughly compact subballast until material is firmly interlocked and surface is true and unyielding.
- G. Top surface of initial layers of subballast shall be smooth, flat and uniformly compacted prior to distributing ballast.
- H. Refer to Section 02857 – SUBBALLAST for material requirements.

3.4 PLACEMENT OF INITIAL BALLAST

- A. Ballast shall not be distributed until the subgrade and the subballast has been completed and accepted as specified above.

- B. Distribute and compact 4" layers of ballast, not to exceed an 8" total, uniformly over the finished subgrade or subballast, prior to tie distribution.
- C. Deliver ballast at a rate no faster than can be satisfactorily incorporated into the work, maintaining a proper interval of operations, and at such times as to permit proper inspection by the MBTA.
- D. To the extent practicable, unload ballast in position for use with a minimum of redistribution and dressing.
- E. Self-spreading vehicles may be used as accepted by the MBTA. When stone is initially spread by a self-spreading vehicle, a power grader may be used to assist spreading operations.
- F. Thoroughly compact ballast until stones are firmly interlocked and surface is true and unyielding.
- G. Top surface of initial layers of ballast shall be smooth, flat and uniformly compacted prior to distributing ties.

3.5 DISTRIBUTING AND SPACING TIMBER CROSS TIES

- A. General
 - 1. Carefully distribute and properly space ties on initial layer of ballast. Space ties at design spacing as follows on center, or as shown on the Design Documents.
 - a. Mainline tie spacing 24".
 - b. Grade Crossing tie spacing 18".
 - c. Turnout tie spacing varies, see Design Documents.
 - 2. Handle ties in a manner to avoid breaking and bruising. Do not throw ties from cars or trucks onto rails or rocks.
 - 3. Place timber so that ties heartwood is down. Place all ties so that the bottom surface of the tie shall have full bearing against the initial layer of ballast.
 - 4. Place ties normal to center line of track.
 - 5. Properly space and align ties prior to rail installation.
 - 6. In placing or spacing treated ties, handle only with tongs or suitable devices. Do not use bars, chisels, forks, mauls, picks, punches, shovels, or sledges for moving ties or placing them in position beneath rails.
 - 7. Avoid unnecessary handling, redistribution, and reloading of ties. To extent practical, distribute ties in proper position for use without further handling.
- B. Remove ties damaged as result of improper handling by the DB Entity and rejected by the MBTA and replace with undamaged ties at no additional cost to the MBTA.

3.6 TIE PLATES - RESILIENT

- A. Install tie plates under each running rail on timber crossties.
- B. Tie Plates shall be new resilient fastener tie plates in accordance with MBTA Maintenance of Way Division, Book of Standard Trackwork, or as shown on Design Documents.
- C. Prior to installation of tie plates, clean contact surfaces to allow proper bearing of tie plate on tie and rail on tie plate.
- D. Locate centerline of tie plates on 8' 6" ties such that the line side of the tie is 18.64" from outer edge of base of rail with 115 RE rail. Tie plate shall be centered on the crosstie under rail.
- E. Locate tie plates on longitudinal centerline of each tie and place square to centerline of rail so that outside shaller of plate bears fully against rail base. Place plate with the downward cant toward center of track.
- F. Secure rail on line end of ties to tie, in proper relation to tie end, before securing opposite rail.
- G. Use line rail as reference in securing opposite rail to proper gauge.
- H. Tie Boring
 - 1. Field bore crossties and switch timber before fastening tie plates.
 - 2. Holes in crossties shall be 3/4" diameter. If other fasteners are used, as per manufacturers recommendations.
 - 3. Location and number of holes shall conform to location and number of screw spikes. Boring of holes in excess of number required will not be permitted.
 - 4. Do not bore holes entirely through tie.
 - 5. After drilling, brush drill chips from top surface of tie.
 - 6. Immediately treat bored hole with pentachlorophenol oil or creosote.
 - 7. Prior to locating position of holes to be bored for second rail to be placed on any tie or timber, position tie laterally so that field side base of first rail is in contact with shaller of plate. Any tolerance between rail base width and plate seat width shall be on gauge side of rail. Position other plate similarly to ensure retention of gauge established.

3.7 RESILIENT RAIL FASTENER SYSTEM

- A. Rail clips shall be installed according to the manufacturer instructions.
- B. Rail clips shall be installed from the right-hand side of the tie plate, facing the rail, with the open end of the clip at the base of the rail.
- C. Rail clips shall be driven until there is approximately 3/8" gap between the edge of the tie plate and the inner edge of the rear arch of the clip.

3.8 SCREW SPIKES

- A. Start and drive screw spikes vertically and aligned with rail.
- B. Screw spikes shall be set and driven in accordance with manufacturer's recommendations and specifications.
- C. Straightening screw spikes shall not be permitted. Screw spikes bent during driving shall be withdrawn and a replacement spike shall be driven.
- D. Number of screw spikes used per tie shall conform to the MBTA Book of Standard Trackwork.
- E. Avoid removal of screw spikes once driven. When necessary, pull spikes and plug hole using treated tie plug.
- F. Under no circumstances shall gauge be adjusted by striking lags, spikes, or plate edge after it is fixed to tie.
- G. Seat rail properly between tie plate shallers, with outside base of rail tight against outside plate shaller.

3.9 INSTALLATION OF CONTINUOUS WELDED RAIL (CWR)

- A. Install and temporarily joint CWR as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION. Lay and joint to produce zero thermal stress in the rail.
- B. Install rail in such a manner that damage to ties or OTM is avoided, and ties are not dislodged from their proper position.
- C. Install temporary six holes, 36” joints using 4 bolts prior to surfacing and aligning track. Leave end holes blank (not drilled).
- D. The track shall be brought to within 1 inch of final line and grade in accordance with Article 3.10 of this Section and the CWR strings shall have their lengths adjusted for zero thermal stress temperature, be vibrated to relieve internal rail stress, and be fully clipped in accordance with Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

3.10 RAIL CLIPPING

- A. Clip CWR as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- B. Final clipping of rail, in ballasted track, shall be done when rail is at its zero thermal stress temperature, and has been vibrated to relieve internal rail stress.
- C. Final rail clipping, in ballasted track, shall not proceed until track has been sufficiently ballasted to prevent tie or track movement due to thermal expansion or contraction in rails and until track has been initially raised, tamped, aligned, and destressed.
- D. Install clips as specified by manufacturer.

1. Use modified clips at temporary bolted joint and insulated joint locations.
- E. Install two clips per tie per plate.
1. Install clips on each plate in an opposite direction and in a consistent pattern.
- F. Clips shall not be overdriven.

3.11 TIE PLUGS

- A. Install treated tie plugs in holes where spikes have been pulled from ties.
- B. Drive plugs into tie to refusal and cut plug flush with top of tie, using an adze, before installing tie plate.

3.12 RAIL ALIGNMENT

- A. General
1. Construct track conforming to alignment and profile data shown on Design Documents.
 2. Alignment is based on centerline of track equidistant between gauge sides of running rails.
 3. For tangent track, profile refers to top of rail in final position. For curved track, profile refers to top of low (inner rail) in final position.

3.13 INSULATED JOINTS – POLY

- A. Insulated joints in accordance to Section 02865 – TRACK APPURTENANCES.
- B. Install 115 RE poly insulated joints at locations shown on Design Documents.
- C. Install insulated joints during installation of 115 RE rail.
- D. Insulated joints shall be installed as suspended joints.
- E. Accurately space and drill holes for bolting of rail in accordance with requirements of the current AREMA Manual for Railway Engineering, Specifications for Steel Rails and MBTA Book of Standard Trackwork. Drill holes with an approved rail drill.
- F. Drill cylindrical holes of specified diameter for the size bolt required through and perpendicular to web of rail.
- G. Use a template, as a drilling guide, to locate holes both vertically from bottom of rail and horizontally from rail end. In no case shall a joint bar be used for this purpose.
- H. Remove all rough edges from holes.

3.14 SURFACING AND ALIGNING

- A. Surface and Align track in accordance with Section 02854 – TRACK SURFACING AND ALIGNMENT.

END OF SECTION

SECTION 02851

RAILROAD RUNNING RAIL

PART 1 - GENERAL

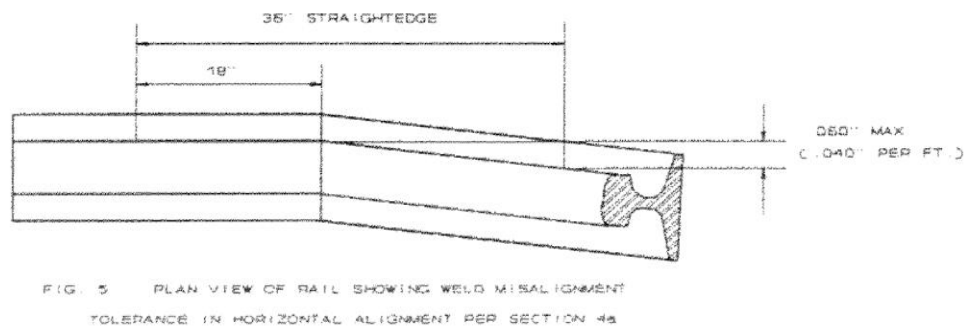
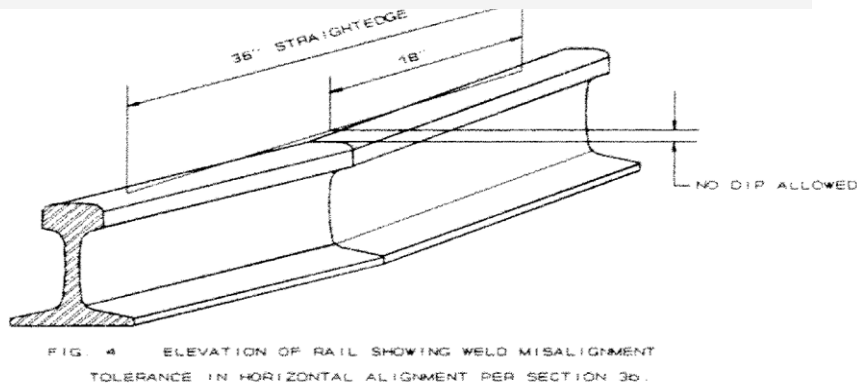
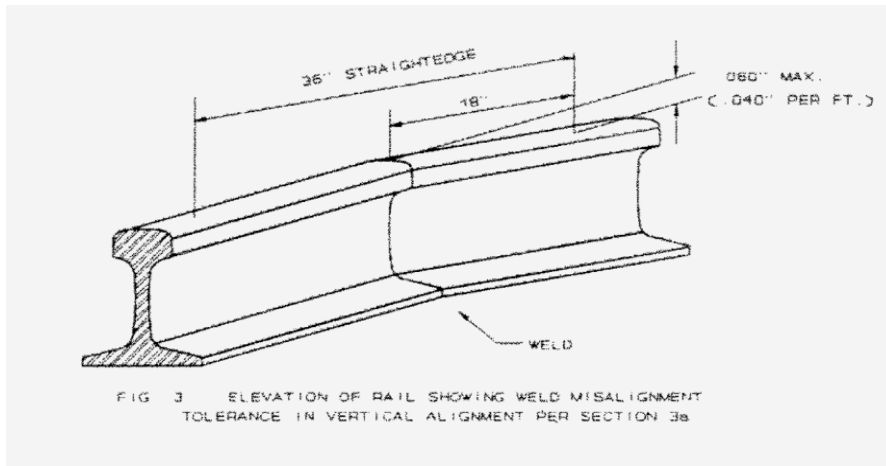
1.1 DESCRIPTION

- A. This Section specifies the manufacture and shipping of head hardened 132 and 115 RE rail, electric flash butt welding of rail into continuous welded rail (CWR) strings and delivery and distribution of CWR strings within Project limits.
- B. The work consists of:
1. Arranging for the shipment of 132 and 115 RE head hardened rail from the rail manufacturer to the Project area.
 2. Electric flash butt welding rail into CWR strings by means of either a fixed plant or a portable, in-track mobile welding unit.
 3. Delivery and proper distribution of CWR strings within project limits.
- C. Related work specified elsewhere:
1. Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION – Procedures for installation, thermal adjustment and maintenance of CWR.
 2. Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION – Overall track construction procedures.
 3. Section 02877 – THERMITE WELDING – Requirements for thermite welding where required.
- D. Project Conditions and General Requirements for CWR fabrication:
1. There will be new 115 RE CWR along the entire length of the transit line. New rail for the commuter line will consist of 132 RE CWR. Electric flash butt welds may be made by either a fixed or semi portable plant and the welded strings moved by approved methods to the installation site, or; the new rail may be placed in track as jointed rail with end holes blank and temporarily secured with four track bolts in 36 inch joint bars. Electric flash butt welds can then be made in-track using an approved, mobile electric flash butt welding unit.
 2. The DB Entity shall plan the work to minimize the number of thermite welds in completed track.
 3. Where new 132 RE rail is to be joined to 115 RE rail, compromise thermite welds shall be used. as specified in Section 02877 – THERMITE WELDING.
 4. Use head hardened rail for all new track on the transit line and commuter line.

1.2 SUBMITTALS

- A. Submit certification from the rail manufacturer that rail furnished meets the physical requirements of the current AREMA Manual.
- B. Prepare a list of all welded rail strings, their location, required length, and if they contain bonded insulated joint plug rails and their location in the string.
- C. Submit welding plant or mobile unit company name.
- D. Prior to production welding, submit proper certification that each shop weld will be warranted by the DB Entity against workmanship or alignment defects.
- E. Submit the identity and qualifications of the certified independent testing laboratory that will perform sample weld inspection and testing. Include qualifications of nondestructive examination specialist performing the radiographic tests.
- F. Prior to commencement of production welding, submit certification that each sample weld has passed required tests and inspections.
- G. Prior to production welding submit schedule for the welding of rail.
- H. Submit daily during periods of production welding, the following:
 - 1. Log of inspections and tests made using form included as Figure 2 of this Section.
 - 2. Number of acceptable welds made.
 - 3. Number of rail strings completed and number and length of each string and type of rail in each string.
- I. Upon the completion of welding CWR strings, submit recorder charts and a record documenting the production of each string of CWR. Included shall be string number; string length; heat number of each piece of rail in the string; number of welds in the string; and number of any weld which had been cut out and re-welded. Use form included as Figure 3 of this Section.
- J. All submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.
- K. Submit a description of the method for pre-curving rail.

**STRAIGHTNESS OF WELDED RAIL JOINTS
TOLERANCE FOR INSPECTION OF WELDED RAIL**



* Figures refer to AREA - Manual for Railway Engineering Sec 4-2-6.23

FIGURE 1

WELD INSPECTION LOG

CONTRACT NO. _____ DATE _____

STRING NO. _____ WELD NO. 1 - CONSECUTIVE NO. _____

		WELDS																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
INSPECTION																						
PHYSICAL																						
VERTICAL																						
HORIZONTAL																						
ULTRASONIC																						
MAGNAFLUX																						
GRINDING																						

WELD NOS. CUT-OUT & REWELDED _____

STRING NO. _____ WELD NO. 1 - CONSECUTIVE NO. _____

		WELDS																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
INSPECTION																						
PHYSICAL																						
VERTICAL																						
HORIZONTAL																						
ULTRASONIC																						
MAGNAFLUX																						
GRINDING																						

WELD NOS. CUT-OUT & REWELDED _____

STRING NO. _____ WELD NO. 1 - CONSECUTIVE NO. _____

SIGNED _____ (INSPECTOR) DATE _____

APPROVED _____ (HAIL PLANT SUPERVISOR)

INSTRUCTIONS: Use ✓ to indicate inspection was made and weld passed for physical, ultrasonic, magnaflex and grinding. Write number of thousands of an inch measured for vertical and horizontal - See Figure 1.

FIGURE 2

**WELDING PLANT
RAIL HEAT NUMBERS**

PROJECT _____ CONTRACT NO. _____

STRING NO. _____ RAIL WT. _____ DATE WELDED _____

RAIL: MFG. _____ YEAR ROLLED _____ TYPE _____

STRING LENGTH _____ MACHINE NO. _____ OPERATOR _____

CONSECUTIVE WELD NUMBERS _____ TO _____

RAIL NUMBER	HEAT NUMBER		RAIL NUMBER	HEAT NUMBER
1 (STARTER)	_____		11	_____
2	_____		12	_____
3	_____		13	_____
4	_____		14	_____
5	_____		15	_____
6	_____		16	_____
7	_____		17	_____
8	_____		18	_____
9	_____		19	_____
10	_____		20	_____

TOTAL WELDS THIS STRING _____

WELDS CUT-OUT

NUMBER	TYPE DEFECT
_____	_____
_____	_____
_____	_____
_____	_____

COMMENTS: _____

SIGNED: _____ APPROVED: _____

PLANT FOREMAN OR OPERATOR PLANT SUPERVISOR

FIGURE 3

1.3 QUALITY CONTROL

A. General

1. Production welds, in track after final acceptance, will be warranted by the DB Entity for one full year.
2. Perform sample and production electric flash butt weld inspection and testing at no additional cost to the MBTA.
3. Sample weld inspection and testing shall be performed by the approved certified independent testing company or laboratory. The MBTA may audit operations to ensure that inspections and tests are being performed in accordance with accepted procedures and in compliance with these Mandatory Specifications.
4. Sample and production welds made in head hardened rail shall be air quenched.
5. Sample and production welds shall have full penetration and complete fusion with no evidence of surface or internal fissures, cracks, porosity or slag type defects.
6. To be accepted, each weld shall fulfill the requirements of the Mandatory Specifications.

B. Electric Flash Butt Weld Qualification, Inspection and Testing

1. Prior to commencement of welding, each welding machine and operator shall be qualified based on sample welds passing the tests specified in this Article 1.3.B of this Section.
 - a. Each welding machine and operator shall make three sample welds using standard and head hardened rail. Three sample welds each of 132 RE standard rail to 132 RE head hardened rail, 132 RE head hardened rail to 132 RE head hardened rail, 115 RE standard rail to 115 RE head hardened rail, 115 RE head hardened rail to 115 RE head hardened rail shall be a set and every set shall be inspected and tested.
 - b. Assign each sample weld a number and mark each weld with that number and type of rail using a permanent marking device.
 - c. Submit with each sample weld for inspection and testing, a record of the following signed by the welding supervision:
 - Sample Weld number.
 - Welding machine identification.
 - Welding machine operator.
 - Brand, rolling date, heat number, and type of rail used on each side of the weldment.
 - Date welded.
 - d. The sample weld shall join two pieces of rail each a minimum of 30" or minimum required by testing agency. Rail pieces to be used for the sample welds shall be cut from 132 RE

rail and 115 RE rail received for this project. Each rail also shall be coded for identification and comparison with the record submitted.

2. Test each set of 3 sample welds as follows:
 - a. Perform Radiographic Tests as specified in Article 1.3.B.3 of this Section on all sample welds.
 - b. Perform Slow Bend Test specified in Article 1.3.B.5 of this Section on one sample weld.
 - c. Perform Hardness Test specified in Article 1.3.B.6 of this Section on one sample weld.
3. Radiographic Testing
 - a. Inspect sample shop welds radiographically in accordance with ASTM E142, ASTM E94, and these Mandatory Specifications for the purpose of detecting flaws in shop welds.
 - b. Radiograph each sample weld on head, web and each side of rail base.
 - c. Identify each radiographic film with Contract number, weldment number, inspection agency, and view. Submit statement of certification with each film to the MBTA, giving comment on any irregularities found in the weld, and whether the weld passes or fails.
 - d. The acceptance criteria for this test shall be full penetration and complete fusion with no evidence of surface or internal fissures or cracks.
 - e. Nondestructive inspection of metal welds by radiographic use of nuclear by-product materials shall be in accordance with United States Nuclear Regulatory Commission Rules and Regulations, Title 10, Atomic Energy, Part 20, Standard for Protection Against Radiation.
 - f. Transportation, handling and storage of hazardous materials used in radiographic inspection of welds shall be performed only by or under the supervision of a technician operating under a proper license.
5. Slow Bend Test
 - a. Subject second sample weld which has passed Radiographic Tests specified in Article 1.3.B.3 of this Section to the Slow Bend Test described in the Proceedings of the AREMA, Chapter 4.
 - b. The acceptance criteria for this test shall be a minimum deflection of one inch with minimum 120,000 pounds per square inch modulus of rupture for standard carbon rail and 0.75" deflection with minimum 125,000 pounds per square inch modulus of rupture for head hardened rail.
6. Hardness Test
 - a. Longitudinally cut a cross section of third sample weld of each type of rail passing Radiographic Tests specified in Article 1.3.B.3 of this Section for a maximum distance of one foot each side of the weld and test by the Brinell Hardness or Rockwell C Hardness Test.

- b. No weld shall have hardness values greater than 400 BHN or 43 Rc. Test welded zone as specified in AREMA. The minimum Brinell Hardness number of parent metal is published at 310 for standard rail and 370 for head hardened rail.
 - c. For a weld to be acceptable the weld material and heat affected zone of each rail, not more than 6 inches from weld center line, shall meet the minimum hardness above for standard or head hardened rail. Hardness within the weld shall be within plus or minus 30 BHN points or plus or minus 5 Rc of parent rails head hardness except at decarburized centerline and at the spherodized edge of the heat affected zone.
 - d. Inspect macroetched section for compliance with shop weld requirements of full penetration, complete fusion, and internal defects specified herein.
- 7. Approval of welding process, welding machine, and operator will depend upon sample welds satisfying the specified requirements. Shall any sample weld fail to satisfy specified requirements, then the welding process, welding machine or both shall be altered or adjusted to produce an acceptable weld and the tests shall be repeated. Any change required to correct sample weld failure, or any change of procedure, equipment or personnel shall require additional submittals as specified in Article 1.2 of this Section.
 - 8. Satisfactorily complete qualification testing specified herein, prior to production welding.

C. Production Welding – Inspection and Testing

- 1. During production welding, test and inspect welds as specified herein to ensure compliance of each shop weld with requirements of these Mandatory Specifications.
- 2. Magnaflux Testing
 - a. Inspect welds by the dry powder magnetic particle method in accordance with ASTM E109.
 - b. Cut out welds giving fault indication in magnetic particle inspection and re-weld rails in accordance with these shop welding specifications.
- 3. Physical Inspection
 - a. Inspect welds with a three-foot certified straightedge similar to a No. 270 Starrett, along the centerline of top of rail and 5/8 inch below top of rail on gauge side of the rail head.
 - b. With straightedge centered over weld the gap between straightedge and rail shall not exceed AREMA requirements of Chapter 4 for surface misalignment tolerance and gauge misalignment tolerance. The relevant data from AREMA for surface alignment is shown as Figure 1 of this Section.
 - c. Cut out welds not meeting these straightness tolerances and re-weld rails in accordance with these shop welding specifications.
 - d. Shop Weld Machine Performance
 - (1) During preparation of sample welds and during production welding, attach a chart recorder, with certified calibration to each welding machine to record platen

movement and current impulses during welding. Chart recorder shall be calibrated at least daily.

- (2) The weld will be rejected if the record indicates a performance which is not in conformance with standards submitted and accepted under Article 1.2.C of this Section.

4. Rejected Welds

The removal and replacement of welds cut out due to not passing a Magnaflux test or a physical inspection or due to improper welding machine function shall be done at the DB Entity's expense.

PART 2 - PRODUCTS

2.1 MATERIALS TO BE FURNISHED BY THE DB ENTITY

- A. The DB Entity shall furnish 80' lengths of 132RE and 115RE section rail to the Project Area. Rail shall be head hardened, high strength rail meeting the requirements of the AREMA Manual Chapter 4, and MBTA Material Specification No. 9633-A. If rail is to be welded using a fixed plant, furnish rail with blank ends. If rail is to be welded in-track after temporarily joining with joint bars, furnish rail with end holes blank and two holes for placing two bolts on each rail end to a 36' joint bar.
- B. Pre-curving of transit rail.
 1. Prior to performing pre-curving, submit shop drawings to show compliance with the requirements below.
 - a. Rail used for curves having a horizontal centerline radius less than 400' shall be pre-curved from beginning (TS or PC) to end of curve (ST or PT).
 - b. Uniformly curve rail, such that the deviation of the interior mid-ordinate offset from the theoretical offset is within the tolerances for straight rail using the appropriate chord distance required by the track construction specification.
 - c. Pre-curved rail shall be identified with painted identity numbering per accepted shop drawing code at end of each rail. As a minimum the identification shall include track number, curve number, and inside or outside rail on curve and sequential number indicating position of rail in curve. Curve points on rails falling at the beginning or ends of curves shall be clearly marked.

PART 3 - EXECUTION

3.1 DELIVERY, STORAGE, AND HANDLING

- A. Rail
 1. Prior to welding, handle rails in accordance with these Mandatory Specifications:

- a. During unloading and handling, rail shall be lifted using a minimum of a two point hitch to avoid causing horizontal set in the rail.
 - b. Rails to be stockpiled by type and length with heads up, separating full length rails from short rails.
 - c. First layer of rail in stockpile shall be on a firm foundation to prevent contact with ground and to protect rails from damage.
 - d. Rails shall be separated in tiers by wood separators at a minimum of five points per 80' rail. Stock used as separators between tiers of rail shall be oak or other hardwoods that will sustain the weight of the rails without crushing.
 - e. Stockpile rails so that brands are all on the same side to reduce handling of rail to the welding machine or placing in track.
2. The DB Entity is responsible for the unloading of rails from the manufacturer. The DB Entity is responsible for the subsequent handling, shipping, storage, loading, unloading, and security of rail relative to the welding and distribution of CWR strings. The DB Entity is responsible for scheduling associated with the movement, welding, delivery, and distribution of rail.

3.2 FABRICATION

A. Continuous Welded Rail

1. General
 - a. Provide continuous welded rail for running rail within work limits as indicated on Design Documents.
 - b. Electric flash butt weld rail in accordance with the current AREMA Specifications for Fabrication of Continuous Welded Rail, Chapter 4, except as modified herein.
 - c. Weld rails with brand of each rail on same side of rail. All CWR strings shall have the brand on the same side throughout the Contract.
 - d. Make all welds by the electric flash butt welding process.
 - e. Straightening of welds shall be performed in a manner which minimizes the bending of rail.
 - f. Incomplete welds or welds that fail to pass inspections per Article 1.3 of this Section shall be cut out using a rail saw and the rails re-welded. The section cut out of rail shall include heat affected zone of each rail. Use of cutting torch or other heat dependent device to cut out defective weld shall not be permitted.
2. Continuous Welded Rail String Lengths
 - a. The maximum CWR string shall be 1,440' in length. The DB Entity shall create a schedule of required strings, their location, and length. Do not weld any length of rail less than 18 feet into a CWR string.

- b. Using a permanent marker, in the web of head hardened rail, clearly mark string number on first rail in a CWR string and string number and length of string, in feet, on the last rail in the string. Use Nissen metal marker as manufactured by J. P. Nissen, Jr., Co. or approved equivalent.
- d. Head hardened rail shall be marked using the color orange.
- e. If it is necessary to drill a hole in the first rail of a CWR string for handling purposes the hole shall be drilled as the second hole per MBTA Standard Plan 1302 except hole diameter to be reduced to 1 3/16" in diameter. If rail is damaged at hole location, the damaged end shall be cut off at DB Entity's expense.

3.3 DISTRIBUTION OF CONTINUOUS WELDED RAIL (CWR) FROM A FIXED PLANT

A. General

- 1. Only load continuous welded rail strings onto rail cars, or other suitable transporting equipment, specially equipped to handle CWR.
- 2. Handling, loading, transporting, and unloading of continuous welded rail shall be in accordance with the current AREMA Manual and Contract Documents.

B. Distribution

- 1. Distribute CWR strings within project limits where required.
 - a. Ends of CWR strings shall be offset and blocked to prevent buckling and the standard overlap shall be 2'.
 - b. Rails shall not be run out over crossings, or across side track side of turnouts but shall be laid on either side of crossings, and side tracks unless otherwise directed by the MBTA.
 - c. Rail strings shall be set on crossties removed from existing track at minimum 100' intervals, one-tier high.
 - d. Rail strings shall be moved to the approved locations by equipment designed to handle CWR without causing damage to the rail, existing or newly constructed track. Dragging of welded strings is prohibited.

C. Rail Installation shall be as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION

3.4 HANDLING 80 FOOT RAILS FOR WELDING IN TRACK WITH A MOBILE WELDING UNIT

- A. Rail Distribution: Distribute rails along ROW adjacent to installation sites using approved rail handling equipment and methods.
- B. Rail Installation shall be as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION

END OF SECTION

SECTION 02853

CONTINUOUS WELDED RAIL INSTALLATION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies requirements for installation of continuous welded rail (CWR) where required within Project limits and includes thermal adjustment of rail to neutral rail temperature, rail clipping, rail grinding, and final ultrasonic testing of rail.
- B. Installation of welded rail shall follow installation of crossties as specified in Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION and in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION and thermal adjustment shall follow initial surfacing and alignment. Work shall also include installing bonded insulated joint-plug rails.
- C. Related work specified elsewhere:
 - 1. Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 - 2. Section 02851 – RAILROAD RUNNING RAIL.

1.2 DB ENTITY RESPONSIBILITIES RELATED TO WORKING WITHIN IN-SERVICE CWR TRACK

- A. In general, these Mandatory Specifications address the installation of welded rail, thermally adjusting to neutral temperature as if the track is being built as new track, not under existing rail traffic. Since part of the trackwork on this Project is within an active commuter rail/freight line, there are many additional requirements and measures to prevent track buckling and the significant dangers inherent from improper procedures. At all times during trackwork on this Project, the DB Entity shall be familiar with and strictly adhere to the Policy on Track Buckling Countermeasures attached to the end of this Section as Attachment B.

1.3 SUBMITTALS

- A. Submit descriptions of equipment and the proposed procedure for rail grinding, prior to initiation of rail grinding. The MBTA Rail Grinding Specifications are applicable to this work; a copy has been included at the end of this Section as Attachment A.
- B. Submit a description of on-track equipment and procedures for final ultrasonic rail and weld testing in installed track, prior to initiation of testing program.
- C. Submit certified final ultrasonic rail test results.

- D. Submit complete record of rail adjustment information on form MBTA Rail Clipping/Anchoring Record included as Attachment C.
- E. All submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.

1.4 QUALITY CONTROL

A. General

1. Perform final rail ultrasonic testing after rail grinding.
2. Ultrasonic testing shall be performed using on- track rail detector car.
3. Rail detector car shall be capable of detecting defects in rail, joints, shop welds, and field welds.
4. Inspection procedure shall include providing a permanent record, on tape or film, of rail tested and defects detected, showing type and location of each defect.

PART 2 - PRODUCTS

2.1 MATERIALS TO BE FURNISHED BY THE DB ENTITY

- A. Provide temporary new or approved relay 132 RE six hole toeless joint bars. This material shall conform to the dimension requirements for 132 RE rail, Standard Plan No. 1322, and shall be in conformance with the attached MS No.9227 in Attachment C.
- B. Provide temporary new or approved relay 115 RE six hole toeless joint bars. This material shall conform to the dimensional requirements for 115 RE rail, Standard Plan No. 320, and shall be in conformance with the attached MS No.9227 in Attachment C.
- C. Provide temporary new track bolt, nut and washer assemblies. Bolts shall be 1 1/8 inch x 5 3/4 inch and conform to the dimensional requirements for the temporary 132 RE joint bar, 115 RE joint bar, and be in conformance with MS No. 9227 in Attachment C and Standard Plan No. 1332.
- D. Electric flash butt welds as specified in Section 02851 – RAILROAD RUNNING RAIL.
- E. Thermite welds as specified in Section 02877 – THERMITE WELDING.

PART 3 - EXECUTION

3.1 WELDED RAIL INSTALLATION USING CWR STRINGS FROM A FIXED PLANT

A. General

1. Installation of CWR strings in track shall follow crosstie distribution and proper spacing of crossties.

2. Prior to start of CWR installation, the DB Entity shall participate in a conference chaired by the MBTA, including other attendees designated by the MBTA, to establish parameters for rail adjustment including the MBTA's requirements for record keeping. DB Entity shall be fully prepared to discuss methods and equipment for adjusting CWR.
 3. DB Entity shall de-stress rail by vibration and thermal adjustment after track has been brought to within one inch of final line and grade through initial surfacing and aligning. De-stressing of track shall be completed prior to final surfacing and aligning.
 4. Field cuts in CWR shall be made only after receiving the acceptance of the MBTA. Designate locations of field cuts by track designation, station of cut end of rail string, and right or left rail determined by facing in the direction of increasing stationing.
 5. Lay CWR so that shop welds in opposite strings are staggered at least ten feet.
 6. CWR strings installed in tracks with rail traffic shall be thermally adjusted as soon as possible after installation.
- B. Handle, and move as necessary, CWR in such a manner and by use of such equipment that will prevent bumping or striking of rail and will avoid damaging or excessively bending the CWR. Lay CWR in a manner which will prevent damage to rail, ties, fasteners, and structures. Do not drop rail. Use rollers to facilitate movement and placement and to reduce risk of damage to ties, fasteners and track appurtenances. Procedures to be in conformance with the AREMA Manual.

C. Cutting and Drilling of Rails

1. CWR strings may have a hole burned or drilled in each end to facilitate handling which shall be cut out prior to welding into track. Cut rail a minimum of 9" back of burned hole and 1" back of drilled hole using a rail saw.
2. Cut rails square and clean using a rail saw.
3. Do not cut rails for the installation of a bolted joint within 30" of a shop weld in the same rail string or opposing rail.
4. Accurately space and drill holes for bolting of rail in accordance with requirements of the current AREMA Manual for Railway Engineering, Specifications for Steel Rails, and MBTA Standard Plan Nos. 1300 and 1302. Drill holes with an approved rail drill. For temporary 132 RE joints and 115 RE joints, drill two holes only, leaving first hole space blank.
5. Drill cylindrical holes of specified diameter for the size bolt required through and perpendicular to web of rail.
6. Use a template, as a drilling guide, to locate holes both vertically from bottom of rail and horizontally from rail end. In no case shall a joint bar be used for this purpose.
7. Remove all rough edges from holes.
8. Cut out rail segments containing holes that are rejected by the MBTA.

9. Install 6 holes, 36" joints using 4 bolts per joint for temporary installations prior to initial surfacing per Section 02854 – TRACK SURFACING AND ALIGNMENT.

3.2 WELDED RAIL INSTALLATION USING STICK RAIL WELDED IN TRACK

A. General Procedures

1. Install new 132RE and 115RE 80' rails on new resilient fastener tie plates. In cases where new rail is laid on existing ties, all spike holes in existing ties shall have new tie plugs inserted.
2. Lay rails so that joints in opposite rails are staggered at least 10'.
3. Rails shall be temporarily joined with four track bolts per 36" joint bars secured by four bolts per joint.
4. When approved mobile electric flash butt welding unit is on track all joint bars shall be removed and rails welded.
5. Adjust rails to rail neutral temperature and clip per applicable requirements of Articles 3.3 and 3.4 of this Section.
6. The rail gap created at the end of a string by flash butt welding strings of rail in track shall be closed by cutting in a plug rail not less than 18' long in tangent or 21' long in curves and welding the plug.

3.3 THERMAL ADJUSTMENT OF CWRSTRINGS

A. General

1. Thermal adjustment shall follow initial surface and alignment to the tolerances as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT.
2. Rail temperature shall be taken after track has been initially surfaced and lined just prior to rail adjustment. The temperature reading shall be used in computation of rail adjustment.
3. Determine rail temperature by an AREMA standard rail thermometer as specified in the current AREMA Manual for Railway Engineering.
4. Determine temperature of rail by placing rail thermometer on shaded side of rail base next to web and leaving it there for not less than five minutes and until no change in its reading is detected.
5. During adjustment of rail constantly monitor and record rail temperature readings of CWR on the Rail Clipping Record/Anchoring form in Attachment C of this Section.

B. Rail Movement and Rail End Gap

1. During thermal adjustment, determine the gap or rail movement between CWR strings and between CWR and bolted rail by the equation:

$$G = (t - T) LK + Q$$

Where:

G = Rail gap (inches)

t = Zero Thermal Stress temperature of 95 degrees Fahrenheit

T = Actual rail temperature at time of laying (degrees Fahrenheit)

L = Length of CWR being laid (feet)

K = Coefficient of thermal expansion for rail steel (0.000078 inches per foot per degree Fahrenheit)

Q = Rail gap as required by respective manufacturer of field weld kit and bonded standard joint. For bolted standard joint Q = 0.125", and for insulated joints Q equals the end post thickness. Q shall be 0.125 if field weld is not expected to be completed prior to operation of the first train over newly installed rail.

2. Take care not to damage rail ends during rail laying, ballasting, and other operations requiring passage of on-track equipment over rail joints. Install plug rail if rail ends are damaged.

C. Temporary Fastening of Rail for Use of On-Track Construction Equipment

1. Prior to placing equipment on newly laid rail, secure rail, allowing for proper gauge, surface, and alignment, in a manner that will prevent damage to CWR, rail fastening assemblies, ties, and other material.
2. Move equipment over partially secured track in such a manner as to prevent damage to structures and trackwork materials.
3. Prior to surfacing, fully clip all ties to allow for track raise and alignment.
4. Remove fastenings to adjust rail to its zero thermal stress length.

3.4 RAIL CLIPPING (ANCHORING)

A. General

Install rail clipping devices as specified herein and in accordance with manufacturer's recommendations.

3.5 RAIL FASTENING

- A. Rail fastening shall be with resilient fasteners. Install rail clips in accordance with the manufacturer's requirements exercising care in not overdriving clips to exceed the deflection limit.
- B. Rail fastening (clipping) shall commence immediately after the rail has achieved the rail neutral temperature and immediately following the rail heater if that method is used to achieve rail neutral temperature.

3.6 RAIL ALIGNMENT

A. General

- 1. Construct track conforming to alignment and profile data shown on Design Documents.
- 2. Alignment is based on centerline of track equidistant between the gauge sides of running rails.
- 3. For tangent track, profile refers to top of rail in the final position. For curved track, profile refers to top of low or inner rail of the curve in the final position.

B. Track Gauge

Measure track gauge between points 5/8" below top of rail and from inside face to inside face of running rails for Commuter Rail, 7/16" for LRT track. Measure track gauge at right angles to alignment of track.

C. Track Cant

- 1. Construct track with a 1:40 toward inclination of rails with respect to top of rail plane, except for track within limits of turnouts.
- 2. Track within turnouts where special turnout plates are used and through frog and guard rails shall be constructed without cant.

3.7 BONDED INSULATED JOINT PLUG RAILS

- A. Work shall include proper handling and placement of bonded insulated joint plug rails.
- B. Install plug rails at required locations within CWR as shown on Design Documents.
- C. The stagger of insulated joints shall not exceed 60", nor be less than 24".
- D. Install insulated joint plug rails while installing CWR. Saw cut CWR strings where required and pull string ahead to continue rail laying.
- E. Insulated joint plug rails shall be installed as suspended joints and crossties shall be re-spaced as necessary to meet this requirement.
- F. Insulated joints shall be clipped with modified "e" clips as shown on the MBTA Standard Plans and shall include a modified insulator in concrete crosstie construction.

- A. Joints created by installation of insulated joint plug rails shall be electric flash butt welded per Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION.

3.2 RAIL GRINDING

- A. Rail grinding shall follow this order.
 - 1. Completion of track to specified tolerances
 - 2. Field welds
 - 3. Rail grinding
 - 4. Final ultrasonic testing
 - 5. Final acceptance
- B. Grind top and gauge side of running rail head only.
- C. Rail metal removed shall be as specified in Rail Grinding Specifications included as Attachment A.
- D. Make number of passes necessary to remove rust, mill scale, surface irregularities and as specified in 3.D, of the Rail Grinding Specification.
- E. After grinding operation, visually and randomly check the rail with a feeler gauge and a straight edge. If surface irregularities in rail head exceed 0.003” in a length of 6”, notify the MBTA and make a determination if additional passes of rail grinders are to be made.

3.3 FINAL ULTRASONIC TESTING

- A. Final ultrasonic testing shall be as specified in Article 1.4 of this Section and performed prior to final inspection and within one week following rail grinding operations. Trackwork, field welds, and rail grinding shall be completed prior to final ultrasonic testing.
- B. DB Entity shall remove and replace defective welds found by ultrasonic testing immediately following test or as otherwise directed by the MBTA. Defective welds shall be removed and replaced with a minimum 18-foot rail in tangent or 21-foot rail in curves and two field welds at DB Entity expense.
- C. After defect is corrected, DB Entity shall have replacement field welds ultrasonically tested.
- D. Rails found to be defective by ultrasonic testing shall be replaced by the DB Entity.

ATTACHMENT

A

October 28, 1985

RAIL GRINDING SPECIFICATIONS FOR RAIL SERVICE
MASSACHUSETTS BAY TRANSPORTATION MBTA

I. Grinding Equipment Specifications.

Grinding equipment to be used on the Rail Service of the MBTA shall use conventional rotating grinding motors (3600 rpm) with a 10" O.D. grinding stone. The stone to be used shall leave an acceptable level of finish on the rail. No gouging of the rail is to be permitted. Significant blueing of the rail by the grinding equipment will be avoided.

Adequate spark guards and water sprays are required to minimize the danger of fires. The grinding equipment shall accommodate sufficient water to permit grinding for a full day under MBTA conditions.

The minimum range of motor adjustment shall be 24 Degrees Gauge to 15 Degrees Field. Motors shall be capable of adjustment (either manual or automatic) within this range so as to achieve the desired MBTA rail pattern(s). Minimum motor size is 15 Hp.

The grinding train shall be capable of grinding between 1.5 and 2.5 mph and shall remove .0008" of metal from the ball of the rail per pass for every 100 Hp available. Thus a 1500 Hp train shall remove .012 inch metal per pass. This metal removal shall be on the ball of the rail, away from any defects. (Metal removal at defects will vary according to defect type). The minimum metal removal for the grinding equipment, per pass, is 0.012". Metal removal measurements for verification will be made using a telebrineller or other suitable measurement device.

Since significant grinding of engine burns or low (battered) weld is expected, the grinding train shall have a "long wave" type feature.

The grinding equipment shall possess stacle clearance capability, to lift motors for switches, frogs, road crossings at its normal grinding, speed. It also shall be capable of grinding only one rail (as required).

II. Rail Grinding Specifications.

Rail grinding on the MBTA is to be carried out for two reasons; maintenance of rail profile and removal of rail surface defects.

Prior to the arrival of the grinding equipment a detailed inspection of the track to be ground will be carried out by railroad and DB Entity personnel.

The following specifications and standards are to be applied to rail grinding on the MBTA.

1. Rail Condition Inspection.

Prior to the arrival of the grinding equipment, DB Entity and railroad personnel will evaluate the condition of the rail in order to effectively plan for the utilization of the equipment, determine the sections to be ground and the number of passes required, and to avoid unnecessary delay. For planning and estimating purposes, it will be assumed that the grinding train utilization will be 60% (i.e. 40% of the time there will be railroad or travel delays.)

DB Entity and railroad supervisory personnel will have available appropriate measurement tools to include profilometer, telebrineller, and straight edge with either taper gage, dial indicator or depth micrometer for monitoring the performance of the grinding equipment.

2. Rail Profile Standards

In the area of rail profile standards, two major areas of activity are addressed: Rail Profile and Rail Flow.

A. Rail Profile

The desired rail profile for the Commuter Rail Service of the MBTA is a profile with a 10" top radius (as shown in Figure 1). Degradation of the railhead from this desired profile (by flattening) shall be monitored through the taking of rail profiles (using a profilometer) or using a "flatness™ gage.

When the profile degrades so that a measurable gap of 2/32 to 3/32 (corresponding to about a 30" radius) is seen when overlaying the desired profile onto the actual profile, then the rail shall be ground to restore the desired rail profile. (This gap is to be at or near the center of the rail head, to evaluate the rail "flatness". If the profile has a radius smaller than 10", the profile is acceptable providing it conforms to the remainder of the profile and lip standards.)

The final profile after grinding shall conform to the profile shown in Figure 1.

Conventional rail grinding equipment (see Rail Grinding Equipment section of this Specification) will be used on the MBTA for both profiling as well as correcting rail head surface defects. If no significant lip is present, a contour type pattern is to be used to restore the rail profile, with a motor distribution of 18 degrees gage to 15 degrees field. This profile shall have the following distribution.

20% of motors between 14 and 18 degrees gage 20% of motors between 5 and 10 degrees gage
15 % of motors between 1/2 and 4 degrees gage 20% of motors between 1 and 3 degrees field
20% of motors between 6 and 9 degrees field 5% motors at 15 degrees field.

B. Rail Flow

Plastic flow or lip will be ground if it results in a degradation of the profile pattern (field) or is excessive (gage). Plastic flow or lip on the gauge side of the rail head shall not exceed 3/16 to 1/4". When such a lip is present it shall be ground. This will be carried out using the conventional contour pattern presented above, but with approximately 10% of the grinding motors shifted to angles between 18 and 24 degrees to the gage. Using this pattern, both areas with and without lip can be ground, without having to continuously change grinding patterns. (Note: this pattern can also be used to grind the rail surface defects, without having to continuously change grinding patterns.)

Plastic flow to the field side of the rail head is a secondary problem on the MBTA. It shall be ground only in those cases where it significantly distorts the desired rail profile. It shall also be ground (or the rail remove) when it is 1/2" or larger in size. Grinding of field side flow will require an additional 5% of the motors shifted to 15 degrees filed.

3. Rail Surface Conditions

The following standards are defined for rail surface conditions on the Commuter Rail Service of the MBTA, These specifications are for corrugations, weld conditions and other rail surface conditions to include engine burns and new rail. This specification addresses only those conditions where grinding is required for maintenance of the rail surface. The list below presents a set of definitions for these rail surface conditions and defects.

A. Corrugations

For rail corrugation, rail grinding will be performed when 80% of the corrugations are .012 to .015" in depth or greater. The minimum length for grinding one section is 3 to 4 rail lengths (120 to 160'), unless the area has a large distribution of corrugations, and a rail grinder is already scheduled to be in the vicinity, in which case any section over one rail length shall be ground. Depth of corrugations after grinding shall be less than 0.005" for 80% of the corrugations. Corrugation depth measurements shall be verified with a parallel straight edge and dial indicator (or depth micrometer).

Rail shall not be ground when corrugation depths exceed 0.060" over 50% of the measured corrugations or if they are isolated, i.e. not near any site scheduled for grinding, and have corrugation depths greater than .050".

The pattern used by MBTA to grind, including the profile pattern(s) discussed in rail profiles (above) shall have grinding motors located in the range of -5 to +5 degrees, to remove rail corrugations. This can be incorporated as part of the contour pattern, if profile grinding is also being carried out. If profile grinding is not required, then additional motors may be used at the top of the railhead to eliminate the corrugations. The profile used shall not result in a flattening of the railhead.

B. Weld Irregularities or Defects

For rail weld irregularities, the following standards are defined:
High welds shall be ground when 25% of the welds are higher than .015 inches. Alternately, high welds can be ground when new rail ground within 20 MGT of installation. After grinding, 80% of the high welds shall be less than .005".

Low welds shall be ground when 25% of the welds are more than .025". After grinding, 80% of the welds shall be less than .010".

Low welds deeper than .040" shall not be ground, but shall be welded or replaced. Depths of welds will be verified using straight edge and taper gage or other suitable measurement equipment.

The pattern used to grind low welds shall have grinding motors located in the range of +/- 15 degrees. This can be incorporated as part of the contour pattern, if profile grinding is also being carried out.

C. Engine Burns.

The grinding of engine burns shall be carried out only if there is significant grouping or clustering of the engine burns. Individual engine burns shall be welded or replaced. Engine burns shall be ground when 50% of the defects are deeper than .020 to .025". Grinding shall take place when there are groups or clusters of defects. After grinding, 80% of the engine burns shall be less than .010" in depth.

Isolated engine burns or groups of engine burns deeper than 0.040" shall not be ground, but shall be welded. If the burn is deeper than 1/8", the rail shall be replaced. Engine burn depth shall be measured using straight edge and dial indicator (or depth micrometer).

The pattern used to grind engine burns shall have grinding motors located between ± 12 degrees. This can be incorporated as part of the contour pattern, if profile grinding is also being carried out.

D. New Rail.

New rail will be ground with one pass of a conventional grinding train with 20 MGT of installation of the rail. A second pass will be ground only if required to remove high welds or other rail surface defects. The pattern used shall be the contour pattern recommended under Rail Profile above.

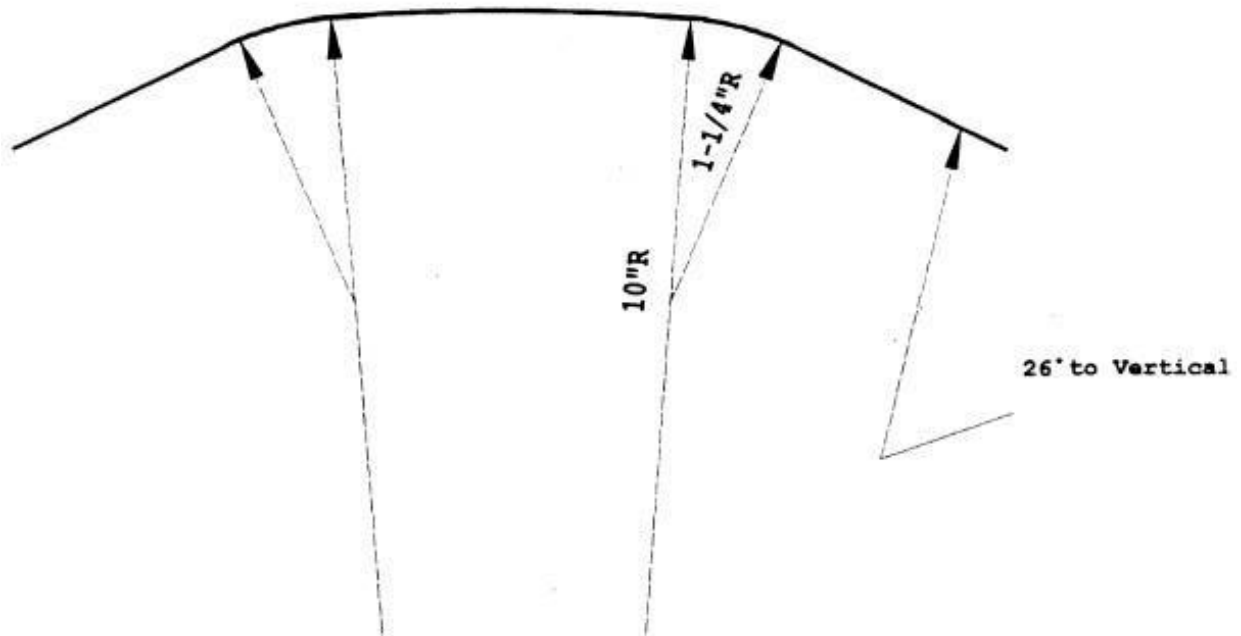


FIGURE 1 RAIL
HEAD PROFILE

ATTACHMENT
B
POLICY ON TRACK BUCKLING
COUNTERMEASURES

POLICY ON
TRACK BUCKLING
COUNTERMEASURES

Office of Asst. Vice President/Chief MBTA 400 N. Capitol Street, NW Washington, DC Effective 8/24/84

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G. E. Ellis

Revised 04/06/88 - For Amtrak's (MBTA) Commuter Rail Operations



B. R. Pohlot

Approved: _____



William MacDonald, Chief Engr.
MBTA

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PART I. Introduction

Buckled track has always been a major concern in the railroad industry. Incidents within the industry of buckled track and derailments due to buckled track have been steadily growing since the introduction of CWR. Industry wide in the United States, FRA reports, under Cause Code 115 (Buckled Track), railroads are experiencing over 100 derailments per year.

Amtrak and the MBTA, by the nature of their operations cannot tolerate risk of buckled track. Buckled track is, in reality, not a cause but is rather the result of some deficiency in the track structure or track maintenance procedures. This means that a properly constructed and maintained piece of track will not buckle from thermal loading during normal seasonal variations of temperature. There shall be something else present for buckling to occur such as misalignment, substandard ballast section, loss of neutral temperature, rail anchor deficiency, etc.

Current research has shown that the critical parameters or conditions influencing track buckling are:

1. Track Lateral Resistance.
2. Track Longitudinal Resistance.
3. Track Curvature.
4. Initial Alignment Deviation.
5. Rail Neutral Temperature.
6. Dynamic Train Loading.

As can be seen above, the operations of the Track Department in its construction and maintenance activities, have complete control over the first five critical items and substantial influence on the sixth item. If track buckling is to be prevented all six items shall be controlled and maintained within standards. Also, effective protective measures shall be applied when conditions are present which take any of the critical items into a danger zone.

Ensuring that track will not buckle depends on the knowledge of buckling causes and safe temperature values and on the ability to detect and/or prevent buckling conditions. In this light, the following is a brief description of the relationship of various Maintenance of Way activities to the critical items influencing track buckling, with the possible result if executed outside of established standards.

Lateral Restraint

<u>Operation</u>		<u>Temperature Condition</u>	<u>Potential Result*</u>
Undercutting)	Above Neutral Temperature	Potential buckling immediately or shortly after operation
Surfacing)		
Cribbing)		
Tie Renewal)		
)	Below Neutral Temperature	Contributes by allowing track movement in curve territory, thereby lowering neutral temperature with potential for buckling next hot season.
)		
)		
)		
)		
)		

Longitudinal Restraint

<u>Operation</u>		<u>Temperature Condition</u>	<u>Potential Result*</u>
Undercutting)	Above Neutral Temperature	Allows longitudinal track movement, thereby altering the neutral temperature producing a potential for immediate buckling at fixed objects or the potential for buckling the following hot season.
Surfacing)		
Cribbing)		
Tie Renewal)		
Anchor/Clip Removal and Application)		
)		
)	Below Neutral Temperature	Allows movement in curve territory producing potential for buckling in following hot season.
)		
)		
)		

* If not executed within prescribed limits.

1. Track Curvature

Curved track is more prone to buckle than tangent track, and as curvature is increased the temperature at which a track will buckle is decreased.

2. Initial Alignment Deviation

Although alignment deviation is a condition rather than a work function, we shall be sensitive to the fact that alignment deviation significantly reduces the temperature increase at which a track will buckle. As an example, a deviation increase from 1" to 1 1/2" will reduce the buckling temperature by as much as 40°F.

3. Rail Neutral Temperature

Shifts in rail neutral temperature are hard to detect and measure. Shifts of 30 °F. to 40°F. for the established neutral temperature for a territory can be critical and lead directly to buckling. In addition to the items described under lateral and longitudinal restraint, other factors influencing rail neutral temperature variations are:

1. Cold rail installation. (Improper Practice)
2. Inadequate rail temperature control or adjustment when replacing rail in maintenance work or field welding.
3. Inadequacy of rail anchors/clips and crib ballast.
4. Lateral shifts in curves through lining operations or track movements.
5. Skeletonizing track for any reason.
6. Inadequate ballast section.

All of the above items, if improperly executed or allowed to exist in a deficient condition, will cause a downward shift in the neutral rail temperature and produce a potential for buckled track.

4. Dynamic Train Loading

In a recent FRA study of 85 derailments due to buckled track, in 90% of the cases the first derailed car was the 10th or greater car in the train. This indicates that the buckling occurs under the train, thereby leading to the conclusion that train loading of the track structure plays a role in the buckling of track. There are a number of ways in which the dynamic train loads influence track buckling.

- a. Train induced uplift of the track structure can cause a large reduction in buckling temperature.
- b. High L/V ratios accelerate the growth of initial misalignments.
- c. Braking and traction forces typically produce an additional 10 tons of compressive force in the track.

Since the above items are sensitive to the geometric condition of the track and the application of slow orders, we shall recognize them when planning and executing track work and the effects on buckling potential.

As can be seen from the previous discussion, all Maintenance of Way track operations are related to the potential for track buckling. Some are more obvious than others. This policy establishes procedures and controls to minimize the possibility of Maintenance of Way track operations adversely affecting the track structure to produce a potential for buckling.

PART II. Track Work Methods and Criteria

To establish and maintain a neutral temperature in CWR territory that will prevent the potential of buckled track, the following work methods and restrictions will be adhered to, in addition to instructions presently contained in the MBTA's MW1.

1. Installing CWR

All CWR (Rail greater than 78' in length) will be installed at temperature between 90°F. and 110°F. inclusive, unless it is specifically accepted by the MBTA. This approval will be specific by track number and milepost location. When the temperature of CWR is below 90°F at the time of installation, the rail shall be expanded to a length which will produce an equivalent neutral temperature between 90°F and 110°F over the entire length inclusive, by use of an approved heating device. The required expansion will be calculated, executed and recorded in accordance with Section 119.5 and 119.6 of Part II of the current MW1. To assure uniform expansion the rail shall be vibrated by an approved rail vibrator. When making emergency adjustments of CWR the tie plates and rail can be tapped lightly along the entire length in lieu of a rail vibrator. For concrete tie territory one fully clipped concrete tie will be considered the same as one (1) wood tie box anchored for purposes of complying with the requirements of Section 119.6 of the MW1.

Any exemption granted by the MBTA will be in written format and remedial and/or protective action will be specified as part of the exemption.

2. Installing Rail Plugs in CWR Territory

When it is necessary to install rail plugs in CWR territory due to replacement of defective rails, field welding, insulated joint failures, etc., an approved heating device shall be used to assure the amount of rail installed is equal to or less than the length of rail removed. Hydraulic expander use is limited to restraining CWR while making field weld or assist their joining of CWR strings in cold weather. If in emergency requirements of this section cannot be met, the Foreman in charge shall accurately complete the information required in Part 111 of this procedure under "Report of Rail Cut in Main CWR Track", and report to his Roadmaster the reason he could not comply with requirements of this section. In addition, the foreman shall take the protective action described in Section 8 of this part.

3. Field Welding Without Rail Plug Installation

When field welding a single joint between CWR strings which have been temperature adjusted and whose rail temperature is less than the neutral temperatures, the necessary gap for welding will not be developed by allowing the rail to contract. The following method will be used:

- a. After re oval of the joint bar, remove with an approved rail saw 1" of rail to provide the required welding gap. Torch cutting of rail is prohibited.
Apply a hydraulic expander to return the rail ends to a 1" gap and while holding this position, proceed to make the weld in accordance with existing procedures.
- c. Upon completion of weld restore anchors or clips in each direction to effective positions as required, before removal of the hydraulic expander.

4. Undercutting; Out of Face Surfacing and Lining; Out of Pace Tie Renewal

(REVISED 10/30/87)

The above operations will not be performed at rail temperatures of less than 30°F.

In emergency situations the MBTA may grant permission upon request of the DB Entity to perform this work at less than 30°F, but the authorization will be specific by track number and milepost location. It will be issued in written form and remedial and/or protective action will be specified as part of the exemption.

5. Panel Turnout or Panel Track Installation in CWR Territory

When installing panel turnouts in CWR territory at less than 90°F rail temperature it is essential that there is no net addition of rail to the track upon completion of the panel installation. To insure this, the following procedure will be used:

- a. Measure the total length of rail in the panels to be installed and the rail temperature at time of measurement.
- b. Calculate the equivalent length of rail in the panels to be installed at 90°F in accordance with Section 119.5 of Part II of the MW1.
- c. Measure on each rail the calculated lengths. If a turnout is being installed, locate the Starting Point to assure the Point of Frog is in the proper location.
- d. Cut the rails according to the measurements made above, and remove the existing track.
- e. Upon installation of the last panel, do not cut rail to fit, but by of an approved heating device or hydraulic rail expander, expand the CWR string being connected to meet the rail of the last panel installed.
- f. During expansion, vibrate or tap the rail and plates to assure uniform expansion.
- g. Upon completion, assure that anchors and/or clips on the CWR in both directions have full bearing and add additional anchors as necessary to comply with Section 213.120(d) of Part I of the MW1.

If, in emergency, the requirement of this section cannot be met, the Foreman in charge shall accurately complete the information required in Part 3 of the procedure under "Rail Cut in Main CWR Track" and report to his Roadmaster the reason he could not comply with the requirements of this section. In addition, the Foreman shall take the protective action described in Section 8 of his part.

6. Cut and Throw of Track

When existing CWR track is cut and thrown at less than 90°F. rail temperature, it will be considered to have lost its temperature adjusted condition and will have to be adjusted in accordance with Section 1 of this part, Installing CWR.

7. Curve Realignment (Out-of-Face)

When curves are realigned out-of-face in excess of the following amounts:

- | | | |
|--------------------|---|---------------------|
| Curves Under 2° |) | 2" to the Outside. |
| |) | 1" to the Inside. |
| Curves 2° and Over |) | 2" to the Outside. |
| |) | 1/2" to the Inside. |

They will be considered to have lost their temperature adjustment and will have to be adjusted in accordance with Section 1 of this part, Installing CWR. Out-of-face curve realignment is defined as shifting a curve consistently in one direction at all throw points. The normal balancing of throws done during high speed surfacing operations does not constitute out-of-face curve realignment.

8. Protective Action

When any of the requirements of this part are not met, a 30 MPH speed restriction will be applied until the requirements of this part are met.

PART III. RECORD OF DISTURBANCE OF MAIN TRACK IN CWR TERRITORY PURPOSE

To maintain a record of any disturbance of main track in CWR territory which can cause a downward shift in the neutral temperature of continuous welded rail. This downward shift of neutral temperature can occur when any of the following operations are conducted below the established neutral temperature:

1. Undercutting.
2. Out-of-face tie replacement.
3. High speed surfacing.
4. Field welding.
- *5. Rail replacement.
6. Anchor removal or clip removal (more than 8 ties per 39' section of rail).
7. Cribbing operations {in excess of 8 cribs per 39' section of rail}.
- *8. Panel track installation.
- *9. Panel turnout installation.
10. Cutting and throwing of track.

*When current destressing procedures are not complied with and rail adjusted to 90°F or above.

IMPLEMENTATION

For purposes of implementation of this procedure, any of the above operations conducted in a manner not in compliance with Part II of this policy, whether under a granted exception or emergency condition, will fall under the Scope of this Part, and following report will be completed.

REPORT OF TRACK DISTURBANCE

When any of the above operations are not conducted in accordance with Part II of this Policy, a "Report of Track Disturbance" will be made by the Foreman in charge. Part A of this form will be completed for all work listed above when the requirements of Part II are not met. Part B will be completed whenever CWR in main track is cut or broken for any reason and the requirements of Part II are not met. The "Report of Track Disturbance Form" with instructions is attached as Appendix A. When this report is completed by the Foreman, Copy A will be forward to the Track Roadmaster with Copy B to be retained by the Foreman for his record.

REPORT OF TRACK MOVEMENT DUE TO SURFACING:

During out of face surfacing operations, the neutral temperature can be adversely affected on curved track by lining to the inside of a curve, on line drift caused by reduced longitudinal resistance of the track structure, and train traffic.

For track receiving out-of-face surfacing, a "Report of Track Movement Due to Surfacing" will be made for each curve worked. This report will be required in addition to the Report of Track Disturbance. This report will be completed by the DB Entity on whose territory the work is being performed. The "Report of Track Movement Due to Surfacing" form with instructions is attached to this procedure as

Appendix B. When this report is completed by the DB Entity, Copy A will be forwarded to the MBTA and Copy B will be retained for his record.

WEEKLY SUMMARY REPORT OF TRACK DISTURBANCE

On a weekly basis, the DB Entity will submit to the MBTA, a "Summary Report of Track Disturbance", attached to this procedure as Appendix C. This report will be reviewed by the MBTA, and the DB Entity will propose correction action at locations identified requiring corrective action.

PART IV. Protective and Corrective Action

1. Annual Inspection

Annually, a walking inspection of all main track will be conducted. This inspection will be made by the MBTA in the company of the DB Entity. The inspection will concentrate on compliance with standards in the following areas:

1. Anchor Pattern
2. Anchor Position
3. Ballast Section
4. Evidence of longitudinal rail movement, particularly at fixed locations, such as turnouts and grade crossings.

The MBTA will, upon completion of the inspection, submit a report of the inspection which identifies track inspected by number and milepost limits, the name of the individuals inspecting, date inspected, and any exceptions found, with protective and corrective action identified.

2. Special Inspection in Hot Weather

When the air temperature is 90 °F or above, all main tracks shall be inspected by qualified Track Inspectors, hired by the DB Entity, in accordance with currently established inspection procedures, outlined in the MBTA's MW-1. The Track Inspector shall make out an individual report for this inspection, and submit it to the MBTA. The DB Entity will log the inspection in his Summary of Special Inspections.

During this inspection, the Track Inspector shall be particularly alert for wavy track, longitudinal rail movement, kinked joints in compression and evidence of lateral track movement. He shall also be aware that the following conditions increase the possibility of buckling:

- a) Recent worked track
- b) Mud spots
- c) Existing deformations in line and surface
- d) Fixed facilities (i.e., turnouts, road crossings, bridges, etc.)
- e) Sub-standard ballast section
- f) Sub-standard anchor pattern

If any track is identified as having any conditions which indicate the possibility of buckling, immediate protective action shall be taken in the form of a slow order or removal from service, depending on severity.

3. Protection of Sub-standard Condition

If a Sub-standard Condition is found to exist, the following minimum protective action will be taken when the air temperature is expected to exceed 80°F:

- a) Substandard Anchor Pattern, or Ineffective Anchors Reduce speed over the affected track to 30 MPH
- b) Substandard Ballast Condition
Reduce speed over the affected track to 30 MPH
- c) Missing clips on concrete tie track.
If both clips are missing on each side of a rail on one tie at a rate of more than four (4) ties per 39' of rail, reduce speed to 30 MPH over the affected track.

4. Protective Slow Order after Surfacing, Undercutting and Out of Face Tie Renewal

A 30 MPH protective slow order will be applied after out-of-face surfacing, undercutting or tie renewal for a period of 24 hours and a minimum of 12 trains over the affected track.

After 24 hours and prior to removal of the slow order, the involved supervisor will verify by conversation with the Chief Dispatcher that the required 12 trains have passed over the track. He will also make a walking inspection over the work area prior to removal of the slow order to determine that there are no deficiencies in the track structure that will prevent the safe passage of trains at scheduled speed.

For existing concrete tie track, which has had out-of-face surfacing and has been treated with the dynamic track stabilizer, or with a crib and shaller compactor with all compacting components fully operational and for a minimum 6-second cycle, the slow release policy will be as follows;

- a) First train 30 MPH over the area. The MDZ in travel configuration may run over its own work at a speed not exceeding 30 MPH and this passage will meet the requirements of "first train 30 MPH over the area."
- b) Walking inspection by the involved supervisor to assure no deficiencies (i.e. misalignments, ballast section, anchoring, etc.) exist which would adversely affect the safe passage of train.
- c) 60 MPH speed restriction for a 24 hour period and the passage of 12 trains for track treated with a Crib & Shaller Compactor or 80 MPH speed restriction for a 24 hour period and the passage of 12 trains for track treated with a Dynamic Track Stabilizer.
- d) After "c" above, the track may be returned to normal speed.

Spot surfacing operations will be protected as follows:

When the air temperature is not expected to exceed 70°F and rail temperature is not expected to exceed the anchoring temperature of record for a 24 hour period after work, the following spot surfacing operations may be conducted with the protection prescribed below:

- Spot Surface & Line 0' to 40' No protection required
- Spot Surface & Line 41' to 200' 60 MPH S.O. for 24 hrs & 12 Trains

The involved supervisor will make a ground inspection of the work area prior to returning the track to scheduled speed to determine that no deficiencies exist in the track structure that will prevent the safe passage of trains at scheduled speed (i.e., full ballast section, proper anchoring, etc.).

If, in fact, the air temperature exceeds 70 °F in the 24 hour period following work and until 1 or 2 trains have passed, then a 30 MPH speed restriction shall be immediately applied.

5. General Speed Restriction and Suspension of Work

(REVISED 04/25/85)

During periods of extreme heat, when air temperatures are 95°F or above during a 24 hour period, a general speed restriction of 80 MPH will be placed in effect over the affected territory for the period that the air temperature is 95°F or above. The general speed restriction will be placed and removed by the MBTA, specifying the territory over which the restriction is to be applied.

In addition, the following work will be suspended when air temperatures are expected to be 95°F or above during a 24 hour period:

- a) High Speed Surfacing
- b) Smoothing (From 11:00 AM to 8:00 PM)
- c) Tie Renewal (Except under a continuous track outage)

6. Working Under a Continuous Track Outage

When undercutting, renewing ties out-of-face, and other work which disturbs the ballast is in progress under a continuous track outage, and it is expected that the air temperature will be 95° or above at the time track is returned to service, the 30 MPH speed restriction will remain in effect until seven (7) days of traffic is accumulated or until the period of high heat ends. The 30 MPH speed restriction, if required after the initial 24 hour period, will be in effect during the period of the day that the air temperature is 95°F or above.

7. Protection of Work Areas far Latent Effect

In addition to the above, track which has been worked within seven (7) days prior to the onset of high heat will be reduced to the Protection Slow Order speed required under Section 4 of this part until seven (7) days of traffic has been accumulated, or the period of high heat ends. The speed restriction, if required after the initial 24 hour period, will be in effect during the period of the day that the air temperature at 95°F or above.

V.GLOSSARY

Braking Force - The longitudinal force induced into the rail as a result of brake application of a train.

Buckling Temperature Increase - The amount that the temperature of the rails of a track shall be increased over the neutral temperature for a track to buckle.

Continuous Welded Rail (CWR) - Rail in excess of 78' in length.

Dynamic Train Loading - Forces which are imparted to the track structure during the passing of a train due to wheel action and vehicle response.

L/V Ratio - The relationship of lateral force on the rail to the vertical force on the rail which is produced by the wheel of a train.

Lateral Resistance - The ability of the track structure to remain in position under the influence of in service forces which are generated in a plane perpendicular to the line of the rail. Lateral resistance is a product of interaction of the ballast with the sides, bottom, and end face of the tie.

Longitudinal Resistance - The ability of the track structure to remain in position under the influence of in service forces which are generated in a plane which is parallel to the line of the rail. Longitudinal resistance is a product of the interaction of the ballast, the tie body, rail anchor bearing, and rail anchor rail grip.

Neutral Temperature - The rail temperature at which there is no internal stress in the rail, either tensile or compressive.

Out of Face Tie Removal - Tie replacement at a rate of more than four (4) ties per 39' rail.

Out of Face Surfacing and Lining - Surfacing and/or lining a continuous piece of track in excess of 500 feet.

Safe Temperature Increase - The amount that the temperature of the rails of a track may be increased over neutral temperature without buckling, considering the influence of lateral geometric imperfections, and lateral resistance.

Smoothing - Spot surfacing where no more than five (5) consecutive ties are disturbed from the tie bed.

Thermal Loading - The compressive forces generated in the rail due to its temperature being increased above its neutral temperature.

Track Breathing - The changing of the neutral temperature of CWR as a result of the natural cycle of seasonal temperature and the effect of the dynamic loading due to train operations.

Track Buckling - The sudden formation of large lateral misalignments caused by high compressive forces, in the presence of some other influencing factors.

Traction Force - The longitudinal force induced into the rail as a result of tractive effort of the locomotive and the rolling of the wheels of allequipment

VI. INSTRUCTIONS FOR PREPARATION OF THE REPORT OF DISTURBED TRACK

A report of disturbed track will be made out as required by Part II of the Policy on Track Buckling Countermeasures. The report will be completed by the Foreman in charge of the work as follows:

Part A - This part will be completed in its entirety any time track is worked and a report is necessary as outlined in the policy.

Part B - This part will be completed any time main track CWR is cut or broken for any reason.

The distance over which rail movement occurred will be measured as follow

1. Prior to cutting the rail or removing bolts from a joint and using yellow marking crayon, make a mark on the base of the rail and tie plate. These marks will be made on every twentieth tie for 900' in each direction.
2. After the rail is cut or the joint is brokers, inspect the marks and identify the last mark showing movement in each direction from the work.
3. Measure the total distance between the marks identified in No. 2 above and record on the form.
4. In the event of a rail weld or joint service failure, the movement shall be estimated by inspecting in each direction for anchor movement. After identifying the last anchors showing movement, measure and record the distance between the anchors identified.

POLICY ON COUNTERMEASURES TO PREVENT TRACK BUCKLING

APPENDIX "A"

Record of Disturbance of Main CWR Track

PART A:

Route: _____ Date: _____ Gang No.: _____
M.P. Location _____ to: _____ Track No.: _____
Type Work Executed: _____
Ambient Air Temperature: _____

Rail Temperature:

Time: _____ AM/PM Temp.: _____
Time: _____ AM/PM Temp.: _____
Time: _____ AM/PM Temp.: _____

Anchoring Pattern in Accord. with MW1: _____ (Yes/No)

If NO, explain _____

Ballast Section Per Standard Plan: _____ (Yes/No)

If NO, explain Deficiency: _____

PART B:

Rail Cut in CWR Territory

Rail: _____ (No/So/East/West)
Amount of Rail Removed: _____
Amount of Rail Installed: _____
Distance over which Rail Movement Occurred: _____

Remarks: _____

(Foreman) - PRINT

Page 32

(Foreman) - SIGNATURE

POLICY ON COUNTERMEASURES TO PREVENT TRACK BUCKLING

APPENDIX "B"

Report of TRACK MOVEMENT DUE TO SURFACING

ROUTE: _____ REPORT DATE _____

DATE WORK DONE: _____ GANG NO.: _____

RAIL TEMPERATURE AT WHICH SURFACING WAS DONE: _____

M.P. LOCATION: _____ to _____ TRACK #: _____

CURVE NO.: _____

Distance from Reference:

<u>Point Number:</u>	<u>Before Surfacing:</u>	<u>24 Hrs.</u>	<u>After 7 Days:</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Track Roadmaster - SIGNATURE

FORM # _____

COMMUTER RAIL DISTRICT ONLY
SUMMARY REPORT OF TRACK DISTURBANCE

Appendix C

DIVISION _____ PERIOD OF REPORT _____ to _____
ROUTE _____ PAGE _____ of _____

Date of Trk. Disturbance	Trk. No.	Milepost Location	Type of Work Executed		
			Amt. Rail Removed	If Rail Cut or Broken Amt. Rail Instltd.	Dist. Rail Mvmt.
Air Temp. at Time of Work		Lowest Rail Temp. During Work			
Reason for Noncompliance with Policy					
Track Roadmasters Remarks					
Date of Trk. Disturbance	Trk. No.	Milepost Location	Type of Work Executed		
Air Temp. at Time of Work		Lowest Rail Temp. During Work	Amt. Rail Removed	If Rail Cut or Broken Amt. Rail Instltd.	Dist. Rail Mvmt.
Reason for Noncompliance with Policy					
Track Roadmasters Remarks					
Date of Trk. Disturbance	Trk. No.	Milepost Location	Type of Work Executed		
Air Temp. at Time of Work		Lowest Rail Temp. During Work	Amt. Rail Removed	If Rail Cut or Broken Amt. Rail Instltd.	Dist. Rail Mvmt.
Reason for Noncompliance with Policy					
Track Roadmasters Remarks					

NOTE: This report is to be completed weekly.
if no disturbance has occurred, write
NONE in incident block and forward to
Division Engineer.

Track Roadmaster Signature _____

ATTACHMENT C
RAIL ANCHORING/CLIPPING RECORD

JOINT BARS & FASTENINGS

MATERIAL AND MANUFACTURE

Standard joint bar material and manufacture shall be in accordance with AREA Manual for Railway Engineering, Chapter 4, Part 2 - Specifications for "Quenched Carbon-Steel Joint Bars and Forged Compromise Joint Bars."

Track bolts and nuts material and manufacture shall be in accordance with AREA Manual, Chapter 4, Part 2, "Specifications for Heat-Treated Carbon-Steel Track Bolts and Carbon-Steel Nuts."

1. Prior to shipment entire bolt thread shall be coated with an approved oil or grease to protect threads.
2. Bolt and nut shall be assembled by turning nut onto bolt at least 2 threads.

Lockwashers material and manufacture shall be in accordance with AREA Manual, Chapter 4, Part 2, "Specifications for Spring Washers."

DESIGN

Joint bars shall be in accordance with MBTA Standard Plans for 115 lb. and 132 lb. rail as specified in the order. All other rail section joint bars shall conform to AREA Manual, Chapter 4, Part 1 with length and punching as specified in the order.

Compromise joints shall be in accordance with MBTA Standard Plans for rail sizes as specified in the order.

Track bolts shall be rolled, button-head, elliptic-neck bolts with wrench fit thread and shall be provided with standard square nuts all per AREA Manual Chapter 4, Part 1. Bolt diameter and length shall be as specified in the order.

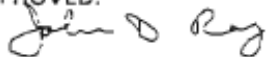
Lock washer diameter shall be as specified in the order and washer configuration shall conform to requirements of ANSI, B27.1, for "Extra Heavy Duty Helical Spring Lock Washers."

INSPECTION

Inspection and testing shall be in conformance with the inspection procedures outlined in AREA Manual, Chapter 4, part 2.

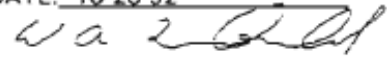
Prior to shipment, the manufacturer or supplier shall submit certified inspection and test reports.

APPROVED:



ENGINEERING OFFICER

DATE: 10-28-92



CHIEF ENGINEERING OFFICER

ISSUE 10-28-92

JOINT BARS & FASTENINGS PAGE 1 OF 2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9227

JOINT BARS & FASTENINGS

Joints, bolts and nuts, and lock washers are subject to inspection at delivery and are at suppliers risk until accepted by the Authority.

DELIVERY

Joints shall be wired into pairs, palletized and strapped for shipment.

Bolts and nuts shall be packed in sealed kegs with a maximum of 200 pounds per keg. Kegs shall be palletized and wrapped or strapped for shipment.

Lock washers shall be packed in steel pails or kegs with a maximum of 200 pounds per container.

Material rejected because of non-conformance with this specification will be returned at supplier's expense.

APPLICABLE STANDARD PLANS

No. 1320

No. 1322

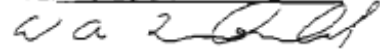
No. 1328

APPROVED:



ENGINEERING OFFICER

DATE: 10-28-92



CHIEF ENGINEERING OFFICER

ISSUE 10-28-92

JOINT BARS & FASTENINGS PAGE 2 OF 2

END OF SECTION

SECTION 02854

TRACK SURFACING AND ALIGNMENT

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies general procedures for curve modifications in existing track which include track throws and changes in superelevation.
- B. Also included are the following:
 - 1. Initial and final surfacing and aligning of tracks and turnouts.
 - 2. Ballast compaction.
 - 3. Curve and superelevation modifications in existing track.
 - 4. Installation of superelevation tags.
 - 5. Resurfacing and aligning of track and turnouts.
- C. The DB Entity shall perform the above work in accordance with applicable recommended practices set forth in the current AREMA Manual for Railway Engineering and as specified herein.

1.2 SUBMITTALS

- A. Submit name and location of proposed ballast supplier and laboratory test results confirming that ballast furnished meets the requirements of Section 02858 – BALLAST.
- B. Submit the type and specifications of equipment to be used in placing, compacting, and tamping ballast, aligning track and turnouts.
- C. Submit charts as specified from tamper/liner for all curves.
- D. All submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.

1.3 HANDLING

- A. Superelevation Tags
 - 1. Shipping
 - a. Tags shall be grouped by markings and wired together; nails shall be in boxes.
 - 2. Delivery
 - a. To be accepted, the superelevation tags delivered to the DB Entity shall conform to these Mandatory Specifications in all respects. Material rejected for non-compliance with these Mandatory Specifications will be returned to the supplier wholly at the supplier's expense.

1.4 QUALITY CONTROL

A. Tolerances

1. Tolerances, cross level, superelevation, and horizontal and vertical alignment of ballasted track shall be as specified herein. Deviation from the cross level, superelevation, horizontal alignment and vertical alignment shall not exceed the tolerances specified in Part 3 of this Section.

PART 2 - PRODUCTS

2.1 MATERIALS TO BE FURNISHED BY THE DB ENTITY

A. Ballast

1. Provide new stone ballast in conformance with the MBTA Specification in Section 02858 – BALLAST.

B. Superelevation Tags

1. New superelevation tags, to mark the superelevation on curved track, shall be stainless steel 22 gauge, American Iron and Steel Institute Type 302 with unpolished finish No. 4. The tags shall be stamped with embossed gothic figures and fraction. Fractions to be as shown on attached MS No. 9254 – Superelevation Tags.
2. Fluted galvanized nails.
3. Epoxy or construction adhesive accepted by the MBTA.

PART 3 - EXECUTION

3.1 CONSTRUCTION TOLERANCES

- #### A. Final surface, aligning, and gauge of track shall be within the following tolerances.

TRACK SURFACE, ALIGNMENT, AND GAUGE TOLERANCES

Deviation from uniform profile on either rail at the mid-ordinate of a 62' chord shall not exceed – 1/4"

Deviations from zero cross level at any point on tangent or from designated elevation on curves or spirals shall not exceed – 1/8"

The difference in cross level between any two points less than 62' apart on tangents or curves shall not exceed – 1/8"

Deviation from uniform alignment between any two points less than 62' apart on tangent and curved track shall not exceed – 1/4"

Deviation from 4' 8 1/2" track gauge shall not exceed – 1/16"

B. Runoff – Vertical Alignment

1. The runoff at the end of a raise into a hold point in track, such as at the Project limits location, shall not exceed ¼” in 62’ of track unless otherwise accepted by the MBTA.

3.2 SURFACING AND ALIGNING NEW TRACK

A. Ballasting

1. Following assembly of track, unload ballast in tie cribs and shallers of track structure.
2. Unload ballast in quantities which will fill tie cribs and provide an adequate amount of ballast for the initial track raise with sufficient surplus to continue to hold track after initial raise.
3. Prior to dumping ballast in track, ties shall be properly spaced as specified and shall be square with rails.
4. DB Entity shall re-space and straighten ties as required before stone is distributed.
5. The DB Entity shall use a ballast regulator machine to distribute the stone ballast in sufficient quantity for tamping the track and for restoring the ballast section.
6. The DB Entity shall avoid pulling sod, vegetation, and other foreign material onto the track structure or shallers for purpose of tamping or dressing the ballast section. Any sod, vegetation or foreign matter inadvertently pulled in shall be removed by the DB Entity prior to tamping.
7. Clean the track way area of all debris and standing water prior to placing of ballast. Do not place ballast on frozen subgrade or subballast.
8. Deliver ballast at a rate no faster than can be satisfactorily incorporated into the work.
9. To the extent practicable, unload ballast in position for use with a minimum of redistribution and dressing.

B. Tamping

1. Tamp ballast with 16 tool, squeeze-vibratory type, power tamping equipment. Control of power tamper shall ensure maximum compaction of ballast uniformly along track. The MBTA will determine tamping variables, including rate of advance, number of passes, number of insertions per tie (if more than two are required), length and number of blades, and frequency of vibration. Tamping tools shall be replaced when the working surface is worn more than 30% of its original surface area. Procedures and equipment shall be as approved. To allow for proper insertion depth below bottom of crossties, the tamping tools shall be adjusted to compensate for concrete/timber crosstie size difference.
2. Tamp ballast thoroughly under both sides of tie from a point 15” inside rails to ends of tie.
3. For each tie, tamp simultaneously inside and outside both running rails on both sides of tie. Minimum tamping insertions will be two.
4. Immediately following each tamping lift, cribs and shallers shall be compacted by a machine specifically designed for this purpose. Crib and shaller compaction machine shall be as approved.

5. The DB Entity shall remove 5 ties per mile, at locations selected by the MBTA, in order that the MBTA may inspect ballast compaction beneath ties. If compaction does not meet requirements of these Mandatory Specifications, additional ties shall be pulled at the MBTA's direction to discover limits of inadequate tamping. Areas of inadequate tamping shall be retamped at no additional cost to the MBTA.
6. Tamping on snow covered or frozen ballast will not be permitted.

C. Initial Surfacing and Aligning

1. Surface and align track and turnouts to achieve horizontal and vertical alignment as specified.
2. Initial surfacing and aligning shall be performed to bring track geometry to within one inch of final profile and to within one inch of final alignment, prior to thermal adjustment of rail.
3. Surface and align track by methods which will prevent undue bending of rail, straining of joints, or damaging of rail fastening assemblies.
4. Surface and align track only after cribs are filled with ballast.
5. The amount of any track lift shall neither exceed three inches nor endanger horizontal and vertical stability of tracks.
6. Perform as many raising and surfacing passes of three inches or less as needed to bring track surface to within one inch of final design elevation as shown on Design Documents.
7. Initially line track to within one inch of final alignment.
8. Restore ties pulled loose during surfacing to full bearing against rail and properly secure them.
9. Remove and replace with new ties and fasteners any ties or fasteners damaged during surfacing operations at no additional expense to the MBTA.

D. Final Surfacing and Aligning

1. Final surfacing and aligning of track and turnouts shall be completed after track has been initially surfaced and aligned, thermally adjusted, clipped and field welded.
2. Final surfacing and aligning shall be performed on all track and turnouts within project limits.
3. Final surfacing and aligning shall be required to bring the track and turnouts to final grade and alignment and to comply with surface and superelevation tolerances specified and shall consist of a lift of one inch maximum unless otherwise directed by the MBTA.
4. During final track raise, line track to final alignment. Track liner employed shall be a fully automatic model capable of determining existing curve data, computing new values for optimum curve value, and lining track to the new values without disturbing track surface. Machine shall be capable of producing a tape or graph showing existing and proposed values and this tape shall be reviewed and accepted by the MBTA prior to final lining. Tape shall become the property of the MBTA.

E. Ballast Compaction and Ballast Dressing

1. Concurrent with both initial and final surfacing and aligning of all tracks and turnouts, consolidate cribs and shallers and dress ballast to conform to ballast section shown on accepted Drawings.
2. Compact ballast shallers and cribs, after each surfacing raise, using a track machine specifically designed for that purpose. Machine shall compact cribs and shallers continuously by applying a combination of pressure and vibration. Ballast compaction shall be completed prior to any train operation.
3. After final surfacing and alignment of track is completed, consolidate cribs and shallers and dress ballast to conform to ballast section shown on MBTA Standard Plans. Top of ballast shall be one inch below base of rail.
4. Subbase outside toe of slope of ballast that has been fouled or disturbed by DB Entity's operations shall be properly sloped as shown on MBTA Standard Plans.
5. Upon completion of final surfacing and aligning produce as-built chart form tamper or liner and submit to the MBTA.

3.3 CURVE RE-ALIGNMENTS AND ADJUSTMENTS IN EXISTING TRACK

- A. All work within existing CWR track shall be governed by the Track Buckling Countermeasure requirements, Attachment B of Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- B. Before realigning existing curves where throws exceed either 2" outward or ½" inward, both rails at the end of curve away from the start of realignment shall be cut in two places and twelve feet of rail removed.
- C. After realignment, surfacing and adjusting superelevation, thermal adjust rail in disturbed track and anchor rail as prescribed in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- D. Cut plug rails not less than 18 feet long and thermite weld into gap created prior to curve re-alignment. Make additional cut in parent rail if gap is less than 18'.

3.4 FINAL TRACK INSPECTIONS

- A. Final horizontal and vertical alignment, gauge, superelevation and cross level shall be within the tolerances specified. In order to determine the acceptability of finished track, the DB Entity together with the MBTA shall conduct a final inspection to establish that track construction is within tolerances specified herein.
- B. Track deviations disclosed by inspection, which exceed tolerances specified herein, shall be corrected by the DB Entity at no additional cost to the MBTA. Reinspections shall be made by the DB Entity and MBTA to ensure that corrections have been made.
- C. Final inspection will include testing by an MBTA furnished track geometry test car capable of testing gauge, cross level, left and right rail profiles, track alignment, twist, warp and superelevation. Test car is capable of measuring the parameters specified above with sufficient accuracy to establish that the track construction is within the specified tolerances.
- D. Notify the MBTA one month in advance regarding the request for the scheduling of final track inspections.

- E. The DB Entity shall correct track deviations, as disclosed by final inspection, at no additional cost to the MBTA.
- F. The DB Entity shall participate in any retesting, required as a result of corrections to work, at no additional cost to the MBTA. Cost of MBTA supplied geometry car and crew, required for retesting, shall be borne by the DB Entity and will not exceed \$1,000.00 per retest.

3.5 SUPERELEVATION TAGS

- A. Use superelevation tags to mark the zero beginning and full elevation points of superelevation and to mark ¼” increments of elevation between zero and full points of superelevation.
- B. Attach tags stamped with superelevation in 1/4” increments from zero superelevation to maximum superelevation for each curve to ties at points approximately one foot inside base of high rail. All numerals shall be ½” in height.
- C. Place tag with numbers parallel to length of tie to be read when facing in direction of increasing elevation except place tag which indicates full elevation parallel with rail to be read from track centerline when facing high rail.
- D. Attach tag to tie using 2 nails per tag on timber ties.

3.6 RESURFACING AND ALIGNMENT

- A. Approximately 3 to 6 months after the completion of all trackwork and prior to Contract Substantial Completion, at a time agreed to by the MBTA, the DB Entity shall resurface and realign all trackwork performed by the DB Entity, as required to restore the track surface, superelevation and line to the originally intended design condition per the Design Documents.
- B. This work shall be performed only on weekends, unless otherwise directed by the MBTA. Track outages for this work shall be requested at least one month in advance of the work. Such request will be subject to MBTA acceptance.
- C. Resurfacing and alignment shall be defined as a smoothing operation to correct deviations from tolerances specified herein whereby all crossties and switch timber are tamped and rack raises are held to less than one inch unless track settlement dictates otherwise.
- D. Existing ballast shall be used. Additional ballast, if required, shall be furnished and installed by the DB Entity.
- E. During this resurfacing and alignment operation, ballast shallers and cribs shall be consolidated and the ballast dressed to conform to the ballast section shown on the Design Documents.
- F. Following completion of track resurfacing and aligning an MBTA furnished geometry car will measure track parameters. Deviations disclosed by this test, which exceed tolerances specified herein, shall be corrected by the DB Entity at no additional cost to the MBTA. Re-inspections shall be made by the DB Entity and MBTA to ensure that corrections have been made.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9254

SUPERELEVATION TAG

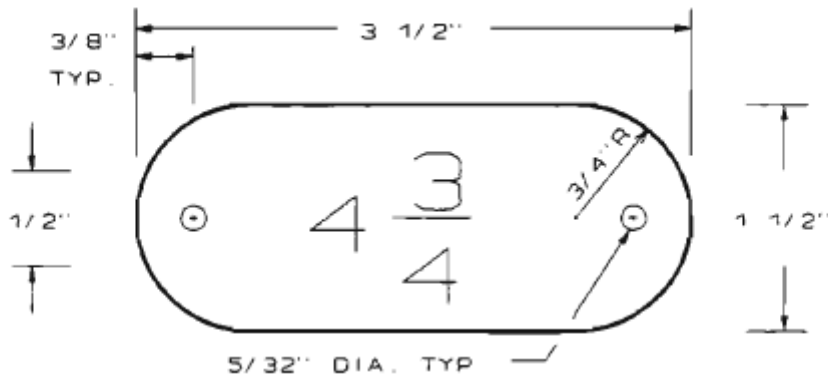
MATERIALS

Superelevation tags shall be 22 gage stainless steel, AISI Type 302 with unpolished finish No. 4.

Nails shall be fluted, galvanized steel nails.

DESIGN

Superelevation tag shall be $1\frac{1}{2}$ inches x $3\frac{1}{2}$ inches as shown:



Tags shall be stamped with embossed gothic figures and fractions specified in the order.

All numerals shall be 1/2 inch in height.

Nails shall be 1/8 inch x $1\frac{1}{2}$ inch with flat head. Supply 3 nails for each tag ordered.

SHIPMENT

Tags shall be grouped by markings and wired together; nails shall be in boxes or kegs depending on quantity ordered.

DELIVERY

To be accepted, superelevation tags and nails shall conform to this specification. Tags and nails are subject to inspection at time of delivery and are at supplier's risk until acceptance. Tags and nails rejected because of non-compliance with this specification will be returned at supplier's expense.

APPROVED:

John D. Roy

ENGINEERING OFFICER

DATE: 10-28-92

W. A. [Signature]

CHIEF ENGINEERING OFFICER

ISSUE 10-28-92

SUPERELEVATION TAG PAGE 1 OF 1

END OF SECTION

SECTION 02855

SPECIAL TRACKWORK

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the furnishing and installation of special trackwork and includes:
 - 1. Furnishing, receiving, unloading, inventorying, stockpiling, securing and distributing new special trackwork metals and treated hardwood switch timber.
 - 2. Installation of special trackwork on a prepared subgrade.

1.2 RELATED SECTIONS

- A. Tolerances, gauge, cross level, superelevation, and horizontal and vertical alignment of turnouts shall be as specified herein and in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION, and Section 02854 – TRACK SURFACING AND ALIGNMENT.
- B. Section 02858 – BALLAST.
- C. Section 02857 – SUBBALLAST.
- D. Section 02851 – RAILROAD RUNNING RAIL.
- E. Section 02865 – TRACK APPURTENANCES.
- F. Section 02871 – TIMBER CROSS TIES.

1.3 HANDLING AND STORAGE

- A. Handle special trackwork materials in a manner that will prevent damage during stockpiling and installation operations.
- B. Transporting and handling of new switch timber shall be as specified for new crossties in Sections 02871 – TIMBER CROSS TIES.
- C. All efforts shall be made to prevent damage to the components by handling. Proper lifting points shall be indicated on all material.
- D. Rail shall be handled with proper devices. The use of chains is prohibited.
- E. Materials stored onsite will be cleaned and protected with a suitable anti-rust protection designed to protect for a minimum of 3 years outside storage.

1.4 REFERENCES

- A. American Railway Engineering and Maintenance of Way Association (AREMA), Manual for Railway Engineering and Portfolio of Trackwork Plans
- B. American Society for Testing and Materials (ASTM)
- C. American Welding Society (AWS)
- D. American Society for Nondestructive Testing (ASNT)
- E. MBTA Maintenance of Way Division Green Line Light Rail Transit Track Maintenance and Safety Standards (LRTMSS)
- F. MBTA Maintenance of Way Division – Book of Standard Trackwork Plans
- G. Transit Cooperative Research Program (TCRP) Report 155: Track Design Handbook for Light Rail Transit, 2nd Edition

1.5 SUBMITTALS

- A. Complete shop drawings will be furnished to the MBTA a minimum of 60 days prior to inspection. Complete erection drawings will be furnished 30 days prior to shipment.
- B. All drawings shall be 22” x 34”. Index to all shop drawings shall be provided. All drawing dimensions and text will be in the English system. A 3” x 5” blank area will be left above the title block for the approval stamp.
- C. All drawings become the property of the MBTA for the purposes of future replacement. The suppliers for complete components, spare parts, and components shall be an accepted MBTA supplier.
- D. Prior to commencing work, submit detailed working drawings and proposed installation procedures of turnouts to the MBTA. Include procedures for handling and installing rail, switches, and frogs.

1.6 QUALITY ASSURANCE AND CONTROL

- A. A qualified independent testing laboratory accepted by the MBTA shall perform all special trackwork inspection and testing. The selected laboratory shall employ the proper equipment and qualified testing personnel for the special trackwork testing and inspection described in these Mandatory Specifications. Special trackwork testing and inspection equipment and personnel shall be subject to acceptance by the MBTA. The MBTA shall monitor the operations at the special trackwork plant to ensure that the inspections and tests are being performed in accordance with accepted procedures and in compliance with these Mandatory Specifications.
- B. Personnel performing nondestructive testing shall be qualified and certified in accordance with ASNT-TC-1A. Only persons certified for NDT Level I and working under a NDT Level II person or persons certified for NDT Level II may perform nondestructive testing.
- C. Testing equipment shall be in good operating condition, of adequate capacity and range, and accurately calibrated. Testing equipment calibration shall be certified and traceable to national standards such as the National Institute of Standards and Technology.

D. Test Program Plan

1. A test program plan shall be prepared identifying the approach for accomplishing each of the specified inspections and tests. The test plan shall include the test sequencing.
2. Equipment specifications and calibration methods for all testing equipment used to perform testing and inspection shall be included in the test program plan. The plan shall indicate the calibration certificates that will be submitted with the test reports.
3. Identity and qualifications of personnel who will perform testing and inspection shall be included in the test program plan. Also include certification records for personnel who will perform nondestructive testing.
4. The test plan shall include the name and location of the testing facility, qualifications of the testing facility, a description of the testing facilities, and a layout of the test equipment that will permit the efficient performance of the testing.
5. The plan shall include the proposed format for reporting test data.
6. The plan shall include the proposed schedule for testing procedure submittals.
7. The test program shall address welding and bonded insulated joint testing separately. The test program plan shall also address qualifications testing and production testing separately.
8. The test program shall include all geometry measurements of individual components and assemble units.
9. After approval of the test program plan, obtain the approval of any proposed changes from the MBTA, in writing, prior to implementing the change.

E. Test Reports

1. Test results shall be submitted in bound units for each special trackwork unit. The test results submittal shall not be submitted until complete.
2. No special trackwork shall be shipped until all components meet all of the quality requirements herein.
3. A report of test results of each test shall be submitted that includes test name, identification of test sample, test procedure references, test equipment identification, test personnel, time and date of test, specified requirements, actual test results, nonconforming items if any, and interpretation of results. The format for the test report shall be arranged so that the data is presented in an orderly manner.
4. Standard computer generated test reports may be used. Such reports shall be supplemented, as required, to provide all information and test and inspection results required by these Mandatory Specifications.
5. Copies of calibration certificates shall be submitted with the initial test reports. If test equipment is recalibrated while work is being performed, calibration certificates shall be submitted for the recalibrated test equipment with the test reports of the first tests performed after recalibration.

- F. The MBTA retains the right to witness all tests and shall be notified not less than 7 days in advance of dates.
- G. The performance of the independent testing is entirely the responsibility of the DB Entity. Any substandard conditions discovered after independent testing and inspection shall be repaired or replaced at no additional cost to the MBTA.

1.7 WELDING

- A. Welders and welding operators shall be qualified in accordance with AWS D15.2, Weld Kit Manufacturer's Welder Certification, or other standard accepted by the MBTA.
- B. Miscellaneous rolled, forged, or cast steel accessory components may be welded provided the carbon content does not exceed 0.40 % and provided a 200 degree F minimum preheat is used for any material with a carbon content greater than 0.30 %. Welding procedure specifications shall be qualified in accordance with AWS B2.1, AWS D1.1, or other standard acceptable to the MBTA.

PART 2 - PRODUCTS

2.1 MATERIALS TO BE FURNISHED BY THE DESIGN BUILDER

- A. Transit Rail Special Trackwork shall consist of 115RE rail (welded in the mainline and jointed in the yard), resilient fasteners, switch points, house tops (switch point protectors), restraining rails, guard rails, frogs, insulated joints, joint bars, switch plates, rods, braces, and associated material as follows:
 - 1. Ballast per Section 02858
 - 2. Subballast per Section 02857
 - 3. Rail per Section 02851
 - 4. Track appurtenances per Section 02865
 - 5. Timber Switch Ties per Section 02871
 - 6. Headblocks shall meet the requirements of MBTA Material Specification 9260.
 - 7. Frogs:
 - a. Frogs for normal operations use shall be flange-bearing type.
 - b. Frogs for emergency operation crossovers shall be jump frog type.
 - c. Manufacture frogs from high strength rail and manganese steel castings.
 - 8. All switch parts shall conform to the MBTA fully guarded, double switch point, curved split switch design with uniform risers.
 - 9. Switch Stands for yard track switches (non-interlocked) shall be Racor model 22P painted orange or approved equal. Switch stands shall be furnished with reflectorized aluminum targets (green for normal position or red for reverse).
 - 10. Switch point cover guard (housetop) shall be manganese steel compatible with switchpoint design.

11. Switch rods shall be vertical insulated type.
12. Special trackwork shall be identified with markings in accordance with AREMA specifications for Special Trackwork. Shop marks, match marks, and identification tags shall be as follows:
 - a. Shop marks shall designate the number of the portion, the connecting trackwork part, the trackwork piece or the miscellaneous material identity; all corresponding to marks indicated on the manufacturer's shop drawings.
 - b. Match marks shall designate adjoining trackwork parts, trackwork pieces, and miscellaneous material at all joints and at their intended locations. The match marks shall correspond with the markings indicated on the manufacturer's shop drawings.
 - c. Shop marks and match marks shall be applied by means of paint markers of different color contrast, capable of being distinguished from one another. All marks shall be clear and legible to permit proper assembly in the field.
 - d. Identification tags shall indicate the following information:
 - (1) The portion, part, and piece numbers.
 - (2) The manufacturer's name or initials.
 - (3) The designation "right hand" or "left hand".
 - (4) The description (abbreviation will be acceptable).
 - (5) The length and number of frog.
 - e. Identification tags shall be stainless steel in accordance with ASTM A176.
 - f. Identification tags and markings shall be of sufficient size to permit in-track identification. The marking letters and numerals shall be at least 3/8" in height.
 - g. Identification tags and markings shall be located such that they will be visible after installation in track and shall be secured to a reinforcing bar or to a web of a rail at the bar or web centerline by means of at least two steel drive rivets.
13. Special Trackwork Fabrication
 - a. Special trackwork shall be accurately fabricated to fit all abutting portions, associated connecting trackwork parts, associated trackwork pieces, and miscellaneous materials.
 - b. Manufacture and workmanship shall be done in accordance with the AREMA Specifications for Special Trackwork.
 - c. Grinding, planing, and drilling of holes shall be done to achieve true alignment and accurate fit at all points. Burrs shall be removed, edges shall be rounded smooth and surfaces shall be free from defects such as nicks, fins, and sharp resistant angles.
 - d. Rails shall be sawed square to their center lines and machined, ground, and beveled smooth to produce the required guage, flangeway, and profile.
 - f. Separator, filler, and heel blocks shall be removed when they are in interference with the proper fit of the separator, filler, and heel blocks.

- g. Countersunk rivets shall fill the countersink completely and the surface shall be ground flush.

PART 3 - EXECUTION

3.1 TURNOUT INSTALLATION

A. General

1. Special trackwork shall be installed over a prepared subgrade in accordance with the MBTA Standard Plans.
2. Special trackwork shall have a complete set of new timbers installed in accordance with MBTA Standard Plans and accepted drawings.
3. Special trackwork components shall be installed in accordance with the manufacturer's shop drawings and AREMA Specifications for Special Trackwork.

3.2 SWITCH TIMBER

- A. All timber in designated special trackwork shall be installed.
- B. Switch plates shall be fully fastened with screw spikes as specified herein.
- C. Plates in turnouts, except self-aligning plates at frogs, shall be fastened using four (4) screw spikes. Screw spikes shall be installed at each corner of plate. Self-aligning plates shall be installed using two screw spikes per plate.

3.3 RAIL FASTENING

- A. Rail fastening except at guard rails shall be with resilient fasteners. Clips shall not be overdriven.
- B. Rail braces shall be properly adjusted to maintain stock rails rigidly in proper position.
- C. Tie Boring
 1. Field bore switch timber before installing screw spikes.
 2. Holes shall be 3/4" diameter and 6 inches deep for 15/16" screw spikes.
 3. Location and number of holes shall conform to location and number of screw spikes. Boring of holes in excess of number required will not be permitted.
 4. Do not bore holes entirely through timbers.
 5. After drilling, brush the drill chips from the top surface of tie.
 6. Prior to locating position of holes to be bored for the second rail of a pair to be placed on any timber, position timber laterally so that field side base of first rail is in contact with shaller of plate and tolerance between rail base width and plate seat width is on the gauge side of rail. Position the other plate similarly to ensure retention of gauge established.

D. Tie Plates

1. Locate and secure special and resilient tie plates as shown on Standard Plans and Design Documents and as specified in this Section.

E. Cutting and Drilling of Rails

1. Cut and drill rails in conformance with these Mandatory Specifications and as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

F. Screw Spiking

1. Screw spikes shall be started vertically square and installed by turning with a power wrench. Screw spikes are not to be driven by use of a hammer. Screw spikes shall be seated squarely against top of plate.

G. Tolerances

1. Rail will be spiked to a track gauge of 4' 8 1/2" plus or minus 1/16".
2. Tie spacing shall be as shown on the accepted drawings and the MBTA Standard Plans. Switch tie spacing shall have a tolerance of plus or minus 1/2" except that ties under switch plates and frog plates shall have a tolerance of plus or minus 1/4".
3. Switch points in the normal position shall be square to the straight stock. Tolerance shall be within 1/4" plus or minus.

H. Rail Anchoring/Clipping

1. Clip rails on both side of every tie throughout turnout units except switch rails and stock rails adjacent to switch rails.

3.4 THERMITE WELDS

- A. Thermite weld all joints in the turnout limits except insulated joints as indicated on MBTA Standard Plans and accepted drawings per Section 02877 – THERMITE WELDING.
- B. Thermite weld all joints within 400' from both ends of all turnouts.

3.5 STANDARD JOINTS

- A. Standard joints, supplied with the special trackwork, shall be installed at the locations shown on the Design Documents. Installation shall be in accordance with the AREMA Specification for Special Trackwork.
- B. Clean and coat rail surfaces, to be covered by joint bars, with an approved oil or grease to prevent corrosion.
- C. Tighten bolts starting at the center of the joint and working toward each end of joint. Tighten bolts during initial installation within the range of 20,000 to 25,000 pounds. For subsequent tightening, bring bolts to a range of 15,000 to 20,000 pounds.

3.6 INSULATED JOINTS

- A. Insulated joints, supplied by the DB Entity, shall be installed at the locations shown on the Design Documents. Installation shall be in accordance with the AREMA Specification for Special Trackwork and manufacturers recommendations for installation.

3.7 BALLASTED TURNOUT CONSTRUCTION

- A. A minimum of 12” of ballast shall be provided under base of switch timber for entire length of turnout.
- B. Uniformly distribute and compact an initial layer of ballast as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT, over the finished subgrade prior to switch timber distribution. The first ballast layer shall not exceed four inches.
- C. Initial and final surfacing and aligning shall be as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT. After accomplishing final grade, re-tamp all ties within the turnout limits a second time without raising the track. Surface, alignment, compaction, ballast dressing, and stone ballast shall conform to all requirements as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT except that two separate passes with approved compactor equipment shall be required through the entire turnout limits including the transition tie areas on both ends of the turnouts and on both tracks.
- D. Establish final top of ballast elevation one inch below base of rail throughout turnouts, except in cribs between point of switch and heel of switch where the ballast level shall be 3 inches below base of rail. Provide additional clearance to switch rods to allow for unrestricted movement of switch rods.
- E. Ballast compaction during all lifts shall be as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT.
- F. In areas of Special Trackwork where standard rail mounted power tamping and compacting equipment cannot be used, use hand held power tamping and compacting equipment.

3.8 FINAL SURFACE AND LINE

- A. Special Trackwork shall be brought to final line and grade as shown on Design Documents and as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT.
- B. Bring Special Trackwork to final line and grade by a final surface life of not more than 1” and final horizontal adjustment of not more than 1”.

- C. Compact ballast after final surfacing and lining as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT.

3.9 LUBRICATION AND ADJUSTMENT

- A. Lubricate sliding surfaces on switch assemblies. Switch plates, under side of switch point, and points of contact on base of stock rail by the switch point shall be wire brushed to remove rust and foreign matter before applying graphite lubricant. Apply graphite lubricant in accordance with manufacturer's recommendation.
- B. Prior to final acceptance, make mechanical adjustments to moveable parts of switch assemblies to ensure that turnouts units are in acceptable operating condition.

END OF SECTION

SECTION 02856

COMMUTER RAIL TRACK CONSTRUCTION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies general requirements for new commuter track construction including, but not limited to the following:
1. Constructing new ballasted commuter track.
 2. Placing and compacting ballast.
 3. Placing and compacting subballast.
 4. Placing and aligning wood ties.
 5. Placing and aligning concrete ties.
 6. Thermal adjustment of existing Continuous Welded Rail (CWR).
 7. Aligning and clamping rail.
 8. Installing welded rail joints.
 9. Initial tamping, gauging, lining and surfacing track.
 10. Testing and corrections/adjustments to completed track.
 11. Other operations as specified.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Delivery, unloading and handling of 132 RE rail and procedures for creating CWR strings is in Section 02851 – RAILROAD RUNNING RAIL.
- B. Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- C. Section 02854 – TRACK SURFACING AND ALIGNMENT.
- D. Turnout procurement and installation is in Section 02855 – SPECIAL TRACKWORK.
- E. Section 02857 – SUBBALLAST.
- F. Section 02858 – BALLAST.
- G. Section 02865 – TRACK APPURTENANCES.
- H. Section 02877 – THERMITE WELDING.

- I. Section 02879 – SIDE TRACK CONSTRUCTION FOR COMMUTER RAIL SYSTEMS.
- J. Removal of existing track, turnouts and disposal of salvaging of materials is in Section 02852 – TRACKWAY DEMOLITION AND SALVAGE.

1.3 GENERAL DESCRIPTION OF NEW TRACK CONSTRUCTION

- A. New Commuter Rail Track shall be new 132 RE head hardened rail electric flash butt welded rail on 7” x 9” x 8’ 6” treated timber ties with resilient fastener tie plates, spring clips and screw spikes.
 - 1. Head hardened rail shall be used for all new track.
 - 2. Electric flash butt welds shall be by a fixed plant or by an on-track mobile unit as specified in Section 02851 – RAILROAD RUNNING RAIL.
 - 3. The use of thermite welds shall be limited to locations where electric flash butt welding is not possible and as permitted by the MBTA.

1.4 APPLICABLE STANDARDS:

- A. The following Codes, Regulations, Reference Standards and Specifications apply to work included in this Section:
 - 1. MBTA Commuter Rail Design Standards Manual.
 - 2. MBTA Book of Standard Plans Track and Roadway
 - 3. MBTA MW-1 Track Standards
 - 4. American Railway Engineering and Maintenance of Way Association, AREMA:
 - a. Manual for Railway Engineering
 - b. Portfolio of Trackwork Plans

1.5 DB ENTITY RESPONSIBILITIES RELATED TO WORKING WITHIN IN-SERVICE CWR TRACK

- A. In general, these Mandatory Specifications address the installation of welded rail, thermally adjusting and mainline track construction as new track, not under existing rail traffic. On this Project, most trackwork is within an active commuter rail/freight line. Consequently, there are many additional requirements and measures to prevent track buckling and the significant dangers inherent from improper procedures. At all times during trackwork on this Project, the DB Entity shall be familiar with and strictly adhere to the track buckling countermeasures attached to Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION as Attachment B, Track Buckling Countermeasures.

1.6 SUBMITTALS

- A. Submit a prepared CPM Construction Plan in accordance with Volume 2, Section 2.5. The CPM Construction Plan shall include descriptions of the following:
 - 1. Construction sequences
 - 2. Construction activities including but not limited to:
 - a. rail distribution and installation
 - b. track removal
 - c. timber crosstie unloading and installation
 - d. ballast distribution
 - e. surface and alignment
 - f. thermal adjustment of CWR
 - g. final ultrasonic inspection and rail grinding
 - h. turnout installation
 - 3. Production Equipment
- B. Submit identity and location of licensed incinerator and land fill facilities proposed for crosstie and switch timber disposal.
- C. Submit detailed trackwork installation plan.
- D. All submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.

1.1 QUALITY CONTROL

- A. Tolerances From Design
 - 1. Final established gauge, cross level, superelevation, vertical and horizontal alignment of tracks are indicated on accepted drawings, and shall be within tolerances from design specified below:
 - a. Horizontal Track Alignment:
Maximum permissible variation from design shall not exceed plus or minus ½”

Rate of change of permissible variation from design shall not exceed plus or minus 3/16" middle ordinate to a 31-foot chord on curves, and 1/16" middle ordinate to a 31-foot chord on tangent

- b. Vertical Track Profile:
Maximum permissible variation from design shall not exceed plus, or minus 1/2".

Rate of change of permissible variation shall not exceed plus, or minus 1/16" middle ordinate to a 31-foot chord

- c. Track Centers:
Maximum permissible variation from design not to exceed plus 1/2", minus zero
- d. Cross Level:
Maximum permissible variation from design at any point plus, or minus 1/16"
- e. Gauge variation: Plus or minus 1/16"

- 2. No tolerances from design shall be allowed at locations where vertical and horizontal clearances are restricted by the MBTA, Standard Plans, and Design Documents such as platforms, abutments, and overhead bridges.

- 3. Tie Spacing. Space ties shall be as follows:

- a. Tie spacing for timber crossties shall be in accordance with Standard Plan 1104.
- b. Within grade crossings, tie spacing shall be 18".
- c. Crosstie spacing at transition locations shall be in accordance with Standard Plan 1108.
- d. In single track the line side of ties will be the field side when facing in an easterly direction. In double track segments the line side will be the field side of both tracks.

- B. Welds, in track after Contract Final Acceptance will be warranted by the DB Entity as specified in Section 02851 – RAILROAD RUNNING RAIL.

PART 2 - PRODUCTS

2.1 TRACK MATERIALS

- A. All materials used in ballasted commuter rail track construction shall be as specified herein and in the relevant sections referenced in Part 1.2 above.

PART 3 - EXECUTION

3.1 GENERAL – NEW TRACK CONSTRUCTION

- A. Following track removal and preparation of subgrade and subballast to the lines and grades on the accepted drawings, construct ballasted track in accordance with these Mandatory Specifications, Standard Plans and Design Documents.
- B. Track removal at ballasted and open deck bridges will be in accordance with these Mandatory Specifications.

3.2 SUBGRADE PREPARATION IN NEW TRACKBED LOCATIONS

- A. Remove existing track structure and fouled ballast and subballast as indicated on the Design Documents.
- B. Smooth and compact subgrade areas, with cross slope as shown on the MBTA Standard Plans, to receive subballast.

3.3 PLACEMENT OF NEW SUBBALLAST

- A. See Section 02857 – SUBBALLAST for further details.
- B. Subballast shall be distributed over subgrade unless otherwise specified in Design Documents.
- C. Distribute and compact eight inch layers of subballast, uniformly over the finished subgrade.
- D. Deliver subballast at a rate no faster than can be satisfactorily incorporated into the work, maintaining a proper interval of operations, and at such times as to permit proper inspection by the MBTA.
- E. Unload subballast in position for use with a minimum of redistribution and dressing.
- F. Self-spreading vehicles may be used as accepted by the MBTA. When subballast is initially spread by self-spreading vehicle, a power grader may be used to assist spreading operations.
- G. Thoroughly compact subballast.
- H. Top surface of initial layers of subballast shall be smooth, flat and uniformly compacted prior to distributing ballast.

3.4 PLACING INITIAL LAYERS OF BALLAST

- A. See Section 02858 – BALLAST for more information.
- B. Ballast shall not be distributed until the subgrade, and where applicable, subballast has been completed and accepted as specified above.
- C. Clean track way area of debris and standing water prior to placing ballast. Do not place ballast on frozen subgrade or frozen subballast.
- D. Distribute and compact four inch layers of ballast, not to exceed an eight inch total, uniformly over the finished subgrade or subballast, prior to tie distribution.

- E. Deliver ballast at a rate no faster than can be satisfactorily incorporated into the work, maintaining a proper interval of operations, and at such times as to permit proper inspection by the MBTA.
- F. To extent practicable, unload ballast in position for use with a minimum of redistribution and dressing.
- G. Self-spreading vehicles may be used as accepted by the MBTA. When stone is initially spread by self-spreading vehicle a power grader may be used to assist spreading operations.
- H. Shape ballast to a true section conforming to the ballast section shown on Standard Plans and Design Documents.
- I. Thoroughly compact each ballast layer until stones are firmly interlocked and surface is true and unyielding.
 - 1. Compact by rolling using either a self-propelled, three-wheel, or two axle roller of such weight that will provide compression under the rear wheels of not less than 350 pounds per linear inch of tread; or using a two or three-wheel tandem roller having a weight per inch of drive roll of not less than 350 pound, and every part of the surface receiving compression from the drive wheels.
 - 2. Compact by vibration using vibratory compactors of either the roller or pad type. Dynamic force for either type shall not be less than 20,000 pounds and the frequency range shall be 1100 to 1500 vpm. Use machines equipped with a governor which can be set and locked to control rate of impulse. Provide a tachometer or other suitable device for accurately checking the frequency of vibration during the compacting operation.
- J. Top surface of initial layers of ballast shall be smooth, flat and uniformly compacted prior to distributing ties.

3.4 DISTRIBUTING AND SPACING TIES

- A. General
 - 1. Carefully distribute and properly space ties on initial layer of ballast. Space ties at design spacing as follows on center, or as shown on the MBTA Standard Plans.
 - a. Mainline timber tie spacing 19 ½”.
 - b. Mainline concrete tie spacing 24”.
 - c. Grade Crossing tie spacing 18”.
 - d. Turnout tie spacing varies see MBTA Standard Plans.
 - 2. Handle treated timber ties in a manner to avoid breaking and bruising. Do not throw ties from cars or trucks onto rails or rocks.

3. Place timber so that ties heartwood is down. Place all ties so that the bottom surface of the tie shall have full bearing against the initial layer of ballast.
4. Lift and support concrete ties during storage, transportation, and placing, in such a manner to prevent chipping, spalling, cracking, and other damage. In no case shall ties be dropped to the roadbed.
5. Place all ties normal to center line of track.
6. Properly space and align all ties prior to rail installation.
7. In placing or spacing treated ties, handle only with tongs or suitable devices. Do not use bars, chisels, forks, mauls, picks, punches, shovels, or sledges for moving ties or placing them in position beneath rails.
8. Avoid unnecessary handling, redistribution, and reloading of all ties. Distribute ties in proper position for use without further handling.
9. Remove any tie damaged as result of improper handling by the DB Entity and rejected by the MBTA and replace with undamaged ties at no additional cost to the MBTA.

3.5 INSTALLATION OF CONTINUOUS WELDED RAIL (CWR)

- A. Install and flash butt weld CWR as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION. Lay and flash butt weld CWR to produce zero thermal stress in the rail.
- B. Install rail in such a manner that damage to ties or OTM is avoided, and ties are not dislodged from their proper position.
 - A. Install temporary six hole, 36” joints using 4 bolts prior to surfacing and aligning track.
 - B. Before flash butt welding CWR strings, the track shall be brought to within one inch of final line and grade in accordance with Section 02854 – TRACK SURFACING AND ALIGNMENT and the CWR strings shall have their lengths adjusted for zero thermal stress temperature, be vibrated to relieve internal rail stress, and be fully clipped in accordance with Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- C. Install permanent insulated joint plug rails at locations shown on Design Documents during the installation of CWR.
- D. Install permanent insulated joint plug rails so that actual joint location will be a suspended joint.

3.5 TIE PLATES - RESILIENT

- A. Timber crossties shall have tie plates installed under each rail.
- B. Prior to installation of tie plates, clean contact surfaces to allow proper bearing of tie plate on tie and rail on tie plate.
- C. Locate tie plates on 8’ 6” ties such that the line side of the tie is 18 ¼” from outer edge of base of rail with 132 RE rail. Tie plate shall be centered on the crosstie under rail.

- D. Locate tie plates on longitudinal centerline of each tie and place square to centerline of rail so that outside shaller of plate bears fully against rail base. Place plate with the downward cant toward center of track.
- E. Secure rail on line end of ties to tie-in proper relation to tie end, before securing opposite rail.
- F. Use line rail as reference in securing opposite rail to proper gauge.
- G. Tie Boring
 - 1. Field bore crossties and switch timber before fastening tie plates.
 - 2. Holes in crossties shall be 5/8" diameter and 6" deep for 15/16" screw spikes.
 - 3. Location and number of holes shall conform to location and number of screw spikes. Boring of holes in excess of number required will not be permitted.
 - 4. Do not bore holes entirely through tie.
 - 5. After drilling, brush drill chips from top surface of tie.
 - 6. Prior to locating position of holes to be bored for second rail to be placed on any tie or timber, position tie laterally so that field side base of first rail is in contact with shaller of plate. Any tolerance between rail base width and plate seat width shall be on gauge side of rail. Position other plate similarly to ensure retention of gauge established.

3.6 SCREW SPIKES

- A. Start and install screw spikes vertically and square with rail. Install spikes straight.
- B. Screw spikes shall be set and driven in accordance with manufacturer's recommendations and specifications.
- C. Straightening screw spikes will not be permitted.
- D. Number of screw spikes used per tie shall conform to the MBTA Standard Plans.
- E. Avoid removal of screw spikes once driven. When necessary, pull spikes and plug hole using treated tie plug.
- F. Under no circumstances shall gauge be adjusted by striking lags, spikes, or plate edge after it is fixed to tie.
- G. Seat rail properly between tie plate shallers. With outside base of rail tight against outside plate shaller.

3.7 TIE PLUGS

- A. Install treated tie plugs in holes where spikes have been pulled from timber ties.
- B. Drive plugs into tie to refusal and cut plug flush with top of tie, using an adze, before installing tie plate.

3.8 RAIL CLIPPING

- A. Clip CWR as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- B. Final clipping of rail, in ballasted track, shall be done when rail is at its zero thermal stress temperature, and has been vibrated to relieve internal rail stress.
- C. Final rail clipping, in ballasted track, shall not proceed until track has been sufficiently ballasted to prevent tie or track movement due to thermal expansion or contraction in rails and until track has been initially raised, tamped, aligned, and de-stressed.
- D. Install clips as specified by manufacturer and as shown on the MBTA Standard Plans.
- E. Install two clips per tie per rail.
- F. Clips shall not be overdriven.

3.9 ELECTRIC FLASH BUTT WELDING

- A. Electric flash butt welding and testing will be as specified in Section 02851 – RAILROAD RUNNING RAIL and the following;
 - 1. Welds in head hardened rail will be air quenched.
 - 2. Removal of rail anchoring shall not exceed 200' in both directions when making a weld.

3.6 RAIL ALIGNMENT

- A. General
 - 1. Construct track conforming to alignment and profile data shown on Design Documents.
 - 2. Alignment is based on centerline of track equidistant between gauge sides of running rails.
 - 3. For tangent track, profile refers to top of rail in final position. For curved track, profile refers to top of low or inner rail in final position.

3.7 INSULATED JOINTS – POLY

- A. Insulated joints shall be in accordance with Section 02865 – TRACK APPURTENANCES.
- B. Install 132 RE poly insulated joints at locations shown on the Design Documents.
- C. Install insulated joints during installation of 132 RE rail.
- D. Insulated joints shall be installed as suspended joints.
- E. Accurately space and drill holes for bolting of rail in accordance with requirements of the current AREMA Manual for Railway Engineering, Specifications for Steel Rails and STANDARD PLAN 1302. Drill holes with an approved rail drill.

- F. Drill cylindrical holes of specified diameter for the size bolt required through and perpendicular to web of rail.
- G. Use a template, as a drilling guide, to locate holes both vertically from bottom of rail and horizontally from rail end. In no case shall a joint bar be used for this purpose.
- H. Remove all rough edges from holes.

3.8 SURFACING AND ALIGNING

- A. Surface and align track as specified in Section 02854 – SURFACING AND ALIGNING TRACK.

END OF SECTION

SECTION 02857

SUBBALLAST

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the type of fine crushed stone to be used for the subballast layer beneath the ballast layer for both the Light Rail Tracks and Commuter Rail Tracks.

1.2 SUBMITTALS

- A. The following submittals shall be submitted to the MBTA for review and approval prior to procuring any material or performing any work required under this Section:
 - 1. Submit name and location of proposed supplier.
 - 2. Submit gradation reports of representative samples of the material furnished together with certification that the material meets the requirements of this specification.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Subballast shall be crushed stone or granulated, expanded or air-cooled slag with an average hardness of 5.5 minimum on Moh's Scale of Hardness.
- B. Subballast shall be composed of clean, hard, uncoated particles free from lumps of clay, shale and other objectionable materials.
- C. Subject to meeting the requirements established in 2.1.A, 2.1.B, and 2.2, et seq., subballast currently placed within the MBTA right-of-way and used as subballast may be reused as subballast within the limits of the Project.
- D. Subject to meeting the requirements established in 2.1.A, 2.1.B, and 2.2, et seq., ballast currently placed within the MBTA right-of-way may be reused as subballast within the limits of the Project.

2.2 GRADATION

Gradation shall be in accordance with ASTM C136 and C117 as follows:

Sieve Size	% Passing by Weight
1 inch	100
3/8 inch	50 to 85
No. 4	35 to 65
No. 10	25 to 50
No. 40	15 to 25
No. 200	4 to 10

The fraction passing the No. 200 sieve shall be less than two-thirds of the fraction passing the No. 40 sieve.

1. Soft Particles – ASTM C235 – 5% of sample weight maximum.
2. Clay lumps and Friable Particles – ASTM C142 – 0.5% maximum.
3. Wear ASTM C131 – 20% maximum.
4. Absorption – ASTM C127 – 0.5% maximum.

Crushing of subballast and ballast proposed for use as subballast shall not be required except the supplier may, at their option, elect to crush any oversize particles present in the deposit as an alternative to screening.

2.3 PRODUCTION

- A. Notify the MBTA, at least 30 days prior to delivery, of the source and location of the source of materials to be used, in order that approval test may be conducted.
- B. Use only the one approved material to complete order. Do not change source of material unless new source and material is accepted, in writing, by the MBTA.
- C. Subballast shall be handled during all stages of production and delivery in a manner that will provide all uniform product and will prevent contamination or segregation.
- D. To satisfy the requirements of this specification, subballast may be screened, crushed, washed or otherwise processed to produce a uniform acceptable product.
- E. Blending of materials to improve quality of product shall not be permitted.

2.4 HANDLING

A. Shipping

Load subballast only into rail cars or trucks which are in good order, tight enough to prevent leakage, waste of material and clean and free from rubbish or any other substance which would foul the subballast material.

B. Handling

1. Handle prepared subballast at production plant, during shipment and at work site so that it is kept clean and free from segregation.
2. Do not make repeated passes of equipment over the same level in stockpile area.

C. If oil-stained ballast or subballast removed from the right-of-way is to be stored off-site prior to reuse, the following precautions are recommended:

1. Place ballast on poly sheeting to minimize the potential for oil from stone to contact underlying surface.

2. Utilize hay bales or similar to create a berm surrounding the stockpile area; drape poly sheeting base over bales.
3. Cover ballast with poly sheeting when not being handled to minimize the potential for rain to cause the oil to be released from the stockpiled stone.

2.5 DELIVERY

The stone subballast delivered to the DB Entity shall conform to these Mandatory Specifications in all respects. Material rejected for non-compliance with these Mandatory Specifications will be returned wholly at the DB Entity's expense.

PART 3 – EXECUTION

Not Used.

END OF SECTION

SECTION 02858

BALLAST

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the coarse, angular crushed stone to be used to create the ballast layer for both the Light Rail Tracks and the Commuter Rail Tracks.
- B. Ballast shall conform to AREMA size No. 4 per AREMA Chapter 1, Part 2, as modified by these Mandatory Specifications.

PART 2 - PRODUCTS

2.1 MATERIAL

Ballast shall be crushed, quarried, washed stone conforming to the current AREMA Specification Chapter 1, Part 2 and the following:

Ballast Requirements:

- 1. Deleterious Substances. The amount of deleterious substances present in prepared ballast shall not exceed the following limits, when using test methods specified herein.

	% By Weight	Method of Test
Soft and Friable Pieces	3.0	ASTM C235
Material Finer than No. 200 Sieve	0.5	ASTM C117
Clay Lumps	0.5	ASTM C142

- 2. ASTM C235 method of test for scratch hardness of coarse aggregate particles.
- 3. ASTM C117 test method for materials finer than No. 200 sieve in mineral aggregate be washing.
- 4. ASTM C142 test method covers the approximate determination of clay lumps and friable particles in aggregate.
- 5. Flat or elongated particles having a length equal to or greater than five times the average thickness of the particle shall not exceed five % by weight of the total when visually inspected.
- 6. Water absorption shall not exceed 0.4 pounds per cubic foot when tested in accordance with ASTM C127.
- 7. Percentage of wear, when tested in the Los Angeles abrasion machine in accordance with ASTM C535, grading No. 2, shall not exceed 18%.

8. Soundness of the prepared ballast shall be such that when tested in the sodium sulphate soundness test in accordance with ASTM C88, weighted average loss shall not exceed 1.5% after 10 cycles of test.
9. Cementing value of the ballast shall not exceed an average value of 320 pounds per square inch for five specimens when tested in accordance with the Logan Walter Page Method (U.S. Department of Agriculture, Bulletin No. 347, 1916, Pg. 15) except as modified as follows:
 - a. A sufficient amount of pea size pieces of the rock, amounting to about 500 grams (1.1 pounds) is revolved in Los Angeles Abrasion Cylinder with three cast iron balls 4.76 cm. (1.875 inch) diameter and weighting approximately 0.43 kilograms (0.95 pounds) at the rate of 30 and 33 revolutions per minute, and the stiff dough at room temperature resulting from about 500 grams (17.64 oz.) of dust screened through a 100 mesh sieve, mixed with sufficient water, thoroughly kneaded for five minutes, allowed to stand in an air tight container for two hours, is molded into cylindrical briquettes 2.54 cm. (1 inch) diameter by 2.54 cm. (1 inch) in height under a pressure of 132 kgs. Per sq. cm. (1877.5 pounds per square inch), after which they are dried for 20 hours in air at room temperature, 4 hours in a hot air bath at a temperature of 100 degrees C (212 degrees F), then cooled for 20 minutes in a desiccator and immediately tested in a compression testing machine for static crushing strength, the bearing heads being suspended by pivots to secure uniform distribution of load, which is applied at 600 pounds per minute, approximately.
10. Determine ballast weight per cubic foot in accordance with ASTM C29.
11. Ballast samples shall be obtained in accordance with ASTM D75.

2.2 HANDLING

A. Shipping

- a. Load ballast only into rail cars or trucks which are in good order, tight enough to prevent leakage and waste of material, and clean and free from rubbish or any substance which would foul the ballast.

B. Handling

- a. Handle prepared ballast at production plant, during shipment, and at work site so that it is kept clean and free from segregation.
- b. Do not make repeated passes of equipment over the same level in stock pile area.

C. Reuse of Previously Accepted Ballast

- a. Subject to 2.4.C, if oil-stained ballast is to be stored off-site prior to reuse, the following precautions are recommended:
 1. Place ballast on poly sheeting to minimize the potential for oil from stone to contact underlying surface.
 2. Utilize hay bales or similar to create a berm surrounding the stockpile area; drape poly sheeting base over bales.

3. Cover ballast with poly sheeting when not being handled to minimize the potential for rain to cause the oil to be released from the stockpiled stone.

2.3 DELIVERY

Stone ballast shall conform to these Mandatory Specifications in all respects. Stone ballast is subject to inspection at delivery and is at the supplier's risk until acceptance. Stone ballast rejected for non-compliance with this specification will be returned at the DB Entity's expense.

2.4 QUALITY CONTROL

A. Ballast Production Site Testing

1. Notify the MBTA of proposed source and location of crushed stone ballast. The independent testing company hired by the DB Entity shall obtain samples of proposed material and test them for conformance to classification, quality, and grading requirements specified in Article 2.1. Samples of ballast for testing shall be taken from each 500 tons of prepared ballast. Sample shall be representative and shall weigh not less than 150 pounds.
2. The DB Entity will notify the MBTA of test results. Failure of ballast to meet these requirements will mean rejection of ballast quarry.
3. Ballast material will be accepted in writing by the MBTA prior to commencing work site delivery.
4. If, during ballast installation, source of ballast changes, the independent testing company hired by the DB Entity will perform tests at new production site in accordance with these Mandatory Specifications. Ballast shall have the same or higher classification, quality, and grading as former ballast used. Work site delivery shall not commence until the MBTA has accepted, in writing, the new ballast source.

B. Ballast Job-Site Testing

1. Periodically during progress of track work, the independent testing company hired by the DB Entity will test samples of the ballast obtained from in-place locations designated by the DB Entity to insure a uniform quality of ballast.
2. If ballast in-place does not conform to Article 2.1 in this section, the DB Entity will notify the MBTA and further loading of ballast will be halted until fault has been corrected. DB Entity shall dispose of all defective material without cost to the MBTA.
3. The MBTA reserves the right to reject any load of ballast arriving at work site for unloading that does not conform to this specification. The load shall be disposed of without cost to the MBTA.

C. Reuse of Previously Accepted Ballast and Placed Ballast

Subject to meeting the requirements of 2.1, et seq., and 2.3, ballast currently placed within the MBTA right-of-way may be reused as ballast within the limits of the Project.

PART 3 - EXECUTION

Not Used.

END OF SECTION

SECTION 02859

SHOP TRACK CONSTRUCTION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Description: Requirements for the construction of new shop track systems within the Vehicle and Maintenance Storage Facility (VMF) shop building including embedded shop track and exterior embedded apron shop track areas; pedestal track in the VMF shop building pit track areas and direct fixation type tracks in the wash track areas to line, surface, and grade and as specified herein. Comply with Section 02850 - LIGHT RAIL TRACK CONSTRUCTION, and this Section.
1. Embedded Shop Track and Exterior Apron Tracks:
 - a. Requirements for installing rail to be embedded using rail boot and support leveling beams.
 - b. Requirements for providing reinforced Portland cement concrete floor and apron slabs with appropriate expansion joint material and joint sealants for the shop building in accordance with the Contract Documents.
 - c. Requirements for providing track that exhibits the proper electrical grounding properties as specified herein.
 - d. Requirements for performing required testing for the grounding of rail.
 - e. Requirements for providing other incidentals and ancillary work required for completing an acceptable facility for the operation of passenger vehicles.
 2. Pedestal Shop Track:
 - a. Requirements for installing rail to the VMF shop building shop floor pedestal beams, using cap plate with welding and additional hardware, as required.
 - b. Requirements for providing track that exhibits the proper electrical grounding properties as specified herein.
 - c. Requirements for performing required testing for the grounding of rail.
 - d. Requirements for performing visual and ultrasonic inspection of the plate welds and adjacent metal after plate cooling.
 - e. Requirements for providing other incidentals and ancillary work required for completing an acceptable facility for the operation of LRT vehicles.
 3. Direct Fixation Wash Track:
 - a. Requirements for providing reinforced Portland cement concrete for track slab with appropriate expansion joint material and joint sealants.

- b. Requirements for constructing direct fixation track with single fastener concrete plinths for wash track.
- c. Requirements for providing track that exhibits the proper electrical insulating properties as specified herein.
- d. Requirements for performing required testing of insulated rail.
- e. Requirements for providing other incidentals and ancillary work required for completing an acceptable facility for the operation of LRT vehicles.

B. Section includes:

1. Track alignment, profile, and geometry.
2. Embedded shop track construction.
3. Laying continuous welded 115RE rail in rail boot.
4. Pedestal shop track construction.
5. Direct fixation wash track construction.
6. Distributing continuous welded rail.
7. Rail gap.
8. Rail temperature.
9. Rail installation.
10. Bonded insulated joints.
11. Traction electrification and signal bonding.
12. Tolerances.
13. Field quality control.

C. Related work specified elsewhere

1. Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
2. Section 02851 – RAILROAD RUNNING RAIL.
3. Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
4. Section 02854 – TRACK SURFACING AND ALIGNMENT.
5. Section 02857 – SUBBALLAST.
6. Section 02858 – BALLAST.

7. Section 02862 – GRADE CROSSINGS.
8. Section 02865 – TRACK APPURTENANCES.
9. Section 02867 – RESTRAINING RAILS.
10. Section 02877 – THERMITE WELDING.
11. Section 03300 – CAST-IN-PLACE CONCRETE
12. Section 03410 – PLANT PRECAST STRUCTURAL CONCRETE
13. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION
14. Section 16829 – INSULATED JOINTS FOR THE LIGHT RAIL SIGNAL SYSTEM

1.2 APPLICABLE STANDARDS

- A. The following Codes, Regulations, Reference Standards and Specifications apply to work included in this Section:
 1. MBTA Track Maintenance Standards.
 2. MBTA Book of Standard Trackwork Drawings
 3. American Railway Engineering and Maintenance of Way Association, AREMA:
 - a. Manual for Railway Engineering.
 - b. Portfolio of Trackwork Plans.

1.3 SUBMITTALS

- A. General: Submittal procedures for all submittals, including but not limited to shop drawings, product data, samples, shall comply with Section 2.7 “Design Submittal Review Management” and Section 2.8“Construction Submittal Requirements”.
- B. Relevant submittals as required under Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
- C. Embedded Shop Track:
 1. Work Plan in accordance with applicable Articles in Part 3 herein.
 2. Product Data: Submittals as required by Related Sections.
 3. Shop Drawings:
 - a. Shop and apron track structural drawings.
 - b. Leveling beams.
 - c. Trackwork grounding within the shop.

4. Certified Test Reports:
 - a. Electrical grounding test results.
 5. Instructions and Procedures:
 - a. Procedures for securing encased CWR 115 RE rail.
 - b. Detailed procedure for achieving uniform longitudinal rail stress in embedded track.
 - c. Procedures for forming and finishing flangeways on the gauge side of the rail.
 - d. Welding procedures for AWS D1.4 Welding Reinforcing Steel.
 6. Submit welder qualifications and certifications.
- D. Pedestal Shop Track:
1. Work Plan in accordance with salient Articles in Part 3 herein.
 2. Product Data: Submittals as required by Related Sections.
 3. Shop Drawings:
 - a. Shop pedestal track structural drawings.
 - b. Trackwork insulation within the shop.
 4. Certified Test Reports:
 - a. Rail weld inspection reports.
 5. Instructions and Procedures:
 - a. Procedures for securing 115 RE rail.
 - b. Detailed procedure for achieving uniform longitudinal rail stress in pedestal track.
- E. Wash Tracks:
1. Work Plan in accordance with applicable Articles in Part 3 herein.
 2. Product Data: Submittals as required by Related Sections.
 3. Shop Drawings:
 - a. Shop wash track structural drawings.
 - b. Other materials as specified herein.
 4. Certified Test Reports:
 - a. Electrical insulating test results as specified herein.

5. Instructions and Procedures:
 - a. Procedures for securing CWR 115 RE rail in accordance with Article 3.09 herein.
 - b. Detailed procedure for achieving uniform longitudinal rail stress in wash track.

1.4 QUALITY CONTROL

- A. General: Refer to the Design-Builder Quality Assurance Plan for Quality Assurance requirements and procedures.
- B. Comply with Section 02850 – LIGHT RAIL TRACK CONSTRUCTION requirements for quality in trackwork construction.

1.5 DELIVERY, STORAGE, AND HANDLING

- B. Comply with the requirements of Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.

PART 2-PRODUCTS

2.1 TRACK MATERIALS AND EQUIPMENT

- A. Furnish all materials and equipment required to construct the trackwork, including, but not limited to, the following:
 1. Rail welding materials and equipment:
 - a. Provide welding materials and equipment for welding rail by both the electric (flash butt) method as specified in Section 02851 – RAILROAD RUNNING RAIL, and the thermite weld method as specified in Section 02877 – THERMITE WELDING. Provide submittals as required in these sections.
 2. Concrete slab work, underlying subbase materials, and associated earthwork shall comply with indicated requirements.
- B. Embedded Shop Track:
 1. Concrete:
 - a. Provide 4,000-psi strength concrete mix for the slabs in accordance with the requirements of Section 03300 – CAST-IN-PLACE CONCRETE.
 - b. Submit structural floor shop drawings for the shop and apron track construction and show details for drainage structures and electrical boxes.
 2. Steel Reinforcement Bars:
 - a. Provide Grade 60, uncoated, pre-formed steel reinforcement bars.

- b. Provide electrical continuity throughout all steel reinforcing bar mats to comply with corrosion control requirements by either welding the reinforcing bar connections or by other means.
 - c. Provide expansion joints and construction joints in reinforced concrete.
3. Insulating Rubber Rail Boot: As shown on the Design Documents and the following requirements:
- a. Elastomeric rubber boot and cuff extrusions shall be pre-formed to fit 115RE rail and 115RE tee rail with attached restraining rail as shown on the Design Documents. Rubber rail boot shall be a continuous extruded elastomeric material with a minimum length of 230 feet. Elastomeric rubber extrusion and cuff material shall be manufactured from Santoprene 121-73 W 175 Thermoplastic Rubber or approved equal.
 - b. Rail boot for use with embedded rail shall not be the same product as that used with at-grade crossings specified in Section 02862 – GRADE CROSSINGS. The two products have different purposes and physical dimensions and are not interchangeable.
 - c. Test Requirements: Submit certification from a testing laboratory that the material to be installed in track will pass the tests listed below. Test reports indicating acceptable material shall be received by the MBTA prior to shipment of material to the job site.
 - 1) Volume Resistivity:
 - a) Test Method: In accordance with ASTM D257, at 50% relative humidity and 77 degrees Fahrenheit resistivity shall be measured for a dry specimen and then for the same specimen after 7 days immersion in a 3% NaCl solution. The specimen from the latter test shall only be wiped dry prior to testing and no more than 1 hour shall elapse between removal from immersion and performing the test.
 - b) Acceptance Criterion: 1×10^{12} ohm-cm minimum.
 - 2) Tensile Strength Test:
 - a) Test Method: In accordance with ASTM D412.
 - b) Acceptance Criterion: 1,200 psi minimum.
 - 3) Chemical Resistance:
 - a) Test Method: In accordance with ASTM D471, oil swell, IRM 903.
 - b) Acceptance Criterion: plus 60% by weight maximum.
 - 4) Absorption of Moisture:
 - a) Test Method: In accordance with ASTM D570.
 - b) Acceptance Criterion: Less than 0.45% water absorption by weight.

- 5) Durometer Hardness Test:
 - a) Test Method: In accordance with ASTM D2240, report for cured specimens and specimens aged 24 hours at 75 degrees Fahrenheit.
 - b) Acceptance Criterion: Shore hardness A: 65 to 75.
- d. Service History: Submit certification and documentation from the manufacturer that the installed product will withstand:
 - 1) AASHTO HS25-44 loading in an urban environment for a minimum of 5 years with no failure. Failure shall be defined as the product not capable of carrying a vehicle or pedestrian in a smooth and safe manner from pavement to rail, requiring replacement or repair of the product.
 - 2) The pressure and abrasion of heavy bus and truck traffic with studded tires or chains, and shall provide a non-skid surface for a minimum of 5 years with no failure.
 - 3) The strength of the adhesive used to join adjacent sections when it is at least 70 % of the cohesive strength of the elastomeric rubber extrusion insert.
- 4. Fiber Expansion Joint Materials: As specified in Section 07920 – JOINT SEALANTS.
- 5. Joint Sealing Materials for Shop Floor and Track Slabs: As specified in Section 07920 – JOINT SEALANTS.
- 6. Aggregate base course: In accordance with Section 02509 – PAVEMENT BASE COURSES.
- C. Pedestal Shop Track:
 - 1. Provide pedestal cap plate, crane rail clip to suit 115RE rail base, 1-inch diameter-8 UNC square head anchor bolt, plain washer, spring lockwasher and hexagon nut.
 - a. Pedestal and base of pedestal hardware are considered part of building construction and shall comply with indicated requirements.
- D. All additional materials to complete the various track installations.
 - 1. Provide all other materials incidental to the construction of the track types that are necessary to provide a complete and acceptable track installation providing the function, appearance, and electrical requirements specified.

2.2 EQUIPMENT

- A. Comply with the equipment requirements specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.

PART 3 - EXECUTION

3.1 TRACK ALIGNMENT, PROFILE, AND GEOMETRY

- A. Construct the track types to the alignment and profile and within the tolerances specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.

3.2 EMBEDDED SHOP TRACK CONSTRUCTION

- A. Construct embedded shop and apron track in accordance with the requirements of Section 02850 – LIGHT RAIL TRACK CONSTRUCTION, and where applicable AREMA Manual for Railway Engineering, Volume 1, Chapter 5, Part 4 , except as modified herein.
- B. Work Plan: Prior to beginning the Work specified in this Section, submit a detailed work plan with supporting drawings describing the installation procedures and showing the details required for the Work.
- C. Sub-Grade Preparation:
 - 1. Prepare the sub-grade in accordance with Section 02300 - EARTHWORK.
- D. Interior Embedded Shop Track and Exterior Apron Track Construction:
 - 1. Fully assemble steel leveling beams and rails, rail boot and other track appurtenances in accordance with the requirements indicated in these Mandatory Specifications, the accepted Track Work Plan, the accepted shop drawings, the assembly drawings and instructions from fabricators and suppliers, and other directives as appropriate. Install embedded track in the shop interior floor to standard 4' 8-1/2" track gauge.
 - 2. Form skeleton track on the leveling beams to required surface, line and gauge prior to placement of floor and apron concrete. Secure the rail in position at the proper track gauge and top of rail elevation to suit the floor height using a leveling beam with two hexagonal bolt and nut leveling screws. Space steel leveling beam in track a distance of 7.5 to 10' apart and as required to hold the horizontal and vertical alignment before concrete is placed.
 - 3. Use slotted bolt holes in the leveling beam channels to allow lateral adjustment of the rail to set the proper track gauge.
 - 4. Prior to the concrete pour, the rails in embedded track rails shall be grounded to the shop electrical substation.

3.3 LAYING CONTINUOUS WELDED 115RE RAIL IN RAIL BOOT

- A. Prepare 115RE CWR string lengths in accordance with the accepted Shop Rail Layout Plan developed as part of the Track Work Plan.
- B. De-stressing Rail in Embedded Shop Track:
 - 1. The zero thermal stress (neutral) temperate for un-booted rail at final closure and fastening is 90 to 110 degrees Fahrenheit.
 - a. To establish an approximate rail temperature for encased booted rail, prepare a temperature rail approximately 6' long encased in rail boot with a slot cut out to place a thermometer against the rail base.

- b. Submit a detailed procedure for achieving uniform longitudinal rail stress in embedded track for the controlled stress temperature as specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

C. Booting and Securing Continuous Welded 115RE Rail in Track:

1. Use a complete rail encapsulation methodology (rail boot) on standard embedded trackwork to obtain the required steel rail/concrete interface protection.
2. Install the rail boot to the rail butting the rail boot sections with joining cuffs and the following:
 - a. Exercise care during the handling of the boot spools or lengths, installation, movement of the rail, installation of the track slab reinforcement, and reinforcement welding operations so that the rail boot will not be damaged.
 - b. Install the rail boot only on clean rail free of dirt and debris.
 1. Inspect the inside of the rail boot to ensure that no rocks, dirt, or other construction debris has fallen into the boot, which could cause damage.
 - c. Install the boot to minimize the number of butting joints required in any length of shop track and outside the designated walkway areas of the shop floor. Butting joints shall preferably be factory cut ends and shall be assembled and retained tight to within 1/8 inch. When necessary to cut rail boot, it shall be cut clean and square in accordance with manufacturer's recommendations.
 - d. Hold the rail boot in place using non-conductive tape laid over the rail head in accordance with the manufacturer's recommendations. The use of tie-wire or metallic hangers against the rail boot is strictly prohibited.
3. Lay, clamp, and fasten 115RE CWR in the insulating rubber boot in accordance with the following procedure:
 - a. Place CWR on leveling beams in accordance with accepted work plan procedures and associated working drawings.
 - b. Determine the rail temperature by using a calibrated rail temperature measuring device placed on the shaded side of the base of the temperature rail, and record and submit to the MBTA the rail temperature and other information specified hereinafter for the time the continuous welded rail track was being fastened:
 1. Location by station, track designation, and left or right rail as determined by facing in the direction of increased stationing.
 2. Date and time.
 3. Rail weight and section, mill brand, year and month rolled, and heat number of the end rails in each CWR string.
 4. Length of CWR string in feet.

5. Air temperature, rail temperature taken on the rail base, and approximate weather conditions.
 6. Adjustment applied specifying type and end movement.
 7. Wire or metallic hangers against the rail boot is strictly prohibited.
- c. Secure the encased rail to the leveling beams during appropriate weather conditions to achieve rail temperatures noted and minimize the chances of solar heat gain expanding the rail during the concrete pour.
 - d. If alignment of the track or rail is necessary after installation of the boot, minimize concentrated force on the boot surface as follows:
 1. Use wood blocks or other means to distribute the force of contact.
 2. Shift the leveling beams if necessary, taking care to not damage the rail boot by applying pressure to it.
 3. Adjusting the rail by using lining bars or similar tools directly against the boot is prohibited.
 - e. Both prior to placing concrete and within 30 minutes of placing the concrete for embedded shop track, take a track alignment condition survey to confirm alignment both vertically and horizontally.
 - f. Take periodic survey checks during concrete placement to confirm that the track has not shifted due to thermal expansion or construction activities.
 - g. Shall track shift under thermal expansion or due to concrete placement, cease placing all concrete. Take corrective actions to realign the track, including the removal of concrete or other methods satisfactory to the MBTA, prior to recommencement of embedded shop track construction.
 - h. Finish concrete surfaces within shop area:
 1. Form and finish flangeways adjacent to the gauge side of the rails to the dimensions shown on the accepted drawings. Concrete surface on the field side of the rails shall be depressed ¼” below the top of rail running surface for a distance of 5” beyond the gauge side of the rail.
4. Final Connections to Adjoining Ballasted Track:
 - a. To minimize the chances of pushing the rail longitudinally through the rail boot, provide final closure between embedded shop track and adjoining ballasted yard track rails only after shop track construction is complete, including any intermediate segments of pedestal or direct fixation track.
 - b. Final connection between embedded shop track and adjoining ballasted track shall occur at rail joint locations in the ballasted track area adjacent to the shop apron track. Join the CWR strings (yard and shop) by the joint installation at the appropriate neutral rail laying temperature in both rails.

3.4 PEDESTAL SHOP TRACK CONSTRUCTION

- A. Construct interior pedestal shop track in accordance with the requirements of Section 02850 – LIGHT RAIL TRACK CONSTRUCTION, and where applicable AREMA Manual for Railway Engineering, Volume 1, Chapter 5. Part 4, except as modified herein.
- B. Work Plan: Prior to beginning the Work specified in this Section, prepare a detailed work plan with supporting drawings describing the installation procedures and showing the details required for the Work.
- C. Install pit track for shop interior pedestal track areas by bolting 115RE rail to a pre-welded plate positioned on the “I Beam” vertical pedestals laterally spaced to provide standard 4’ 8-1/2” track gauge and the vertical height to suit the pit track rail elevation.
 - 1. Pedestal trestle construction: Comply with applicable portions of referenced Sections in these Mandatory Specifications as listed in Article 1.1C herein.
 - 2. String the rail in place over the pedestal top plates, position rail to horizontal and vertical track alignment, and track gauge, bolting the rails in place.
 - 3. The pit track rails shall be grounded to the shop electrical system.

3.5 DIRECT FIXATION WASH TRACK CONSTRUCTION

- A. Construct wash track in accordance with the accepted drawings, the requirements of Section 02850 – LIGHT RAIL TRACK CONSTRUCTION, except as modified herein.
- B. Work Plan: Prior to beginning the Work specified in this Section, prepare a detailed work plan with supporting working drawings describing the installation procedures and showing the details required for the Work.
- C. Installation procedure:
 - 1. Placement of extra-length anchor bolt inserts in the base concrete by epoxy grout installation method.
 - 2. Placement of plinth and pad concrete with skeleton track.
 - a. Construct the base slab located beneath wash and inspection tracks in accordance with indicated requirements and the following:
 - 1. Prior to placing concrete confirm both vertical and horizontal alignment.
 - 2. Correct all defects in the aggregate base course material prior to placement of the concrete track slab.
 - 3. Place the concrete track slab in accordance with Section 03300 – CAST-IN-PLACE CONCRETE.
 - 4. Provide electrical continuity throughout all steel reinforcing bar mats to comply with corrosion control requirements by either welding the reinforcing bar

connections or by other means. Perform electrical tests after concrete is placed as specified herein.

5. Install the single track slab sections in one pour.
 6. Locate the top surface of the concrete slab at the base of plinth elevation.
- b. Construct skeleton track on the cured concrete slab and mark locations of fastener anchor bolt holes.
 1. Mark anchor bolt locations using direct fixation fastener with anchor bolt adjustment centered on serrated adjustment section.
 - c. Drill hole diameter and depth to suit special elongated anchor insert and roughen sides of drilled hole for epoxy grout connection.
 - d. Roughen surface of track slab in areas to be covered by plinth concrete.
 - e. Clean area of laitance and debris.
 - f. Reset skeleton track to final alignment and grade to set anchor inserts in drilled holes to proper elevation at top of plinth or pads. Install inserts to protrude above track slab. Inspect the anchor insert epoxy coating before installation; apply approved epoxy paint to areas with damaged coating, if necessary.
 - g. Use top down skeleton track with suspended fasteners with temporary bolted clip/clamps to accurately locate the inserts in the parent slab, and positively secure the anchor inserts against displacement during epoxy grout installation into the concrete track slab.
 - h. Install and position anchor inserts to be flush with the top of the eventual concrete plinth or pad surface to plus 0" or minus 1/8". Provide anchor inserts that are free of loose scale, grease, or other foreign matter.
 - i. Check track alignment and grade prior to placing epoxy grout to permanently secure anchor inserts. Loosen track assembly at fastener rail base once epoxy grout has reach transfer load strength.
 - j. Place plinth and pad formwork to proper height and alignment for track installation.
 - k. Place plinth pad concrete.
 1. Finish the direct fixation fastener bearing seat area, which is the concrete surface area covered by the direct fixation fastener insulating shim, with a uniform steel-troweled cement mortar finish to provide a smooth and uniform bearing surface capable of supporting 100% of the direct fixation fastener.
 2. Construct abbreviated direct fixation fastener concrete track pads and plinths in conformance with the requirements of Section 03300 – CAST-IN-PLACE CONCRETE.

3.6 DISTRIBUTING CONTINUOUS WELDED RAIL

- A. Distribute continuously welded rail in accordance with the requirements specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

3.7 RAIL TEMPERATURE

- A. The zero thermal stress temperature at final closure and fastening for CWR pedestal track and direct fixation track is as noted in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION except that tracks which are constructed within erected buildings and will therefore always be in the shade shall be fastened at a temperature between 90 and 110 degrees Fahrenheit.

3.8 RAIL INSTALLATION

- A. Lay, clamp, fasten, and weld CWR in pedestal track and direct fixation track according to the procedure specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
- B. Install running rail and pre-curved rail in accordance with Section 02851 – RAILROAD RUNNING RAIL.

3.9 BONDED INSULATED JOINTS

- A. Locate bonded insulated rail joints within ballasted track if required.
 - 1. Coordinate construction so that embedded track through the apron areas is complete prior to construction of adjoining ballasted track under Section 02858 – BALLAST.
 - 2. Locate bonded insulated joints centered in the joints between adjacent crossties.
 - 3. Install and test bonded insulated joints in accordance with Section 16829 – INSULATED JOINTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

3.10 TOLERANCES

- A. Conform to the track construction tolerances and concrete finish tolerances specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.

3.11 FIELD QUALITY CONTROL

- A. Incomplete or inadequate quality control documentation will be sufficient grounds for rejection of installed materials.
- B. Final Alignment and Track Inspections:
 - 1. Inspect track construction to verify that the final horizontal and vertical alignment, track gauge, and cross level are within the tolerances specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
- C. Electrical Trackwork Testing:
 - 1. As the Work on the embedded pedestal and direct fixation track sections proceed, perform rail grounding integrity, and rail-to-rail and rail-to-ground electrical resistance tests along the track.

Testing shall be in accordance with Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION.

2. Use the same independent corrosion control firm that will perform the electrical trackwork isolation testing on ballasted track construction outside of the shop building.
3. Testing shall demonstrate that the rails within the shop building and the adjoining aprons, pedestal track, wash tracks and inspection tracks are grounded.

D. Anchor Bolt Insert Tests:

1. During the construction period, intermittently conduct the restrained pull-out test, unrestrained pull-out test, and torsion test as described below on 30 % of the grouted inserts.
 - a. Randomly select inserts, unless otherwise directed by the MBTA.
 - b. Notify the MBTA 24 hours in advance of the location and time of insert testing.
2. Test Methods and Acceptance Criteria: Perform restrained and unrestrained pull-out tests and torsion tests.

END OF SECTION

SECTION 02862

GRADE CROSSINGS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The work specified in this Section shall include the design and construction of rubber rail seal and grade crossing panels as indicated on the accepted drawings, including both at-grade and aerial viaduct pedestrian track crossings and panels placed between the rail and edge of station platform.

1.2 SUBMITTALS

- A. Shop Drawings
 - 1. Detailed description of construction procedures for the specific type of grade crossing to be installed.
 - 2. Product data for crossing materials.

PART 2 - PRODUCTS

2.1 GRADE CROSSINGS, GENERAL

- 1. Commuter rail grade crossings shall be designed in accordance with MBTA Commuter Rail Book of Standard Plans Dwg Nos. 3100, 3106, and 3108.
- 2. Transit rail grade crossings shall be designed in accordance with MBTA MOW Book of Standard Plans Dwg Nos. 145 and 155.
- 3. Design crossings with full depth rubber panels on the commuter line and transit line for at-grade and aerial viaduct pedestrian crossings.
- 4. Design removable full depth rubber panels for use on the field side of the rail along the edge of station platform at all low-level transit passenger stations.
- 5. Design grade crossings with surface of rubber rail seal and bituminous concrete on the commuter line and transit line at the following locations:
 - a. ROW Hi-rail access pads (multiple locations)
 - b. 3rd Avenue grade crossing
- 6. Modular full-depth rubber and elastomeric rail seal products shall be fabricated by a qualified manufacturer regularly engaged in the production of such items for commuter and transit rail applications.
- 7. Crossing material shall be insulator type design to retard stray current. Crossing module material shall provide volume bulk resistivity of 1×10^7 ohm-cm according to ASTM D257.

8. Rubber Rail Seals:
 - a. Crossing material shall be an elastomeric type, designed and manufactured of 100% virgin rubber and having the ability to interface with a bituminous surface. All rubber materials shall meet ASTM Specification D-2000, M4A712, B35, C32, EA14, G21, and Z1 thru Z6.
 - b. Crossing material shall be capable of being installed and secured using the approved rail fastener system on timber ties using 132 RE or 115 RE rail sections.

PART 3 – EXECUTION

3.1 GRADE CROSSING CONSTRUCTION

1. Crossing placement shall be coordinated with insulated joint locations.
2. Installation of rubber crossing material shall be in accordance with manufacturer's recommendations and MBTA Standard Drawings.

END OF SECTION

SECTION 02865

TRACK APPURTENANCES

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section describes the requirements for furnishing and installing miscellaneous track appurtenances which may be required.

1.2 APPLICABLE STANDARDS

- A. The following Codes, Regulations, Reference Standards and Specifications apply to work included in this Section:

1. American Railway Engineering and Maintenance of Way Association (AREMA):
 - a. Manual for Railway Engineering.
 - b. Portfolio of Trackwork Plans.
2. MBTA Book of Standard Trackwork Plans
3. American Society of Mechanical Engineers (ASME):
 - a. ASME B1.1 Unified Inch Screw Threads (UN and UNR Tread Form)
 - b. ASME B1.3 Screw Thread Gaging Systems for Applicability: Inch and Metric Screw Threads
 - c. ASME B.18.2.1 Square, Hex, Heavy Hex, and Askew Bolts and Hex, Heavy Hex, Hex Flange and Lag Screws
4. ASTM International (ASTM)
 - a. ASTM A36 Carbon Structural Steel
 - b. ASTM A123 Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
 - c. ASTM A325 Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
 - d. ASTM D257 Test Methods for DC Resistance or Conductance of Insulating Material Tensile Strength
 - e. ASTM D395 Test Methods for Rubber Property – Compression Set
 - f. ASTM D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
 - g. ASTM D471 Test Methods for Rubber Property – Effect of Liquids

- h. ASTM D570 Test Methods for Water Absorption of Plastics
 - i. ASTM D573 Test Methods for Rubber – Deterioration in an Air Oven
 - j. ASTM D1002 Test Methods for Apparent Shear Strength of Single Lap Joint Adhesively Bonded Metal Loading (Metal to Metal)
 - k. ASTM D1149 Test Methods for Rubber Deterioration – Surface Ozone Cracking in a Chamber Ozone Controlled Environment
 - l. ASTM D2137 Test Methods for Rubber Property – Brittleness Point of Flexible Polymers and Coated Fabrics
 - m. ASTM D2240 Test Methods for Rubber Property – Durometer Hardness
5. National Electrical Manufacturers Associates (NEMA):
- a. NEMA Standard L1

1.3 RELATED WORK

- A. Other specification sections that relate to the work include, but are not limited to, the following:
 - 1. Section 02886 – BALLAST MATS
 - 2. Section 03300 – CAST-IN-PLACE CONCRETE

1.4 QUALITY ASSURANCE

- A. Prior to the procurement of any material or the commencement of any work, obtain certified reports from the manufacturers or from laboratories accepted by the MBTA indicating the critical properties of all track appurtenances, as specified.
- B. Inspection
 - 1. The MBTA shall have free entry to the track appurtenance manufacturing facilities at all times while the work under this Section is in progress.
 - 2. The MBTA shall be provided with all proper facilities and testing equipment to ensure that the track appurtenances being furnished to the MBTA are as specified.

1.5 SUBMITTALS

- A. The following submittals shall be made to the MBTA for review prior to procuring any material or performing any work required under this Section:
 - 1. Submit name, manufacturer’s catalog cuts and specifications.
 - 2. Submit certified manufacturers’ test reports or test reports from a laboratory accepted by the MBTA establishing the critical properties of each track appurtenance to the satisfaction of the MBTA.

3. Submit shop drawings detailing the manufacture and recommended installation procedures for the rail bond system.
- B. All submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.

PART 2 – PRODUCTS

2.1 MATERIALS

A. Bumping Posts for Transit Line

1. Bumping posts for LRT (Green Line) track shall be Type WA as manufactured by the Western-Cullen-Hayes, Inc. or equivalent, meeting the requirements specified herein.
2. A complete bumping post assembly shall consist of a steel bumping post equipped with a shock absorbent head of multiple-spring and shockbed design.
3. All components used in the manufacture of bumping posts shall conform to the dimensional requirements of Section 115 RE rail unless specified otherwise. Bumping posts shall be designed for severe service conditions. Assembly shall be symmetrical about the centerline of track
4. Bumping posts shall be designed to be bolted to the running rails. No part of the assembly shall extend more than two inches below the rail base. Bumping post components shall clear the vehicle regardless of its position. Bumping post to vehicle clearances shall be based on vehicle coupler swing radius, swing angle and coupler size.
5. Dimensions shown on MBTA MOW Standard Plan No. 925 are based on prevailing train designs in use at the time of Plan preparation (June 2001). Different vehicle designs may require dimensional modifications to bumping post design. The DB Entity is responsible for determining the suitability of bumping post design to prevailing car design upon receipt of car data from the MBTA. Identify on submittals the vehicle design used for design of bumping posts.
6. Bumping post heads shall engage the vehicle anti-climber. Heads shall be shock absorbent design, such as the Hayco Shock-Free head manufactured by the Western-Cullen-Hayes, Inc. or equivalent.

B. Hydraulic Bumping Posts for Transit Line

1. Where specified in accepted drawings hydraulic bumping posts are required. Hydraulic bumping post – An energy absorbing and automatic resetting bumping post capable of withstanding a six mph impact from trains weighing 385 tons without damage to the vehicle or the bumping post. Provide Track Mounted Hydraulic Transit Bumper meeting these criteria as manufactured by Western-Cullen-Hayes, Inc. model WH, or approved equal.
2. Bumping posts shall be bolted to the running rails and shall not require anchoring to cross ties. No part of the assembly shall extend more than two inches below the rail base.
3. The hydraulic bumping post shall be provided for use with transit vehicles. The striking face shall engage the transit vehicle's anti-climber. Bumping post components shall clear the transit

vehicle coupler regardless of its position. Clearances shall be based on the coupler swing radius, swing angle, and size of coupler indicated.

C. Joint Bars and Associated Hardware

1. Standard joint bar assembly to consist of two toeless, headfree bars of the rail section and length indicated, track bolts, nuts and washers in quantity as dictated by the specified joint bar length. All material and processes shall be in accordance with the current AREMA manual for Railway Engineering, Chapter 4, Part 3 – Specifications for Quenched Carbon Steel Joint Bars.
2. Track bolts and nuts material and manufacture shall be in accordance with the current AREMA Manual, Chapter 4, Part 3 – Specifications for Heat-Treated Carbon Steel Track Bolts and Carbon Steel Nuts.
 - a. Prior to shipment, entire bolt thread shall be coated with an appropriate oil or grease to protect the threads during shipment and storage.
 - b. Bolt and nut shall be assembled for shipment by turning the nut onto the bolt at least two threads.
3. Lockwasher material and manufacture shall be in accordance with the current AREMA Manual, Chapter 4, Part 3 – Specifications for Spring Washers.
4. Joint bars for transit lines shall be in accordance with Plan No. 320 in the MBTA M.O.W. Division Book of Standard Trackwork Plans. Joint bars for commuter line shall be in accordance with MBTA Standard Plan No. 1320 for 115 LB RE rail or Standard Plan No. 1322 for 132 LB RE rail. Varying lengths of bars and different rail sections may be specified by any particular order. Length and bar punching will be indicated in the order.
5. Compromise joint bars for transit lines shall be in accordance with Plan No. 350 in the MBTA M.O.W. Division Book of Standard Trackwork Plans for the rail sizes as specified in the order. Compromise joint bars for commuter lines shall be in accordance with MBTA Standard Plan No. 1328.
6. Track bolts shall be rolled, button-head, elliptic neck bolts with wrench fit thread and shall be provided with standard square nuts all per the current AREMA Manual Chapter 4, Part 3. Bolt diameter and length shall be as specified in the order.
7. Lock washer diameter shall be as specified in the order and washer configuration shall conform to requirements of ANSI, B27.1, for Extra Heavy Duty Helical Spring Lock Washers.

D. Cut Track Spike

1. Refer to MS No. 9212 in this section.

E. Split Switch Derails

1. Refer to MS No. 9215 in this section.

F. Insulated Bonded Joint Plug Rail

1. Refer to MS No. 9221 in this section (See paragraph 3.8.B of this Section).

G. Insulated Joint Kit

1. Refer to MS No. 9224 in this section (See paragraph 3.9.B of this Section).

H. Resilient Fastener

1. Refer to MS No. 9245 in this section.

I. Screw Spikes

1. Refer to MS No. 9246 in this section.

J. Tie Plate Resilient Fastener

1. Refer to MS No. 9269 in this section.

K. Tie Plug – Treated

1. Refer to MS No. 9275 in this section.

L. Restraining Rail Lubricators

1. Where specified by the accepted drawings, a single track restraining rail lubrication system shall be installed. A single track restraining rail lubricator systems meeting these criteria as manufactured by SKF-Lincoln Industrial Corp. or approved equal.
2. The single track restraining rail lubrication system shall include a metallic weather resistant cabinet with durable powder coated finish housing the pump, controller, power supply and reservoir with 200 lbs. grease capacity. When not installed on above grade structures, the metallic cabinet shall be placed on a concrete leveling pad.
3. The single track restraining rail lubrication system shall have an oversized 24 Volt DC solar panel to charge battery cells and shall be designed to be theft resistant.
4. A grease pump shall be installed which provides low flow (7 cubic inches/minute) at high pressure (4,000 psig) and is able to pump an equal amount of grease to each applicator bar at a distance of up to 200 feet from the reservoir.
5. The system shall include two restraining rail applicator bar assemblies. The assembly shall consist of a valve divider block to distribute grease evenly to ports on the assembly bars.
6. The system shall have a non-contacting wheel sensor, controller with wheel counter and adjustment dials to allow precision grease pumping on time (in seconds) per cycle (specified number of axle count) basis.

PART 3 – EXECUTION

3.1 BUMPING POSTS

- A. Prior to fabrication, the manufacturer shall submit shop drawings showing details of materials, manufacturing procedures and tolerances for review and acceptance. Identify on shop drawings the vehicle design used for design of bumping posts.

- B. Bumping Posts shall conform to these Mandatory Specifications in all respects. Bumping posts rejected for non-compliance with these Mandatory Specifications will be returned at the DB Entity's expense.
- C. Installation of bumping posts shall be in conformance with MBTA Standard Plan No. 3010, the manufacturer's recommendations and specifications.

3.2 JOINT BARS AND ASSOCIATED HARDWARE

- A. Inspection and testing shall be in conformance with the inspection procedures outlined in the current AREMA Manual, Chapter 4, Part 3.
- B. Prior to shipment, the manufacturer or supplier shall submit certified inspection and test reports as required.
- C. Joints shall be wired into matched pairs, palletized and strapped for shipment.
- D. Bolts and nuts shall be packed in sealed kegs with a maximum of 200 lbs. per keg. Kegs shall be palletized and wrapped or strapped for shipment.
- E. Lock washers shall be packed in steel pails or kegs with a maximum of 200 lbs. per container.
- F. To be accepted, all material specified herein shall conform to these Mandatory Specifications in every respect. Material is at the supplier's risk until accepted at the specified delivery site by an authorized representative of the MBTA. Material rejected for non-compliance with these Mandatory Specifications will be returned to the supplier wholly at the supplier's expense.

3.5 CUT TRACK SPIKE

- A. Refer to MS No. 9212 in this Section.

3.6 SPLIT SWITCH DERAILS

- A. Refer to MS No. 9215 in this Section.
- B. Installation of split switch derails shall be according to the manufacturer's recommendations, MBTA Standard Plan No. 3006, and as specified in
 - 1. Section 02854 – TRACK SURFACING AND ALIGNMENT
 - 2. Section 02855 – SPECIAL TRACKWORK

3.7 INSULATED BONDED JOINT PLUG RAIL

- A. Refer to MS No. 9221 in this Section.
- B. End posts in insulated joints; both plug rails and bolted poly, shall be 3/8" thick rather than 3/16" as indicated on attached MS sheets to improve insulator reliability.

3.8 INSULATED JOINT KIT

- A. Refer to MS No. 9224 in this Section.

- B. End posts in insulated joints; both plug rails and bolted poly, shall be 3/8” thick rather than 3/16” as indicated on attached MS sheets to improve insulator reliability.
- C. Installation of insulated joints shall be as specified in
 - 1. Sections 02850 – LIGHT RAIL TRACK CONSTRUCTION
 - 2. Sections 02856 – COMMUTER RAIL TRACK CONSTRUCTION
 - 3. Sections 02879 – SIDE TRACK CONSTRUCTION FOR COMMUTER RAIL SYSTEMS

3.9 RESILIENT FASTENER

- A. Refer to MS No. 9245 in this Section.

3.10 SCREW SPIKES

- A. Refer to MS No. 9246 in this Section.

3.11 TIE PLATE RESILIENT FASTENER

- A. Refer to MS No. 9269 in this Section.

3.12 TIE PLUG – TREATED

- A. Refer to MS No. 9275 in this Section.

3.13 COMPROMISE JOINTS

- A. Installation of compromise joints at the siding locations shown on the Design Documents shall be according to the manufacturer’s recommendations, MBTA Standard Plan 1328, and as specified in
 - 1. Sections 02879 – SIDE TRACK CONSTRUCTION FOR COMMUTER RAIL SYSTEMS

3.14 RESTRAINING RAIL LUBRICATORS

- A. Installation of restraining rail lubricators at the restraining rail locations shown on the Design Documents shall be according to the manufacturer’s recommendations.
- B. At-grade installations shall have a 6’x 7’ leveling pad installed beneath the metallic weather resistant cabinet.
- C. All metallic weather resistant cabinets and associated equipment shall be clear of the light rail vehicle’s clearance envelope.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9212

CUT TRACK SPIKE

MATERIALS

Cut track spikes shall conform to material and workmanship specifications of the AREA Manual for Railroad Engineering, Chapter 5, Part 2 - "Specifications for Soft-Steel Track Spikes".

DESIGN

Cut track spikes shall be in accordance with MBTA Book of Standard Plans.

INSPECTION

Inspection shall be in accordance with the inspection procedures outlined in AREA Manual Chapter 5, Part 2.

SHIPMENT

All cut track spikes shall be packed in sealed-top kegs or other suitable container, with a maximum of 200 pounds of non-defective cut track spikes per container.

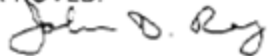
DELIVERY

To be accepted, the cut track spikes offered shall conform to this specification in all respects. All spikes are subject to inspection at delivery and are at the supplier's risk until acceptance. All spikes rejected for non-compliance with this specification will be returned at the supplier's expense.

APPLICABLE STANDARD PLANS

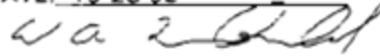
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CUT TRACK SPIKE PAGE 1 OF 1

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9215

DERAIL - SPLIT SWITCH

MATERIALS

Materials shall conform to AREA-Portfolio of Trackwork Plans - Plan No. 100-89 "Specification for Special Trackwork".

DESIGN

Split switch derail shall be a 16'-6" switch point complete with 39 foot undercut stock rail, switch plates, rail braces, solid heel block, operating rod and support bracket, connecting rod, and switch stand in accordance with MBTA Standard Plans 3006 and 3007. Derail shall be for right or left hand as specified in the order.

Switch point and stock rail shall be manufactured from heat treated rail per MBTA Material Specification No. 9233 titled "Rail - High Strength Running".

MANUFACTURE

Split switch derail shall include, but not be limited to, the following components in accordance with MBTA Standard Plans specified by plan number.

- 16'-6" Switch Point
- Heel Block Assembly
- 39'-0" Undercut Stock Rail
- Adjustable Brace Plates
- Switch Rail Stop
- Adjustable Rocker Clip
- Switch Rod
- Turnout Plates
- Rail Braces
- New Century Switch Stand
- Operating Rod Support Bracket
- Screw Spikes


MATERIALS TO BE SUPPLIED BY OTHERS

Lock Spikes, Cut Track Spikes and Switch Timber

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DERAIL - SPLIT SWITCH PAGE 1 OF 2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9215

DERAIL - SPLIT SWITCH

SHIPMENT

Switch point and stock rail shall be blocked and banded together; switch rods shall be banded together; plates, braces and switch stands shall be palletized and wrapped or banded for shipment. All shall be marked to identify them as a unit.

INSPECTION

The manufacturer shall be responsible for all tests and inspections necessary to ensure that the split switch derail conform to this specification and the MBTA Standard Plans referenced herein.

DELIVERY

To be accepted switch point derail must conform to this specification in all respects. Switch point derail is subject to inspection at time of delivery and is at supplier's risk until accepted by the Authority. Switch point derail rejected for non-compliance with this specification will be returned at supplier's expense.

APPLICABLE STANDARD PLANS

No. 2104	No. 2350
No. 2106	No. 2352
No. 2107	No. 3007
No. 2340	No. 3020

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DERAIL - SPLIT SWITCH PAGE 2 OF 2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9221

INSULATED BONDED JOINT PLUG RAIL

MATERIALS

Insulated joints shall be in conformance with AREA Manual for Railway Engineering, Chapter 4, Part 2, "Specification for Quenched Carbon-Steel Joint Bars".

Rail shall be No. 1, fully heat-treated, high strength steel rail with no "A" rails. Rail shall conform to MBTA Material Specification No. 9233 titled "Rail - High Strength Running".

DESIGN

The joint bars shall be 36 inch, full-face contact design, conforming to the rail section specified and shall consist of joint bars, end posts, bushings, bolts, nuts, washers and insulated polyplate tie plates (when specified on the order), as manufactured by Portec or equivalent.

Joint bars shall conform to rail size specified in the order.

MANUFACTURE

Rail shall be two pieces, with lengths as specified on the order, jointed to form a plug rail. Web of rail where joint is to be bonded shall be ground free of brandings to provide a full contact fit.


Joint Bars - Joint bars to be smooth and straight with all burrs removed. The inside face of the joint bars shall have all insulating material pre-bonded and shall be free of stamping or branding. The fabrication tolerances shall be as follows:

Fishing Height - Plus or minus 1/64 inch
Straightness - Plus or minus 1/32 inch in 36 inches
Length - Plus or minus 1/8 inch

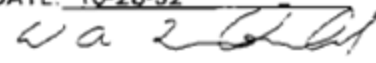
Joint bars shall be designed so that when fully assembled and bonded to rail 3/4 of an inch of rail base, on each side of the rail, shall be exposed to allow application of rail fasteners.

Insulation - Insulation materials shall be of high pressure, laminated design, impervious to oil, grease and water. The material shall have electrical resistance characteristics equal to or greater than fiber insulation meeting the requirements of the AAR Manual, Part 116, Signal Section Specification 216-46.

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MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9221

INSULATED BONDED JOINT PLUG RAIL

End posts shall be manufactured to fit ball, web, and base and shall be 3/16 inch thick and shall project 1/4 inch plus to 1/16 inch minus below the base of rail.

Fasteners - Insulated bonded joints shall be bolted together with six high strength 1 inch bolts. The bolts shall be in conformance with ASTM Specification A490 having Class 2A and 2B thread fit. The fastener provided must provide a positive means for maintaining the tension in the bolts by a lock-nut complying with Industrial Fastener Institute Standard IFI-100 and IFI-101, or approved equivalent. Flat washers, if required, shall be hardened A-325 or A-490 quenched and tempered carbon steel.

Adhesive - The adhesive shall have a shelf life of at least one year when stored in a protected, weather tight location at reasonable storage temperatures, and shall withstand the requirements of the prescribed mechanical testing.

TESTING

The manufacturer shall perform and certify in writing prior to shipment, that three assembled joints, representative of the joints offered, have successfully passed the following tests:

Rolling Load Test
Longitudinal Compressive Strength

Rolling Load Test - The rail joint shall be mounted on a 33 inch stroke rolling load test machine, supported on 36 inch centers, with the joint centered between the supports. Apply a 44,400 pound wheel load on the rail for 2,000,000 cycles and measure and record to the nearest 0.001 inch the deflection of the rail at the centerline of the joint. The deflection at the ends of the joint shall also be measured at every 500,000 cycles. The wheel path shall travel from a point 6 inches from the center of the joint to a point 9 inches outside the opposite end of the joint. Total range of deflection of the joint shall not exceed 0.065 inches during the test and the joint shall show no evidence of failure by bending. The electrical resistance test shall then be performed and the test results shall be within the acceptance criteria specified.

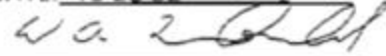
The Longitudinal Compression Test shall then be performed on the test specimens and the results shall be within the acceptance criteria specified.

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INSULATED BONDED JOINT PLUG RAIL PAGE 2 OF 4

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9221

INSULATED BONDED JOINT PLUG RAIL

Longitudinal Compression Test - The assembled joint shall be sawn in half where the rails are joined together in a manner which will prevent over-heating and damage to the epoxy bond. The cut shall be perpendicular to the center line of the top of rail.

A fixture or device shall be used so that the reaction at the sawn ends occurs only on the face of the joint bars when a load is applied to the centroid of the rail at the opposite end. The load shall be applied in increments of 25,000 pounds, maintaining each load increment until the deflection of the rail stops before increasing the load. The load shall be increased to 650,000 pounds and a record of loading and differential movement of the rail, measured to 0.001 inch shall be measured for each increment. The joint shall show no indication of slippage prior to reaching a compressive load of 650,000 pounds and the movement shall be less than 1/8 inch in any direction. The relative position of the rail and joint bar shall be within 1/32 inch of its original value when the load is removed.

The manufacturer shall perform and certify in writing, prior to shipment, that each assembled INSULATED BONDED JOINT PLUG RAIL, in the order, has successfully passed the following Electrical Resistance Test.

Electrical Resistance Test - A rail joint shall be assembled in accordance with manufacturer's recommendations and supported on non-conducting material. With 500 volts dc applied to the rail across the bonded insulated joint for a duration of three minutes, the current flow through the joint should be measured to the nearest 0.1 micro ampere. The minimum acceptable resistance for the test shall be 10 megohms. With 50 volts ac applied to the rail across the bonded insulated joint for a duration of three minutes, the impedance shall be measured with an accuracy of plus or minus 2 degrees. This test shall be repeated three times, once with a frequency in the range from 10Hz to 100Hz, again with a frequency in the range from 200Hz to 1000Hz and again in the range from 2000Hz to 10KHz. The minimum acceptable impedance for any of these tests shall be 10,000 ohms.

S. Alleghany

APPROVED:

John D. Ray

ENGINEERING OFFICER

DATE: 10-28-92

W. A. [Signature]

CHIEF ENGINEERING OFFICER

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9221

INSULATED BONDED JOINT PLUG RAIL

FABRICATION

All insulated bonded joint plug rails shall be fully shop assembled prior to shipment.

Insulated bonded joint plug rails shall be in accordance with MBTA Standard Plan to lengths as specified in the order.

SUBMITTALS

Prior to shipment, the manufacturer shall submit shop drawing showing materials and fabrication tolerances.

Prior to shipment, the manufacturer shall submit certified test results for tests described under testing.

All submittals shall be made to the Chief Engineering Officer, or his designee, for review.

DELIVERY

To be accepted, insulated bonded joint plug rails shall conform to this specification in all respects. Insulated bonded joint plug rails are subject to inspection at delivery and are at the supplier's risk until acceptance. Insulated bonded joint plug rails rejected for non-compliance with this specification will be returned at the supplier's expense.

APPLICABLE STANDARD PLANS

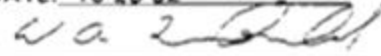
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INSULATED BONDED JOINT PLUG RAIL PAGE 4 OF 4

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9224

INSULATED JOINT KIT

MATERIALS

Insulated joint bars shall be manufactured to conform to AREA Manual for Railway Engineering, Chapter 4, Part 2, "Specifications for Quenched Carbon-Steel Joint Bars".

DESIGN

Insulated joint shall be 36 inch, 6 hole, short toe, full face design, conforming to the configuration of the rail section ordered, bars shall be insulated with a polymeric material.

Joint shall consist of joint bars, bolts, nuts and washers, end posts, and bushings packaged as a unit.

Joint shall conform to rail size specified in the order.

End posts shall be 3/16 inch thick and shall project 1/4 inch plus to 1/16 inch minus below the base of the rail.

SUBMITTAL


Prior to fabrication, the manufacturer shall submit shop drawings showing details of materials, manufacturing procedures, and tolerances to the Chief Engineering Officer, or his designee, for review.

Upon completion of the testing, submit certified results in writing including statement that joints have passed the test and are approved.

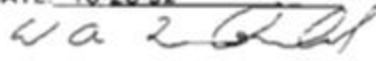
MANUFACTURE

Joint bars shall be smooth and straight with all burrs removed. The bars shall be short toe type so that when the joint is completely assembled 3/4 of an inch of rail base, on both sides of the rail, shall be exposed to allow application of rail fasteners. The face of the joint bar shall be free of stamping or branding. Boring of bolt holes shall be for 1 1/8 inch bolts spaced as shown on MBTA STANDARD PLAN for rail section ordered.

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INSULATED JOINT KIT PAGE 1 OF 3

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9224

INSULATED JOINT KIT

Insulation shall be a uniform, single pour, polymeric insulation material, equivalent to that manufactured by Portec, Inc. Joint insulation, end post and bushing insulation material shall be impervious to oil, grease and water, and shall have electrical resistance characteristics equal to or greater than fiber insulation meeting the requirements of the AAR Signal Manual Part 14.5.1. Insulated joints shall be highly resistant to abrading, cracking, cutting, spalling and fatigue failure under impact loads, and shall exhibit deflection characteristics comparable to standard steel rail joints.

Fasteners - insulated joint kits shall be supplied with six high strength 1 1/8 inch bolts. The bolts shall be in conformance with ASTM Specification A490 having Class 2A and 2B thread fit. The fastener provided must provide a positive means for maintaining the tension in the bolts by a lock-nut complying with Industrial Fastener Institute Standard IFI-100 and IFI-101, or approved equivalent. Flat washers, if required shall be hardened A325 or A490 quenched and tempered carbon steel.

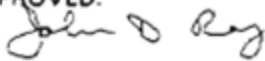
TESTING

The manufacturer shall perform and certify in writing, prior to shipment, that three assembled joints have successfully passed the following tests:

Electrical Resistance Test
Rolling Load Test

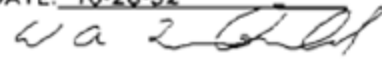
Electrical Resistance Test - A rail joint shall be assembled in accordance with manufacturer's recommendations and supported on non-conducting material. With 500 volts dc applied to the rail across the insulated joint for a duration of three minutes, the current flow through the joint should be measured to the nearest 0.1 micro ampere. The minimum acceptable resistance for the test shall be 10 megohms. With 50 volts dc applied to the rail across the insulated joint for a duration of three minutes, the impedance shall be measured with an accuracy of plus or minus 2 percent. This test shall be repeated three times, once with a frequency in the range from 20Hz to 100Hz, again with a frequency in the range from 200Hz to 1000Hz and again in the range from 2000Hz to 10KHz. The minimum acceptable impedance for any of these tests shall be 10,000 ohms.

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INSULATED JOINT KIT PAGE 2 OF 3

INSULATED JOINT KIT

Rolling Load Test - The rail joint used in the Electrical Resistance Test shall be fully assembled onto two pieces of rail, each a minimum of 30 inches in length, and mounted on a 33 inch stroke rolling load test machine, supported on 36 inch centers, with the joint centered between the supports. Apply a 44,400 pound wheel load on the rail for 2,000,000 cycles and measure and record to the nearest 0.001 inch the deflection of the rail at the centerline of the joint. The deflection at the ends of the joint shall also be measured at every 500,000 cycles. The wheel path shall travel from a point 6 inches from the center of the joint to a point 9 in. outside the opposite end of the joint. Total range of deflection of the joint shall not exceed 0.065 inches during the test and the joint shall show no evidence of failure by bending. The electrical resistance test shall then be repeated and the test results shall be within the acceptance criteria specified.

SHIPMENT

Insulated joint shall be packaged in kit form with each kit containing all necessary materials and instructions to install the joint.

DELIVERY

To be accepted, insulated joint kits shall conform to this specification in all respects. Insulated joint kits are subject to inspection at delivery and are at the supplier's risk until acceptance. Insulated joint kits rejected for non-compliance with this specification will be returned at the supplier's expense.

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MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9245

RESILIENT FASTENER

MATERIAL

Resilient fastener shall be manufactured from high quality spring steel bar stock.

DESIGN & MANUFACTURE

Resilient fastener shall be designed and manufactured to fit MBTA Standard Resilient Fastener Tie Plate for rail weight as specified in the order.

Resilient fastener shall be designed to resist rail longitudinal forces by exerting downward pressure on the base of the rail by spring action.

Resilient fastener shall be designed to be installed by driving with hand tools or applied mechanically by an on-track machine.

Resilient fastener shall be designed so that application pressure shall be by driving parallel to length of rail to avoid possible damage to rail base by scoring.

Resilient fastener shall have a minimum hold down force of 2750 pounds for each fastener.

Minimum static longitudinal slip per complete rail fastener assembly with two resilient fasteners in place shall be 5500 pounds.

Resilient fastener shall be designed to be installed and removed by one man using readily available track tools or by commercially available equipment and shall be capable of removal and reapplication without appreciable loss of hold down force.

TESTING

Representative samples from each run of resilient fasteners shall be tested and certified that they meet this specification in all respects.

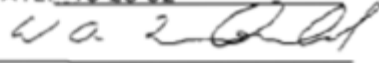
SUBMITTAL

Submit results of testing and certification that resilient fasteners meet or exceed this specification.

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RESILIENT FASTENER PAGE 1 OF 2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9245

RESILIENT FASTENER

SHIPMENT

Resilient fasteners shall be packed 50 fasteners per bag in heavy canvas or other suitable bags and have waterproof tags attached identifying the manufacturer and the order number.

DELIVERY

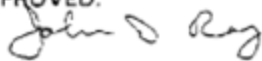
To be accepted resilient fasteners shall conform to this specification in all respects. Fasteners are subject to inspection at time of delivery and are at manufacturer's or supplier's risk until accepted. Fasteners rejected for non-compliance with this specification will be returned at supplier's expense.

APPLICABLE STANDARD PLANS

No. 1224

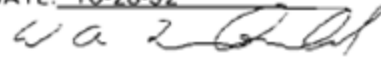
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RESILIENT FASTENER PAGE 2 OF 2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9246

SCREW SPIKES

MATERIALS

Screw spikes shall be hot forged from medium carbon steel conforming with ASTM designation A-66.

DESIGNS

Screw spikes shall be in accordance with MBTA Book of Standard Plans.

Screw spikes shall be either 7/8 inch by 5 3/4 inches measured under the head or 15/16 inch by 6 inches measured under the head as specified on the order.

Screw spikes shall be manufactured to comply with ASTM A-66 to meet the following physical requirements.

Tensile Strength - Minimum psi 60,000
Yield Point - psi 0.5 tensile strength
Elongation - 18 percent in 2 inches
Heads shall be "S" style

INSPECTION

Inspection shall be in accordance with the inspection procedures outlined in AREA Manual.

SHIPMENT

Screw spikes shall be packed in sealed-top kegs or other suitable containers, with a maximum of 200 pounds of non-defective lags per container.


DELIVERY

To be accepted, screw spikes offered shall conform to this specification in all respects. Screw spikes are subject to inspection at delivery and are at supplier's risk until acceptance. Screw spikes rejected for non-compliance with this specification will be returned at supplier's expense.

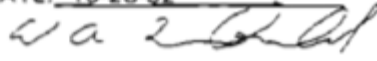
APPLICABLE STANDARD PLANS

No. 1218

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SCREW SPIKES PAGE 1 OF 1

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9269

TIE PLATE - RESILIENT FASTENER

MATERIALS

New resilient fastener tie plate shall conform to AREA Manual For Railway Engineering, Chapter 5, Part 1 - "Specification For Low-Carbon Steel Tie Plates"

MANUFACTURE

Each new resilient fastener tie plate shall have 6 hole punching, 1:40 cant, and shall be in accordance with MBTA Standard Plans.

Material order shall specify plan number required.

INSPECTION

Resilient fastener tie plates are subject to inspection at delivery for compliance with these specifications.

SHIPMENT

Resilient fastener tie plates shall be handled and shipped in accordance with currently accepted practices and as specified in the order.

DELIVERY

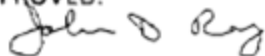
To be accepted, resilient fastener tie plates offered shall conform to this specification in all respects. Resilient fastener tie plates are subject to inspection at delivery and are at the supplier's risk until acceptance. Resilient fastener tie plates rejected for non-compliance with this specification will be returned at the supplier's expense.

APPLICABLE STANDARD PLANS

No. 1224

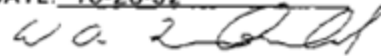
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TIE PLATES - RESILIENT PAGE 1 OF 1

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9275

TIE-PLUG - TREATED

MATERIAL

Tie plug shall be manufactured from sound, seasoned, straight grained wood, free from knots and other defects in compliance with AREA Manual, Chapter 5, Part 1, Section 7 - "Specifications for Tie Plugs".

DESIGN

The plugs shall be manufactured in two varieties, both for 5/8 inch spikes, notched and unnotched. The variety shall be specified in the material order and shall be sized as follows:

Notched tie plugs shall be in sticks of five plugs per stick. Tie plugs shall be 5/8 inch by 5/8 inch x 4½ inches.

Unnotched tie plugs shall be in sticks 5/8 inch by 5/8 inch x 22½ inches long.

TREATMENT

Tie plugs shall be treated with a 60/40 creosote and petroleum solution with retention of 8 pounds per cubic foot in accordance with AREA Manual, Chapter 3, Part 6.

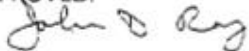
SHIPMENT

Treated tie plugs shall be bundled 100 sticks per bundle, palletized, and strapped for shipment.

DELIVERY

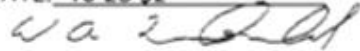
To be accepted, treated tie plugs shall conform to this specification in all respects. Treated tie plugs are subject to inspection at delivery and are at supplier's risk until acceptance. Treated tie plugs rejected for non-compliance with this specification will be returned at supplier's expense.

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TIE PLUG - TREATED PAGE 1 OF 1

END OF SECTION

SECTION 02867

RESTRAINING RAILS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Work under this Section covers furnishing all labor, materials, and equipment for the manufacture, testing, fabricating, shipping and installation of 132RE restraining rail and all associated hardware as required to provide a complete restraining rail installation for the Project.
- B. Definitions: Terminology used in this Section is consistent with definitions and glossaries contained in the American Railway Engineering and Maintenance of Way Association's Manual for Railway Engineering and Portfolio to Trackwork Plans.
- C. Related Work Specified Elsewhere:
 - 1. Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 - 2. Section 02851 – RAILROAD RUNNING RAIL.

1.2 REFERENCES

- A. Restraining Rail MBTA MOW Standard plan no's. 305, 330, 335, 370.
- B. The following Codes, Regulations, Reference Standards and Specifications apply to the Work. Where the DB Entity substitutes a foreign standard for a United States standard, or a United States standard for foreign standard, he shall provide a written comparison with sufficient explanatory text and data to prove to the satisfaction of the MBTA that the requirements of the referenced standard and this Section will be achieved.
- C. Standards
 - 1. The American Railway Engineering and Maintenance of Way Association Manual for Railway Engineering (AREMA Manual), Chapter 4.
 - 2. American Society for Testing and Materials (ASTM):

ASTMA27	Standard Specification for Steel Castings, Carbon, for Standard Application
ASTMA36	Standard Specification for Structural Steel
ASTMA123	Standard Specification for Zinc (Hot-Dip Galvanized) Castings on Iron and Steel Products
ASTMA325	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

ASTMA536	Standard Specification for Ductile Iron Castings
ASTMA563	Standard Specification for Carbon and Alloy Steel Nuts
ASTMF436	Standard Specification for Hardened Steel Washers
ASTME10	Standard Method of Brinell Hardness for Metallic Materials

1.3 SUBMITTALS

- A. Submit a list of proposed suppliers for all components prior to procurement. Subsequent changes in proposed suppliers shall be submitted as they occur.
- B. Submit the following to the MBTA for review at least 30 days before the anticipated rolling dates:
 - 1. The date scheduled for the rail production, inspection, shipment and final delivery.
 - 2. A detailed description of the steel metallurgy.
 - 3. Lengths in which the rail section will be provided.
 - 4. A description of the method and verification testing to achieve the required rail hardness.
 - 5. A detailed description of other components used in the restraining rail assemblies including but not limited to shims, bolts, washers, and nuts.
 - 6. Shop drawings showing rail layouts, end details, joint and separator block details and locations, and details of rail fastening assembly.
 - 7. A description of pre-curving procedures.
- C. Provide test records, including mechanical properties tests, hardness measurements, ultrasonic test records and all other required test documentation, for review during any in-plant inspection and formal submittal to the MBTA.
- D. All submittals will be reviewed for general conformance with the intent of the contract documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.

1.4 QUALITY CONTROL

- A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality required by the Contract Documents.
- B. Records of all inspection work by the DB Entity shall be kept complete and available to the MBTA during the performance of the contract.
- C. Rail fastening system quality assurance records shall remain available from the supplier for a minimum of 7 years.

D. Inspection and Testing:

1. The products and material incorporated into the work will be subject to inspection by the Independent Testing Agency hired by the DB Entity, at the DB Entity's and Subcontractor's facilities, place of manufacture, the shipping point, and at the shipping destination. The inspection frequency will be reviewed by the MBTA.
2. Whether or not the MBTA inspects or tests any materials, the DB Entity will not be relieved from any responsibility regarding defects or other failures to meet the requirements in the Contract Documents, or will such inspection or testing be considered as a guarantee of acceptance of any material which may be delivered later.
3. Perform all tests and analyses specified in Chapter 4, Part 2, of the AREMA Manual and submit the results in accordance with this Section.
4. Have the manufacturer furnish all the rail inspection results required to complete.
5. Perform all rail tests and inspections at the mill prior to shipment. Assume full responsibility for all testing indicated. Give the MBTA and the Independent Testing Agency hired by the DB Entity sufficient notice when testing in any form is proposed so to witness the tests. Provide the MBTA and the Independent Testing Agency hired by the DB Entity free entry at all times to the manufacturer's mill to inspect and processing and testing of rail while work on this Project is being performed. Perform all tests specified herein at no additional cost to the MBTA. Testing shall be performed by a NIST certified testing facility, either in-house or using a certified independent testing firm.
6. Hardness tests shall be conducted in accordance with ASTM A370, Brinell Hardness. Shall the manufacturer perform the testing by another method for his own convenience, the results shall be converted to Brinell Hardness in accordance with the tables in ASTM E10. Hardness testing by methods established for rail hardness; i.e., Rockwell, Brinell, or Vickers, shall be used.

1.5 DELIVERY, HANDLING AND STORAGE

- A. Restraining rail shall be stacked and banded for shipment. Package small loose plates, bolts, washers and nuts in secure shipping boxes and kegs.
- B. Lift restraining rail at multiple points, with the rail weight evenly distributed to each lift point. Handle carefully to avoid damage.
- C. Load restraining rail with adequate wood strips between the tiers of rail to prevent damage in transit.

PART 2 - PRODUCTS

2.1 RESTRAINING RAIL

- A. The restraining rail configuration shall be that shown in the MBTA standard plans.
 1. Tolerance shall be +/- 0.020" for width of section from back to guarding face.
 2. All other tolerances shall be +/- 0.040".

B. Metallurgy and Physical Properties

1. The chemical composition shall be in accordance with one of the following:
 - a. AREMA Manual, Chapter 4, Part 2.
2. Alloying to improve rail hardness shall not exceed the chemical limits allowed in AREMA Manual, Chapter 4.
3. The rail shall be head hardened and have a minimum Brinell Hardness Number (BHN) of 370 in accordance with Chapter 4 of the AREMA Manual.

C. Section Lengths

1. The standard length shall be 80', unless otherwise requested.
2. The minimum length between an insulated and standard joint shall be 15'.
3. The minimum length adjacent to an end section shall be 15'.

D. Fabrication

1. Restraining rails shall be fabricated with a sheared base as shown on MBTA MOW Standard Dwg. No. 305.
2. Restraining rail ends shall be drilled for joint application as shown on the Design Documents and MBTA standard plans.
3. Restraining rails shall be drilled every 23" for installation of separator block assemblies.

2.2 RESTRAINING RAIL ASSEMBLIES

A. General:

1. The rail fastening system shall be produced by an ISO 9001 certified manufacturer with a minimum of 25 years of documented experience in design and manufacturing.
2. The supplier shall be the original designer of the product and shall have a minimum of 25 years of experience in the design, manufacture, and supply of resilient rail fastening systems.
3. The rail fastening system shall be suitable for installation and extraction with hand tools and automated machinery.
4. Adjustment of the rail head gap shall be possible by the installation of different insulator post thicknesses.

B. Separator Blocks: Cast ductile iron, grade 65-45-12 per ASTM A536.

C. Shims: Steel per ASTM A36.

D. Separator Bolts: 1 3/8" diameter square head, Type 3, per ASTM A325.

E. Cast Baseplate: Cast ductile iron, grade 80-55-06, per ASTM A536.

- F. Rail Clips:
 - 1. Nominal rail clip clamping force shall be a minimum of 2,750 lbs.
- G. Rail Clip shall be manufactured from alloy spring steel with a surface hardness of HRC 44 to HRC 48. Marks caused by forming tools shall be smooth and free of burrs.
- H. Screw Spikes: Provide per Section 02865 – TRACK APPURTENANCES and the MBTA standard plans.

2.3 JOINT BARS

- A. Joint bars and associated hardware shall be as noted in Section 02865 – TRACK APPURTENANCES.

2.4 SPARE PARTS

- A. Provide as spare parts, two standard lengths of Restraining Rail and ten assemblies including clips and baseplates.
- B. Deliver spare parts to a location designated by the MBTA.

PART 3 - EXECUTION

3.1 GENERAL

- A. An installation plan specific to Restraining Rail Installation Locations shall be developed prior to fabrication of restraining rail.
- B. The restraining rail lengths shall be pre-cut to length for the curve. Rail less than or equal to 400-foot radius shall be pre-curved. Rails shall be pre-curved in accordance with the requirements of Section 02851 – RAILROAD RUNNING RAIL.
- C. Track having a centerline radius equal to or less than 1000' shall have restraining rail added to the gauge side of the inside rail.
- D. Track having a centerline radius equal to or less than 100' shall have restraining rail added to both sides.
- E. End flares for the beginning pieces of restraining rail shall be milled in the shop before delivery to the site. Fabrication of end flares in the field is prohibited.
- F. Install insulated restraining rail joints to correspond to running rail insulated joints.
- G. Restraining rail assembly shall be installed in accordance with manufacturer's instructions.
- H. Identification Marking
 - 1. Each piece of restraining rail shall be marked to indicate its proposed installed location.
 - 2. Marks shall be in at least two locations on each piece, widely separated, located on the top to be visible after installation.

- I. Install joint and separator block bolts and nuts to a tension of 20,000 to 25,000 pounds using a track wrench or power torque wrench. Retighten all bolts to a tension of 15,000 to 25,000 pounds prior to acceptance of restraining rail installation.
- J. Flangeway shall be 1 5/8”.

END OF SECTION

SECTION 02871

TIMBER CROSS TIES

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section includes specifications for the manufacture, treatment, inspection and shipment of new timber cross-ties.
- B. Related work specified elsewhere:
 - 1. Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements”
 - 2. Section 02850 – LIGHT RAIL TRACK CONSTRUCTION
 - 3. Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION
 - 4. Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION

1.2 QUALITY CONTROL

- A. The following codes, regulations, reference standards and specification apply to work included in this Section:
 - 1. American Railway Engineering and Maintenance of Way Association (AREMA), Manual for Railway Engineering.
 - 2. American Wood Preservers Association, AWPA
- B. The MBTA shall have free entry at all times to the facilities to observe the milling, treating, and loading of ties. This observation, if made, will be general in nature and will not alter the fact that acceptance/rejection of the product will be made upon delivery.
- C. DB Entity shall require the manufacturer to perform tests and inspections as specified in Chapter 30 of the current AREMA Manual and as required herein. Prior to shipment, DB Entity shall provide written verification of the manufacturer's performance of the specified tests and inspections along with a manufacturer's certification that the ties provided comply with these Mandatory Specifications. Ties will not be accepted without the manufacturer's certificate and verifications.
- D. Tie inspection and testing shall be made at the treating facility prior to shipment.
- E. To be accepted ties shall meet the requirements of the AREMA Manual Chapter 30 and these Specifications.
- F. Ties will not be accepted until unloaded at the job site and are at DB Entity's risk until accepted. Material not in compliance with these Mandatory Specifications shall be removed and replaced with acceptable ties at no additional cost to the MBTA.

1.3 SUBMITTALS

- A. Submittals will be reviewed for general conformance with these Mandatory Specifications. This review will not relieve the DB Entity of final responsibility for the quality of the material furnished.

- B. Prior to shipment, the DB Entity shall submit certified inspection and test reports as specified herein.
- C. Submit proposed shipping schedule for crossties.

PART 2 - PRODUCTS

2.1 WOOD SPECIES

- A. Crossties shall be new, creosote treated with a minimum of 90 % oak and the balance shall be hardwoods of the following species: Beech, Birches Hard, Cherries and Maples.

2.2 ANTI-SPLITTING NAIL PLATES

- A. Anti-Splitting Nail Plates shall be manufactured from a minimum of 18 gage galvanized steel conforming to ASTM A446 Grade 4, and the galvanizing conforming to ASTM A525. End plate shall have teeth not less than 3/8” in length and of sufficient sharpness to fully penetrate oak ties. Plate shall be fabricated so that teeth twist vertically to provide better grip in tie. Plates shall be 6” by 7” accordance with MBTA RRO Standard Dwg. No. 1106.

2.3 GENERAL QUALITY

- A. Ties shall conform to MBTA RRO Standard MS 9209 – CROSS TIE – TREATED attached in this Section.
- B. Ties shall be manufactured from sound, live timber and shall be free from any defects that may impair strength or durability as further described in this section. Every effort shall be made to get the felled timber to mill and milled timber to treatment facility for seasoning as quickly as possible, to avoid wood fiber infection.
- C. All ties shall be straight, well sawn on four sides, cut square at the ends, have top and bottom parallel and have bark completely removed. A tie will be considered straight when a straight line along the top, from the middle of one end to the middle of the other end, is entirely within the tie and when a straight line along a side, from the middle of one end to the middle of the other end, is everywhere more than 2” from the top and bottom of the tie. The top and bottom will be considered parallel when any difference in the thickness at the sides and ends is less than or equal to 1/2”. Ties shall be free from the following defects:

- 1. Decay - Ties that show decay of any nature and ties that show strain from being left in the log too long will be rejected. "Blue stain" is not decay and is permissible in any wood.
- 2. Holes - Ties will be rejected if a large hole, or numerous holes with the net effect of a large hole, is present. A large hole is one exceeding 1/2” in

diameter and 3 inches deep within the Rail Bearing Area (RBA), or more than one-fourth the width of the surface on which it appears and 3” deep outside the RBA. The RBA is the area of the tie between 20” and 40” from its middle.

3. Knots - Ties with a large knot, or numerous knots with the net effect of a large knot within the RBA will be rejected. A large knot is one whose average diameter is greater than one-fourth the width of the surface on which it appears.
4. Shake - Shake greater than one-third the width of the tie will be cause for rejection of the tie.
5. Split - A tie will be rejected if a split exceeds 5 inches long or 1/2” wide.
6. Slanting Grain - A tie will be rejected if a slant in grain more than 1:15 is present, except in the case of woods with interlocking grain.
7. Wane - Excessive wane will be cause for rejection of the tie.

D. Anti-Splitting End Plates shall be applied to both ends of every tie prior to seasoning.

E. Crosstie Dimensions

1. Crossties shall be AREMA 7-inch grade and shall be 7” by 9” in cross section with a maximum of 1” of wane in the RBA. A maximum of 20 % of the 7” grade ties may be 7” by 8” in cross section with no wane in the RBA. The length shall be 8’ 6”. Longer ties will be used at turnouts and grade crossings per Design Documents.
2. The lengths and thickness specified are minimum dimensions. Ties over one inch wider, thicker or longer, at any point, then the specified dimensions will be rejected.

F. Brand top of each tie with year treated, MBTA, and identity of the treating facility as specified in the AREMA Manual, Chapter 30. The branding shall appear on the tie so that when properly installed in track with the branded side up, the heartside of the tie shall face down. In lieu of top branding, the required information may be included on the anti-splitting end plate. Submit details of branded end plate for acceptance.

2.4 INSPECTION, SEASONING AND TREATMENT

A. Inspection

1. Green ties will be inspected at the time of delivery to seasoning area. Dry ties will be subject to inspection after seasoning and before treatment.
2. Inspector will make a close examination of the top, bottom, sides and ends of each tie. Each tie will be graded independently without regard for the grading of the others in the same lot.
3. Ties are subject to inspection at delivery.
4. Anti-splitting plates that are found to be loose or not firmly against the end of the tie will be cause for rejection of the tie.

B. Seasoning

1. Cross ties shall be air seasoned prior to treatment. Ties shall be stacked for seasoning in accordance with AREMA Manual, Chapter 30, Part 3. Seasoning shall continue for at least 12 months and no more than 18 months.
2. In the absence of air seasoned cross ties, the Boulton drying process may be used. If the Boulton process is used, conditioning shall continue until moisture removal rate indicates a % moisture retained equal to a 12 month air dried cross tie, but not less than 45 % by weight.
3. A minimum of 20 borer cores per treatment charge shall be taken of seasoned ties to determine that adequate drying has taken place.
4. The borer cores shall be taken mid-way between the ends and mid-way between the top and bottom faces of the tie. Three 3-inch borer cores shall be taken to determined moisture content.

C. Treatment

1. Prior to treatment, anti-splitting plates shall be checked by the treating facility to ensure that plates are firmly imbedded in the tie. If plates are found to be loose or not flush against the end of the tie, plate shall be firmly pressed against the tie before treatment begins.
2. Cross tie treatment shall be to retention of seven pounds or to refusal of 60/40 creosote coal tar solution per cubic foot of timber in accordance with the AREMA Manual, Chapter 30, Part 3, Sections 6 and 7.
3. A minimum of 20 borings shall be taken per charge after treatment to determine proper penetration.

PART 3 - EXECUTION

3.1 GENERAL

- A. DB Entity shall furnish all cross ties as required to perform the track work as indicated in the Design Documents.

3.2 END PLATING

- A. Each tie shall be end plated on both ends. End plates shall be machine applied so that the nail teeth side of the plate is flush with the end surface of the tie.

3.3 MACHINING CROSS TIES

- A. General: Machining of wood cross ties shall be completed before seasoning and shall be completed before treatment.

3.4 DELIVERY

- A. Handle ties during all phases of processing and loading so as not to cause damage to the material.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9209

CROSSTIE - TREATED

MATERIALS

Crossties shall be manufactured such that a minimum of 90% of the order is from Group A and the remainder of the order is from Group D below:

- Group A - All Oaks
- Group D - Beech, Birch, Cherries, Hard Maples

Anti-splitting end plates shall be galvanized steel plate in accordance with MBTA Standard Plan.

DESIGN

Crossties shall be 8 feet 6 inches in length and shall be 7 inches by 9 inches in cross section with a maximum of 1 inch of wane allowed in the rail bearing areas. A maximum of 30 percent of the order may be 7 inches by 8 inches in cross section with no wane allowed in the rail bearing areas.

The lengths and thicknesses specified are minimum dimensions. Ties over one inch wider or thicker, or over three inches longer, at any point, than the dimensions specified above, will be rejected.

Anti-splitting end plates shall be 6 inches by 7 inches and shall be installed in accordance with MBTA Standard Plan.

Anti-splitting end plates shall be embossed with letters and figures a minimum of one-half inch in height. Embossing shall include the following:

Authorities identification - MBTA
Last two digit of year treated - 93
Producer's name or symbol-XXCo.

Finished identifying brand shall appear as:

MBTA-93-XXCo.

and shall be positioned along the top of the plate on the 7 inch side.

MANUFACTURE

Crossties shall be manufactured from sound, live timber and must be free from any defects that may impair their strength or durability as crossties as further described in this section. Every effort

APPROVED:


ENGINEERING OFFICER

DATE: 10-28-92


CHIEF ENGINEERING OFFICER

ISSUE 10-28-92

CROSSTIE - TREATED PAGE 1 OF 4

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9209

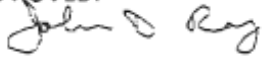
CROSSTIE - TREATED

should be made to get the felled timber to mill and milled timber to treatment facility for seasoning as quickly as possible, to avoid wood fiber infection.

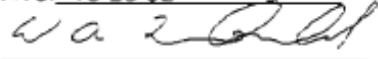
All ties shall be straight, well sawn on four sides, cut square at the ends, have top and bottom parallel and have bark completely removed. A tie will be considered straight when a straight line along the top, from the middle of one end to the middle of the other end, is entirely within the tie and when a straight line along a side, from the middle of one end to the middle of the other end, is everywhere more than 2 inches from the top and bottom of the tie. The top and bottom will be considered parallel when any difference in the thickness at the sides and ends is less than or equal to 1/2 inch. Crossties shall be free from the following defects:

1. Decay - Ties that show decay of any nature and ties that show stain from being left in the log too long will be rejected. "Blue stain" is not decay and is permissible in any wood.
 2. Holes - Ties will be rejected if a large hole, or numerous holes with the net effect of a large hole, is present. A large hole is one exceeding 1/2 inch in diameter and 3 inches deep within the RBA*, or more than one-fourth the width of the surface on which it appears and 3 inches deep outside the RBA*.
 3. Knots - Ties with a large knot, or numerous knots with the net effect of a large knot within the RBA* will be rejected. A large knot is one whose average diameter is greater than one-fourth the width of the surface on which it appears.
- *RBA - Rail Bearing Area - the area of the tie between 20 inches and 40 inches from its middle.
4. Shake - Shake greater than one-third the width of the tie will be cause for rejection of the tie.
 5. Split - A tie will be rejected if a split exceeds 5 inches long or 1/2 inch wide.
 6. Slanting Grain - A tie will be rejected if a slant in grain in excess of 1:15 is present, except in the case of woods with interlocking grain.

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CHIEF ENGINEERING OFFICER

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CROSSTIE - TREATED PAGE 2 OF 4

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9209

CROSSTIE - TREATED

7. Wane - Excessive wane will be cause for rejection of the tie.

INSPECTION

Green ties will be inspected at the time of delivery to seasoning area. Dry ties will be subject to inspection after seasoning and before treatment.

Inspector will make a close examination of the top, bottom, sides and ends of each tie. Each tie will be graded independently without regard for the grading of the others in the same lot. Ties covered with ice, or too muddied for ready examination, will be rejected. The responsibility and expense for the inspection described above will be borne by the manufacturer.

When conditions warrant, in the judgment of the Chief Engineering Officer or his designee, ties will be inspected at other points, and all ties are subject to inspection at delivery.

Anti-splitting plates that are found to be loose or not firmly against the end of the tie will be cause for rejection of the tie.

SEASONING

Crossties shall be air seasoned prior to treatment. Ties shall be stacked for seasoning in accordance with AREA Specifications, Chapter 3, Part 5, Section 6. Seasoning shall continue for at least 12 months and no more than 18 months.

In the absence of air seasoned crossties, the Vapor or Boulton drying process may be used with the permission of the Chief Engineering Officer, or his designee. If the Vapor or Boulton process is used, conditioning should continue until moisture removal rate indicates a percent moisture retained equal to a 12 month air dried cross tie, but not less than 45 percent by weight.

Sufficient borer cores shall be taken of seasoned ties to determine that adequate drying has taken place so that ties may be satisfactorily penetrated with preservative.

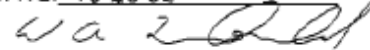
Prior to seasoning, all crossties shall have anti-splitting devices applied at each end of the tie.

APPROVED:



ENGINEERING OFFICER

DATE: 10-28-92



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CROSSTIE - TREATED PAGE 3 OF 4

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9209

CROSSTIE - TREATED

TREATMENT

Prior to treatment anti-splitting plates must be checked to ensure that plates are firmly imbedded in the tie. If plates are found to be loose or not flush against the end of the tie, plate shall be firmly pressed against the tie before treatment begins.

Crosstie treatment shall be to retention of seven pounds or to refusal of 60/40 creosote and petroleum per cubic foot of timber in accordance with the latest AREA Manual, Chapter 3, Parts 7, 8, & 9.

Sufficient number of borings shall be taken after treatment to determine proper penetration.

SUBMITTALS

Prior to shipment, the manufacturer shall submit certified inspection and test reports to the Chief Engineering Officer, or his designee, for review.

SHIPMENT

Ties shall be bundled in groups of 24 pieces, in a configuration of four rows of 6 on edge with two 2 inch by 0.05 inch heavy duty steel bands with two seals per band. Wood dunnage shall be placed on the bottom of the transportation vehicle and between tiers to facilitate unloading operations.

DELIVERY

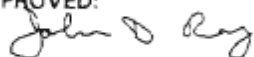
To be accepted, the ties offered shall conform to this specification in all respects and are at the supplier's risk until acceptance at the specified delivery site. Ties which are rejected for non-compliance with this specification will be returned at the supplier's expense.

APPLICABLE STANDARD PLANS

No. 1100

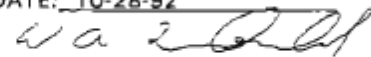
No. 1106

APPROVED:



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DATE: 10-28-92



CHIEF ENGINEERING OFFICER

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CROSSTIE - TREATED PAGE 4 OF 4

END OF SECTION

SECTION 02872

PRECAST CONCRETE CROSS TIES

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the furnishings and installation of precast concrete ties to replace any existing precast concrete cross ties on the New Hampshire Mainline that may be determined unsuitable for continued use.

1.2 SUBMITTALS

- A. Submittals will be reviewed for general conformance with these Mandatory Specifications. This review will not relieve the DB Entity of final responsibility for the quality of the material furnished.
 - 1. Submit proposed shipping schedule for crossties.
 - 2. Submit product data together with certification that the material meets the requirements of this specification.
 - 3. Name and location of proposed supplier.

PART 2-PRODUCTS

2.1 MATERIALS TO BE FURNISHED BY DB ENTITY

A. Concrete Ties

- 1. If concrete tie is not suitable, replace existing concrete tie.
- 2. Monoblock design type reinforced concrete design in accordance with longitudinal and cross-sectional configuration indicated in MBTA Standard RRO Dwg no. 1120.
- 3. Include inserts for fastenings to secure running rails in all concrete ties.

2.2 FABRICATION

A. Concrete Ties

- 1. Conform to the material and testing requirements of AREMA Chapter 30 Specifications of Concrete Ties (and Fastenings).

PART 3 -EXECUTION

3.1 HANDLING

- A. Handle ties during all phases of processing and loading so as not to cause damage to the material.
- B. Further information on placement of concrete ties is covered in Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION.
- C. Replace defective concrete ties with new concrete ties.

END OF SECTION

SECTION 02877

THERMITE WELDING

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section includes specifications for thermite welds within turnout limits as shown on the Standard Plans and for closure welds within track where permitted by these Mandatory Specifications and the MBTA.

1.2 LIMITATIONS ON USE OF THERMITE WELDS

- A. The DB Entity shall plan and schedule the work to minimize the use of thermite welds. In general, thermite welds shall be allowed only within special trackwork, at closure welds when installing new CWR strings in existing track, when welding in plug rails at curve adjustments when a mobile welding unit is not available, and for closure welds near grade crossing installations.
- B. Compromise thermite welds shall be allowed to join 132 RE rail to existing 115 RE rail currently in track. At these locations, the DB Entity shall determine if the length of 115 RE rail being joined to 132 RE rail is less than 200', resulting in a short "island" of the smaller section. In such case, provide additional new 132 RE rail, eliminating two compromise welds over a short distance. 115RE rail "Island" track structure will need to be lowered to accommodate taller 132 RE rail.

1.3 SUBMITTALS

- A. Submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures and sequences to be utilized.
- B. Submittals shall be legible and reproducible.
- C. Prior to initiation of thermite welding, submit detailed specifications showing proposed quick-preheat, self-tapping thermite weld kit and method and procedure for thermite welding. Specifications submitted shall comply with these Mandatory Specifications and those of weld kit manufacturer.
- D. Submit qualification certification for each supervisor and field welder who will perform work on this Contract. Weld supervisors and welders shall be required, upon request of the MBTA, to submit their qualification certificate throughout the duration of the project.
- E. Submit name of independent testing agency and certification that testing laboratory and persons who shall perform ultrasonic testing of field welds have previously tested a minimum of 250 welds.
- F. Submit documentation that sample thermite welds have been tested and that welds meet or exceed requirements of this section.
- G. Submit certified ultrasonic inspection results for field welds.

1.4 QUALITY CONTROL

The thermite welding process can only be successful if it is carried out by thoroughly trained and well-disciplined personnel. It will be the responsibility of the DB Entity to organize and coordinate all preparation and training activities for its personnel, including participation by welding kit supplier as required. DB Entity is also responsible for documenting the preparation and training activities for submittal to the MBTA. Cost of all preparation and training activity shall be included in the contract line item for field welding.

A. General

1. The DB Entity shall perform sample weld testing and inspection at no additional cost to the MBTA.
2. Sample weld testing and inspection shall be performed by an accepted certified independent testing laboratory. The MBTA may audit operations to ensure that inspection and tests are being performed in accordance with accepted procedures and in compliance with these specifications.
3. To be accepted, sample welds shall fulfill the requirements of these Mandatory Specifications.

B. Field Weld Qualification Inspection and Testing

1. Prior to field welding, welds and each welding crew shall be qualified as specified below. Welding crews shall prepare, in accordance with method and procedure for thermite field welding, submitted and approved under Article 1.3 of this Section, at least three samples of each type of thermite weld; high strength rail welded to high strength rail, high strength rail welded to standard rail, and standard rail welded to standard rail. Each welding crew shall perform at least one of each type of sample weld. Sample welds shall join two pieces of commuter line 132 RE rail a minimum of 30” or longer as required by testing laboratory. Sample will also be provided of 115 RE rail for transit line.
2. Test three sample welds from each type of rail as follows:
 - a. Perform Radiographic Test on all sample welds from each type of rail.
 - b. Perform Slow Bend Test specified in this Section on second sample weld from each type of rail.
 - c. Perform Hardness Test specified in this Section on third sample weld from each type of rail.
 - d. Perform Manual Ultrasonic Test specified in this Section on all sample welds
3. Radiographic Testing
 - a. Inspect welds radiographically in accordance with ASTM E142, ASTM E94, and these Mandatory Specifications for purpose of detecting flaws in field welds.

- b. Radiographic tests shall detect flaws in welds with sufficient detail to establish weld's ability to meet the requirements specified herein.
 - c. Radiograph four areas of each weld, head, web, and each side of base.
 - d. Identify each radiographic film with Contract Number, sample number, rail identity, date, welder identity, inspection agency, and view.
 - e. The acceptance criteria for this test shall indicate full penetration and complete fusion with no evidence of surface or internal fissures or cracks.
 - f. Nondestructive inspection of metal welds by radiographic use of nuclear by- product materials shall be in accordance with United States Nuclear Regulatory Commission Rules and Regulations, Title 10, Atomic Energy, Part 20, Standard for Protection Against Radiation.
 - g. Transportation, handling, and storage of hazardous materials used in radiographic inspection of welds shall be performed only by, or under supervision of, a person of proven experience and ability operating under a proper license.
4. Slow Bend Test
- a. Subject a second sample weld from each type of rail which has passed Radiographic Test to the Slow Bend Test described in the Proceedings of the AREMA Manual, Chapter 4.
 - b. Acceptance criteria for this test shall be minimum deflection of $\frac{3}{4}$ " and 100,000 pounds per square inch modulus of rupture.
5. Hardness Test
- a. A third sample weld of each type of rail passing the Radiographic Test shall be longitudinally sectioned for a distance of one foot either side of weld, microetched, and tested by the Rockwell Hardness test using a 150 kg diamond sphero-conical penetrator. Test results shall be converted to Brinell Hardness Numbers.
 - b. Rail shall be tested for hardness on sectioned face on both sides of weld, at $\frac{1}{2}$ " increments on three lines until the hardness is that of parent metal. One test line will be at center of head, second at center of web and third at center of base. Parent metal hardness shall be reached not more than 6 inches from weld center line or weld shall fail this test. The minimum Brinell number of parent metal is published as 300 for standard rail and 341 for high strength rail.
 - c. Inspect microetched section for compliance with field weld requirements of full penetration, complete fusion, and internal defects specified herein.
6. Manual Ultrasonic Testing
- a. Inspect sample welds ultrasonically in accordance with recommendations of the Nov, 23-30, 1983 Proceedings of Association of American Railroads entitled "Railroad Rail

Welding" Pages 191-205.

- b. Acceptance criteria for this test shall be as specified in Article 1.4.E.4 of this Section.
7. Approval of weld kit, welding process, and welding crews will depend upon all sample welds satisfying the specified requirements. Shall any sample weld fail to satisfy the specified requirements, the welding process, the welding crew, or both, will not be qualified for the work.
8. Employ a supervisor for each welding crew, who has been trained and certified for performing thermite field welding by manufacturer supplying weld kits. Shall supervisor of welding crew be replaced during the Work, welding crew shall be re-qualified under the new supervisor.
9. Prior to performing welds in specified work, satisfactorily qualify welds and welding crew as specified herein.
10. If DB Entity changes supplier of welding kits, or welders during the job, repeat all above sample weld testing.

C. Preparation and Training for Field Welding

1. Prior to making sample welds and prior to field welding, the DB Entity shall coordinate with the welding kit manufacturer the following at no additional cost to the MBTA.
 - a. Provide a detailed list of tools, equipment, and supplies required to make field welds. Copies shall be delivered to the MBTA and shall be kept on the job site with welders at all times.
 - b. Provide a detailed procedure for making field welds, consistent with MBTA's requirements. Field welds shall be made with approved kits. If there are different types of welds in the Contract, for example; different sizes or types of rail and compromise joints, a procedure shall be provided for each. Copies of procedures shall be delivered to the MBTA and shall be kept on job site with welders at all times.
 - c. Organize and conduct training course for welders. The MBTA may also participate in course. Course shall include "hands on" experience for all students. An outline or other material describing course shall be submitted to the MBTA for review and acceptance. Course work shall include the different type welds called for in Contract. All welders will participate in course, even if they have taken it for a previous job. Qualified welders will receive a dated Certification Card, signed by a Supplier Representative, accepted by the MBTA, which shall be available for inspection at any time.
 - d. Organize and conduct refresher training courses for welders every six months. The MBTA may participate in these courses as well. Record shall be kept by DB Entity and the MBTA indicating that their personnel have taken part in refresher courses. Welder's Certification Card shall be updated to reflect same.
 - e. Make random inspections of the welding work in progress, at least every three months, to insure that proper tools, equipment, and supplies are being used, and that their procedures are being followed.

- f. The welding kit manufacturer shall be on call to assist the DB Entity and the MBTA in case any unusual problems arise in the field. Supplier shall be prepared to provide for laboratory testing needed to solve a problem, and shall have the capability of tracking their kit materials backward through the chain of production.

2. Responsibilities of the DB Entity

- a. Coordinate welder training program described above, including provision of documentation required by the MBTA to describe course, and verify that DB Entity's personnel have successfully completed course work.

D. Field Weld Record

1. DB Entity shall provide the MBTA with a complete and up-to-date record of all welds, welders, and welding kits. This record shall be submitted on the accepted MBTA standard form which includes, but is not limited to, the following information for each weld.

- a. Weld number, location by track designation and station, date and time weld made
- b. Rail identification including section, heat number, date rolled and rail hardness. Different weld kits based on hardness.
- c. Kit manufacturer and identity of each mold and portion
- d. Weather conditions, air and rail temperature
- e. Rail gap
- f. Name of welder and DB Entity's foreman

2. A copy of accepted MBTA form Figure 02877-3 has been made part of this Section.

E. Field Weld In-Track Testing

1. During field welding, hand test and inspect all field welds as specified herein to ensure compliance of welds to requirements of these Mandatory Specifications.
 - a. Thermite welds shall be visually and dimensionally inspected as soon as weld has been completed regardless of whether track has been designated as "in revenue service" or "out of revenue service."
 - b. Manual ultrasonic testing of thermite welds in track designated as "in revenue service" shall be completed within 24 hours of weld completion.
 - c. Manual ultrasonic testing of thermite welds in track designated as "out of revenue service" shall be completed within 30 days from date of welding but in all cases prior to the resumption of train operations.
 - d. It shall be the responsibility of the DB Entity to follow above criteria and ensure that

all welds are properly inspected and tested at no additional cost to the MBTA.

2. Manual Ultrasonic Testing

- a. Inspect all field welds ultrasonically in accordance with recommendations of the Nov. 29-30,1983 Proceedings of Association of American Railroads entitled "Railroad Rail Welding" pages 191 -205. Weld quality shall meet requirements of this Section.
- b. For each field weld, complete and submit the MBTA Ultrasonic Test Report attached to the rear of this Section as Figure 02877 –2.

3. Test Procedures – Ultrasonic

- a. Testing organization shall submit to the MBTA detailed test procedure and description of test equipment including calibration blocks that will be utilized in testing process. Calibration process shall be able to permit detection of any defect including the size, type, and location. Test procedure and equipment shall include, but not be limited to the following:

Calibration:

- o Calibrate when starting work and at least every hour.
- o Recalibrate if there is a change in probes or cables.
- o Use I.I.W. Type 1 and Type B-1 steel test blocks for calibration. A rail with drilled holes may be used in addition. If a rail is used, a duplicate shall be provided to the MBTA.

Web Test:

- o Use two 45 degree probes placed on top of rail in pitch-catch configuration.
- o Scan from top to bottom of weld with both probes.
- o Scan top and bottom edges of weld with a single probe.
- o Scan from both sides of weld.

Head Test:

- o Use two 45 degree probes placed on sides of the rail head in pitch-catch configuration.
- o Scan across weld with both probes angling them up and down to cover entire cross-section of weld.
- o Scan each vertical edge of weld with a single probe.
- o Scan from both sides of weld.

Base Test:

- o Use a 70 degree probe, place probe on top of base far enough back from center of weld so that beam is following the "3/4 W" path.
- o Move toward and away from weld, angling probe from side to side.
- o Scan both sides of base and from both sides of weld.

- b. Test crew shall fully document their findings, on accepted MBTA standard form. This form shall include, but is not limited to, identification of: test equipment used, calibration, weld number and location, members of test crew, date and time of test, description of defects, and recommendation to accept or reject weld. The MBTA accepted form Figure 02877-2 has been made a part of this Section.
4. Acceptance Criteria – Ultrasonic
- a. No defect in the weld of any size will be accepted in the head, web or base of rail.
 - b. MBTA Materials Testing Lab may perform random manual ultrasonic tests of field welds. The MBTA is currently using equipment supplied by Krautkramer, and personnel who have been trained with this equipment.
5. Physical Inspection
- a. DB Entity shall visually and dimensionally inspect each field weld to determine conformance with alignment and finishing tolerances specified herein.
 - b. When weld is made and molds and risers removed weld shall be checked for obvious failures such as an incomplete weld.
 - c. Once weld has been ground and weld temperature is less than 200 degrees F, physical inspections shall be made to verify acceptance criteria.
6. Acceptance Criteria – Physical
- a. There shall be no visible voids, ratholes, nicks or gouges in surfaces which have been ground.
 - b. Weld collar in web zone and base of rail shall not be ground except to remove notches created by upset conditions. Sharp protrusions and gouges shall be blended into rail and weld collar contour to eliminate possible stress risers.
 - c. Combined vertical offset and crown camber at top of rail, at rail temperature of 200 degree F or less, shall not exceed 0.060 inches, measured as shown on Figure 02877-1. NO DIP CAMBER will be allowed.
 - d. Combined horizontal offset and horizontal kink camber at side of rail head, at rail temperature of 200 degree F or less, shall not exceed 0.060 inch, as shown on Figure 02877-1.
 - e. A finished deviation of not more than plus 0.010" or minus 0.00" from parent section of rail head surface shall be allowed.
 - f. If field weld, because of certain field conditions, is located within 4 ½" of a rail support, the sides and bottom of the rail base shall be within plus 0.012" or minus 0.00" of parent section.
 - g. Weld straightness tolerances shall be as shown on attached Figure 02877-1.

7. Defective Welds

Defective welds shall be cut out and replaced with a 19' 6" section of new rail in tangent or 21' in curves, welded in place, at no additional cost to the MBTA.

8. Final Ultrasonic Testing

Final ultrasonic testing shall be performed by an on track detector car as specified in Section 02853 – CWRINSTALLATION.

PART 2 - PRODUCTS

2.1 MATERIAL TO BE FURNISHED BY THE DB ENTITY

- A. Furnish complete thermite weld kits conforming to attached MS No. 9266 and this Section.

PART 3 - EXECUTION

3.1 THERMITE WELDING

A. General

1. Thermite field welds shall be made to join rails within turnout limits as shown on the Standard Plans and as specified in Article 1.2 of this Section.
2. Ends of rails to be welded shall be saw cut. Torch cutting of rails will not be allowed.
3. Do not locate field welds within the following locations in standard track work:
 - a. Within 8' of the center of any bonded or insulated joint.
 - b. Within 14' of a field weld in the same rail.
 - c. Within 4' of a plant weld in the same rail.
 - d. Within 10' of the centerline of any joint (except bonded insulated joints)
 - e. Within 2' of a thermite weld in the opposite rail.
 - f. Within 6" of any hole drilled in rail.
 - g. Within 9" of a weld which has been cut out.
 - h. On or within 4 ½" of a tie plate or concrete tie rail seat.
 - i. Within a grade crossing.
4. In the case of special trackwork (turnouts and rail crossings) some exceptions to above will be allowed, with acceptance of the MBTA.

5. If plug rails are required to meet requirements shown above, or to replace a defective weld, minimum length of plug rail is 18' in tangent and 21' in curves.
6. Thermite welding process generates extremely high temperature (up to 5000° F) accompanied by flames, sparks, hot molten metal, and slag. Extreme caution shall be observed by welders and others in the vicinity. The following precautions shall be observed.
 - a. During welding process, prevent hot molten metal and slag from contacting water, snow, or ice as an explosion could occur.
 - b. Properly dispose of hot slag, slag pans, top and side risers, or other hot scrap. Be sure that this material is not left where it could be stepped on, causing serious injury.
 - c. Wear welding goggles or safety glasses and other safety equipment as appropriate.
 - d. During and after welding, avoid burning or damaging rail pads, ties and timbers, or setting fire to wayside areas. A fire extinguisher shall be required at weld site (2 1/2 gallon water type extinguisher).
 - e. Keep welding tanks, hoses, and other flammables a safe distance from the weld site.
 - f. Do not make field welds on open deck bridges or timber structures.
 - g. Unused thermite material shall be kept in an approved secure, dry, weather tight location, consistent with applicable fire regulations so that it will not be accessible to unauthorized persons.
 - h. When welding rails in track on lines in service, be sure that rail fastenings, anchors or clips, pads, and insulators, are properly installed prior to restoration of service.

B. Weld Quality

1. Weld quality shall be as specified in Article 1.4 of this Section.

C. Welding Requirements

1. Use approved kits that are self-tapping and require minimum preheating.
2. Saw-cut rail ends at right angles to rail. Clean the surface of rail for a length of approximately six inches from each end, free of all grease, dirt, loose oxide, scale and moisture. Remove burrs and lipped metal which would interfere with the proper fit of molds.
3. At time of field welding, rails shall be aligned to produce a weld which, with respect to alignment, shall be in accordance with Article 1.4.E.6 of this Section.
 - a. Proper rail end alignment shall be achieved by use of an approved alignment device designed and manufactured for this purpose. In no case will use of track jacks or track spikes be allowed for rail end alignment.
 - b. Striking of rail with blunt tools, such as a maul, is prohibited.

- c. DB Entity shall assure that rail ends are secured against longitudinal, vertical, lateral or twisting movement during and immediately after the welding process. Rail puller/expanders shall be used to prevent movement. Rail clips or anchors shall be installed if there is a chance of longitudinal movement.
 - d. At time of field welding, rail gap shall be as specified by manufacturer of the weld kit.
4. The following restrictions limit when field welds can be made, and specify special procedures required under certain environmental conditions.
- a. It is important that weld is not subjected to a sudden strain by-releasing hydraulic pressure too quickly. The rail puller/expander shall be left in place until rail has cooled to below 500 degrees F. Any movement of rail before weld has cooled to at least 500 degrees F. may result in failure of weld.
 - b. Hydraulic rail puller/expander shall not be used to establish proper rail end gap.
 - c. When welding rail in track on lines in service, allow sufficient time to complete weld so that surface finish, and temperature of welded joint will permit safe operation of scheduled trains without delay to service. Temperature of welded joint shall be 200 degrees F or less before rail traffic is allowed to pass over weld.
 - d. Thermite field welds shall be made in accordance with and shall not deviate from manufacturer's recommendations and AREMA Chapter 4. Short cuts in recommended pre-heating process are prohibited.
5. Trim and grind weld to meet the following requirements and as otherwise specified by manufacturer:
- a. Finish weld to the tolerances specified in Article 1.4 of this Section.
 - b. A rail shear, specifically designed for the purpose, shall be utilized to remove weld upset. Use of a saw, cutting torch or other hand held devices is prohibited.
 - c. Rail profile grinder specifically designed for the purpose, shall be utilized to finish grind top and sides of weld. Use of hand held grinder is prohibited.

As specified in Article 1.4.E.6.b of this Section, weld collar in the web zone and base of rail shall not be ground except to remove notches created by upset

and weld collar contour to eliminate possible stress risers. Remove, by grinding, defects visible to the unaided eye. If removal by grinding cannot be accomplished without damaging rail, remove the weld. Take precautions to avoid excessive pressure during grinding of weld in order to prevent overheating of rail surface.

- d. Finish grinding shall be done only when weld temperature is less than 200 degrees F.
- e. Overheating rail when grinding shall be avoided. Since weld has cooled to below 200 degrees F. prior to grinding, the temperature rise due to grinding shall not exceed this level.
- f. Finish rail grinding on top and sides of weld shall be completed prior to operation of trains over weld.

D. Weld Identification

- 1. Mark weld identification on field side of rail using a permanent metal marker as manufactured by J.P. Nissen, Jr. Co., or approved equivalent and record required information in conformance with Article 1.4.D.

E. Weld Cleanup

- 1. Clean up and remove waste material such as paper and plastic containers, scraps of metal, slag, and molds.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9266

THERMITE WELD KIT

MATERIAL

Thermite weld kits shall contain a mixture of aluminum and iron oxide, which when ignited, produces a filler metal to fuse the rail ends together, by heat produced by the thermite reaction. Each weld kit shall also contain all molds, luting material and thimble required to complete one weld.

DESIGN

Thermite weld kits shall be self-tapping crucible type requiring minimum pre-heating as manufactured by Calorite, Inc., or approved equivalent.

QUALITY ASSURANCE

The manufacturer shall maintain comprehensive continuously operated quality control procedures to ensure that each weld kit supplied is free of flaws or defects in materials and manufacture.

TESTING


The manufacturer shall perform and certify in writing prior to shipment, that representative weld kits have successfully passed the following tests:

1. Prepare, in accordance with manufacturer's recommended procedures, three sample thermite welds on the proposed rail section and type. Rail to be supplied by the weld manufacturer.
2. Test all welds radiographically in accordance with ASTM Designation E142 "Controlling Quality of Radiographic Testing". At least four areas shall be radiographed (head, web and each side of base) with sufficient detail to detect flaws to establish the ability of the weld to meet the requirement specified herein.

Each weld shall have full penetration and complete fusion with no evidence of surface or internal fissures. Porosity or slag type defects will be tolerated provided the radiograph shows:

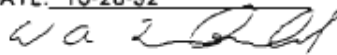
- a. The largest defect does not exceed 1/8 inch in any dimension.
- b. The total area of all defects does not exceed 0.060 square inches.

APPROVED:



ENGINEERING OFFICER

DATE: 10-28-92



CHIEF ENGINEERING OFFICER

ISSUE 10-28-92

THERMITE WELD KIT PAGE 1 OF 2

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9266

THERMITE WELD KIT

- c. The sum of the greatest dimension of defects in a line shall not exceed 3/8 inch.

Non-destructive testing of welds by radiographic use of nuclear by-product material shall be conducted by a laboratory licensed by the U.S. Nuclear Regulatory Commission.

3. Subject all test welds to the Slow Bend Test as described in the Proceedings of the AREA, Volume 68. The acceptable criteria for this test shall be a minimum deflection of one inch and 100,000 pounds per square inch modulus of rupture.

SUBMITTALS

The manufacturer shall submit detailed description of Quality Assurance program used in the manufacture and handling of all weld kit components.

The manufacturer shall submit certification that the Quality Assurance program was in place and was applied to all welds kits supplied in the order.

The manufacturer shall submit certification that representative samples of the weld kits provided meet the test requirements as described herein.

The manufacturer shall provide complete detailed instructions for welding procedures including preparation, preheating and crucible tapping.

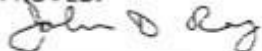
SHIPMENT

Thermite weld materials shall be shipped in kit form with each kit containing all necessary materials to complete one thermite weld. Packaging shall be water-proof to resist damage to molds and thermite charge.

DELIVERY

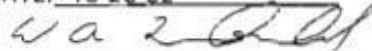
To be accepted, thermite weld kits offered shall conform to this specification in all respects. Thermite weld kits are subject to inspection at delivery and are at the supplier's risk until acceptance. Thermite weld kits rejected for non compliance with this specification will be returned at the supplier's expense.

APPROVED:



ENGINEERING OFFICER

DATE: 10-28-92

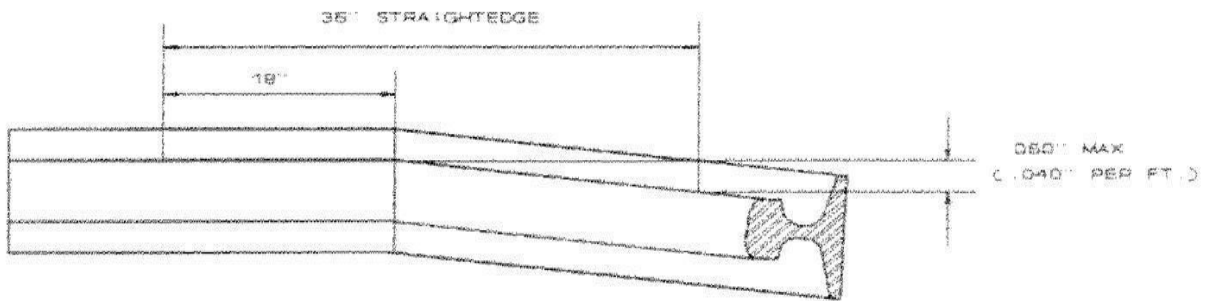
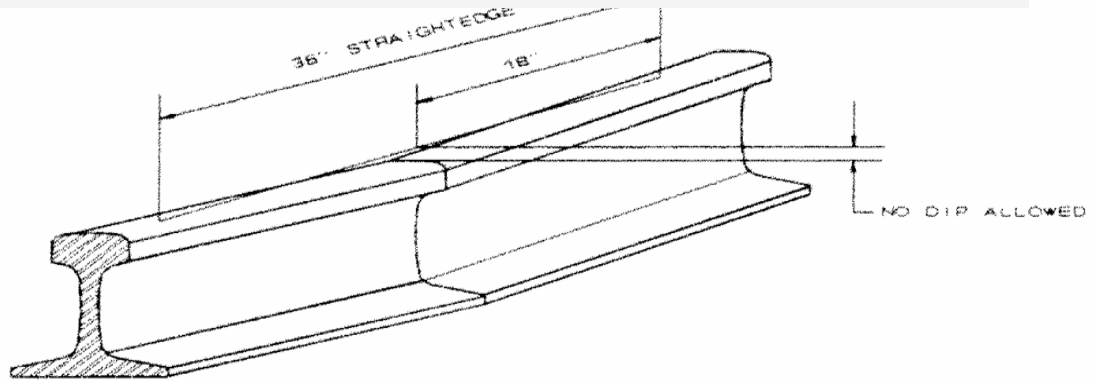
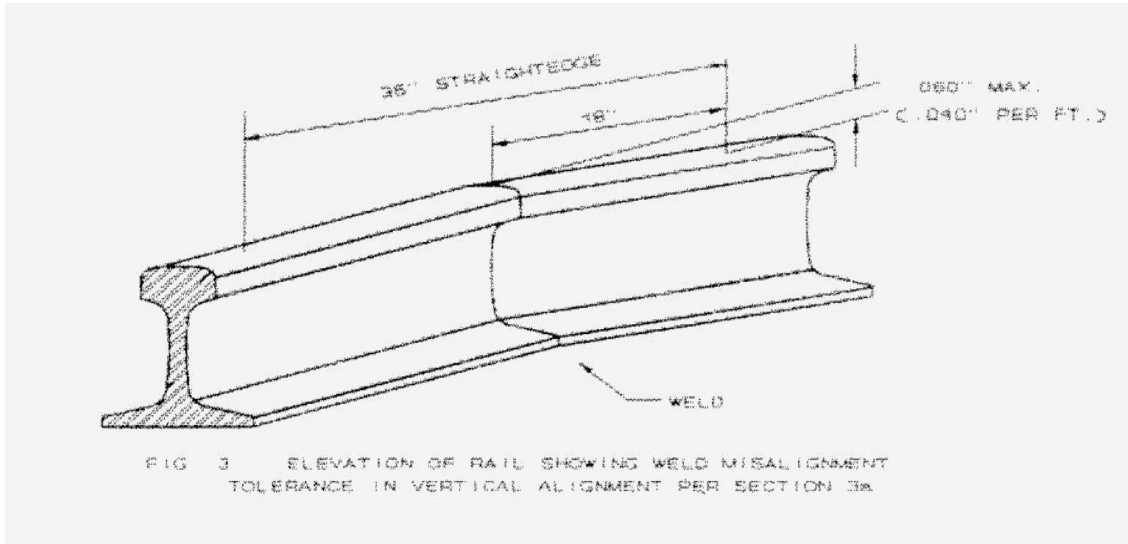


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THERMITE WELD KIT PAGE 2 OF 2

**STRAIGHTNESS OF WELDED RAIL
JOINTS TOLERANCE FOR
INSPECTION OF WELDED RAIL**



* Figures refer to AREA - Manual for Railway Engineering Sec 4-2-6.23

FIGURE 02877 - 1

MBTA ULTRASONIC TEST REPORTFORM

MBTA ULTRASONIC TEST REPORT FORM

Project: _____

Weld No.: _____

Location: _____

Test Date: _____ Time: _____

Testing Agency: _____ Name of Tester: _____

Test Equipment Used: _____

Calibration: _____ Date: _____ Time: _____

Test Results: _____

Description of Defects: _____

Wt. of Rail: _____

Weld Kit Mfgr: _____

Signature of Tester

Head
Area C

Web
Area B

Base
Area A

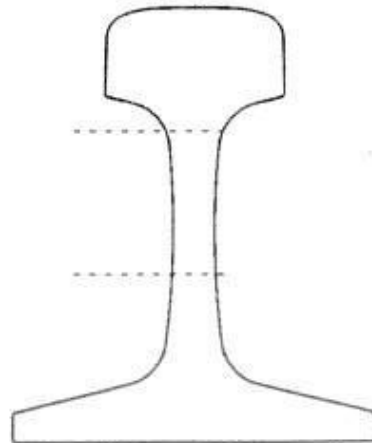


FIGURE 02877 – 2

MBTA FIELD WELD IDENTIFICATION FORM

MBTA FIELD WELD IDENTIFICATION FORM

Project: _____

Weld No.: _____

Location: _____

Weld Made: Date: _____ Time: _____

North or East Rail:

Wt.: _____ Section: _____ Kind of Steel: _____

Mfgr./Mill: _____ Roller Yr.: _____ Mo.: _____

Heat No.: _____ Rail Ltr.: _____ Ingot No.: _____

South or West Rail:

Wt.: _____ Section: _____ Kind of Steel: _____

Mfgr./Mill: _____ Roller Yr.: _____ Mo.: _____

Heat No.: _____ Rail Ltr.: _____ Ingot No.: _____

Weld Kit Mfgr.: _____

Portion Lot & Date: _____ Mold Lot & Date: _____

Air Temp.: _____ Rail Temp.: _____ Weather: _____

Rail Gap: _____ Track Alignment: _____

Weld Alignment: Vertical: ___ Head Horiz.: ___ Base Horiz.: _____

Contractor: _____ Welder: _____ Supervisor: _____

MBTA Personnel: _____

Remarks: _____

Signature of Welder: _____

**FIGURE 02877 – 3
END OF SECTION**

SECTION 02879

SIDE TRACK CONSTRUCTION FOR COMMUTER RAIL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies new and relay sidetrack construction and tie-ins to existing track sidings.
- B. Work under this Section is at the following locations and generally includes but is not limited to the following:
 - 1. Milepost 1.8, Somerville – reconstruction of Yard 10 tracks west and east of Washington Street Bridge.
- C. Work under this Section includes both new and relay rail sections and tie-ins to existing track, all of varying rail sections. DB Entity shall provide joint bars as required at each location for a complete installation. Provide transition section not less than 18' long where weight differences between rail sections exceed 20 pound per yard.

1.2 SUBMITTALS

- A. Submit CPM Construction Plan as specified in Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION Article 1.6. The CPM shall include the coordination plan developed by the DB Entity together with the operating railroad and the industry located on active sidings.
- B. Submit identity and location of licensed incinerator and land fill facilities proposed for crosstie and switch timber disposal.
- C. All submittals will be reviewed for general conformance with the intent of the Contract Documents. This review will not relieve the DB Entity of final responsibility for the means, methods, procedures, and sequences to be utilized.

1.3 QUALITY CONTROL

- A. Tolerance from Design
 - 1. Final established gauge, cross level, super-elevation, and vertical and horizontal alignment of tracks shall be as indicated on accepted drawings, and shall be within tolerances from design specified below.
 - a. Horizontal Track Alignment
Maximum permissible variation from design shall not exceed plus or minus ½”

Rate of change of permissible variation from design shall not exceed plus or minus 3/16”. Middle ordinate to a 31' chord on curves, and 0.0052' middle ordinate to a 31' chord on tangent
 - b. Vertical Track

Profile Maximum permissible variation from design shall not exceed plus or minus 1/16" middle ordinate to a 31' chord

c. Track Centers

Maximum permissible variation from design shall not exceed plus ½", minus zero

d. Cross Level

Maximum permissible variation from design at any point plus or minus 1/16"

e. Gauge Variation

None

2. No tolerances from design shall be allowed at locations where vertical and horizontal clearances are restricted by the MBTA, Standard Plans, and Design Documents such as platforms, abutments, and overhead bridges.
3. Tie spacing in new track siding shall be 19 ½".
4. Joint bars in new side tracks shall be new 36", six hole joint bars for the rail section furnished complete with six bolt assemblies per joint.
5. Joint bars in existing track to be rehabilitated shall match existing units and be sized for the rail in place. Furnish additional fit relay joint bars and new bolt assemblies for all joints replaced and where rails are replaced with salvaged material.
6. If salvaged relay rail is of different rail section, provide compromise joint bars to match rail sections.

1.4 DELIVERY AND HANDLING

- A. Handle all materials in a manner which will prevent damage during loading, transporting, unloading and distributing.

PART 2 - PRODUCTS

2.1 MATERIALS TO BE FURNISHED BY THE DB ENTITY

- A. New 132 RE and 115 RE rail as specified in Section 02851 – RAILROAD RUNNING RAIL.
- B. New 7" x 9" x 8'-6" treated timber cross ties as specified in Section 02871 – TIMBER CROSS TIES.
- C. New 132 RE and 115 RE 6 hole, joint bars with 6 bolt assemblies as specified in Section 02865 – TRACK APPURTENANCES.
- D. New 132 RE and 115RE 6 hole, steel poly type insulated joints as specified in Section 02865 – TRACK APPURTENANCES.

- E. Compromise joint bars, as specified in Section 02865 – TRACK APPURTENANCES.
- F. New cut track spikes, as specified in Section 02865 – TRACK APPURTENANCES.
- G. New tie plugs as specified in Section 02865 – TRACK APPURTENANCES.
- H. Stone ballast as specified in Section 02858 – BALLAST.
- I. Tie Plate Standard – MS 9272 attached and as specified in Section 02865 – TRACK APPURTENANCES.

PART 3 - EXECUTION

3.1 GENERAL

- A. Following track removal and preparation of subgrade to the lines and grades on the accepted drawings, construct ballasted sidetracks, in accordance with these Mandatory Specifications, Standard Plans, and Design Documents to the zero inch raise or hold point.
- B. Replace existing defective cross ties on track prior to raising the track to the proposed profile as directed by the MBTA.

3.2 TRACK REMOVAL

- A. Prior to track construction the existing sidetrack and any turnouts shall be dismantled and removed to the limits shown on the Design Documents.
- B. Turnout metals, excluding spikes, lags, track bolts, nuts and washers, shall be salvaged and either reused as required for track rehabilitation or returned to the MBTA.
- C. Rail, joint bars, and tie plates shall be salvaged and either used for track rehabilitation or returned to the MBTA.
- D. Track bolts, nuts, washers, spikes, anchors, and lags shall become the property of the DB Entity and shall be disposed of off of the MBTA's property.
- E. Track and turnout dismantling shall be done using equipment and procedures that will not damage salvaged material or make it unfit for future use. If a torch is used to remove bolts from joints, care shall be taken so as not to damage joint bars.
- F. Salvaged rail and other track components not used in rehabilitation shall be delivered to a designated MBTA material yard within 50 miles of the Project. Materials shall be separated, not mixed together, by class, type, and weight and stockpiled as directed by yard personnel.
- G. Crosstie and switch timber disposal shall be as specified in Section 02852 – TRACKWAY DEMOLITION AND SALVAGE.

3.3 SUBGRADE PREPARATION IN NEW TRACKBED LOCATIONS

- A. Existing track structure, fouled ballast, and subballast removal shall be as specified in Section 02852 – TRACKWAY DEMOLITION AND SALVAGE.

- B. Smooth and compact subgrade areas, with cross slope as shown on the Design Documents, to receive subballast.

3.4 PLACEMENT OF NEW SUBBALLAST

- A. Subballast shall be distributed over subgrade unless otherwise specified in Design Documents.
- B. Distribute and compact eight inch layers of subballast, uniformly over the finished subgrade.
- C. Deliver subballast at a rate no faster than can be satisfactorily incorporated into the work, maintaining a proper interval of operations, and at such times as to permit proper inspection by the MBTA.
- D. To extent practicable, unload subballast in position for use with a minimum of redistribution and dressing.
- E. Self-spreading vehicles may be used as accepted by the MBTA. When subballast is initially spread by self-spreading vehicle, a power grader may be used to assist spreading operations.
- F. Thoroughly compact subballast until material is firmly interlocked and surface is true and unyielding.
- G. Top surface of initial layers of subballast shall be smooth, flat and uniformly compacted prior to distributing ballast.

3.5 PLACING INITIAL LAYERS OF BALLAST

- A. Ballast shall not be distributed until the subgrade and where applicable subballast has been completed and accepted as specified above. Clean track way area of debris and standing water prior to placing ballast. Do not place ballast on frozen subgrade or frozen subballast.
- B. Distribute and compact four inch layers of ballast, not to exceed an eight inch total, uniformly over the finished subgrade or sub-ballast, prior to tie distribution.
- C. Deliver ballast at a rate no faster than can be satisfactorily incorporated into the work, maintaining a proper interval of operations, and at such times as to permit proper inspection by the MBTA.
- D. To extent practicable, unload ballast in position for use with a minimum of redistribution and dressing.
- E. Self-spreading vehicles may be used as accepted by the MBTA. When stone is initially spread by self-spreading vehicle a power grader may be used to assist spreading operations.
- F. Shape ballast to a true section conforming to the ballast section shown on Standard Plans and Design Documents.
- G. Thoroughly compact each ballast layer until stones are firmly interlocked and surface is true and unyielding. Compact each lift with not less than four passes of a roller or a vibratory compactor subject to the following requirements:

1. Compact by rolling using either a self-propelled, three-wheel, or two axle roller of such weight that will provide compression under the rear wheels of not less than 350 pounds per linear inch of tread; or using a two or three-wheel tandem roller having a weight per inch of drive roll of not less than 350 pound, and every part of the surface receiving compression from the drive wheels.
 2. Compact by vibration using vibratory compactors of either the roller or pad type. Dynamic force for either type shall not be less than 20,000 pounds and the frequency range shall be 1100 to 1500 vpm. Use machines equipped with a governor which can be set and locked to control rate of impulse. Provide a tachometer or other suitable device for accurately checking the frequency of vibration during the compacting operation.
- H. Top surface of initial layers of ballast shall be smooth, flat and uniformly compacted prior to distributing ties.

3.6 DISTRIBUTING AND SPACING TIES

A. General

1. Carefully distribute and properly space ties on initial layer of ballast. Space ties at design spacing of 19 ½" on center and as further specified in Article 1.3.
2. Place timber ties so that heartwood is down.
3. Handle treated ties in a manner to avoid breaking and bruising. Do not throw ties from cars or trucks onto rails or rocks.
4. Place ties normal to center line of track.
5. Properly space and align ties prior to rail installation.
6. In placing or spacing treated ties, handle only with tongs or suitable devices. Do not use bars, chisels, forks, mauls, picks, punches, shovels, or sledges for moving ties or placing them in position beneath rails.
7. Avoid unnecessary handling, redistribution, and reloading of ties. To extent practical, distribute ties in proper position for use without further handling.
8. Remove ties damaged as result of improper handling by the DB Entity and rejected by the MBTA and replace with undamaged ties at no additional cost to the MBTA.

3.7 RAIL INSTALLATION

- A. Install new 132 RE or 115 RE rail as jointed rail once beyond long timbers of turnouts connecting to main line.
- B. Lay rail in such a manner that damage to ties or other materials is avoided and ties are not dislodged from their proper position.

3.8 INSULATED JOINTS - POLY

- A. Install 132 RE poly insulated joints at locations shown on the Design Documents.

- B. Install insulated joints during installation of 132 RE rail.
- C. Insulated joints will be installed as suspended joints.
- D. Accurately space and drill holes for bolting of rail in accordance with requirements of the current AREMA Manual for Railway Engineering, Specifications for Steel Rails, Chapter 4, Part 1 and STANDARD PLAN 1302. Drill holes with an approved rail drill.
- E. Drill cylindrical holes of specified diameter for the size bolt required through and perpendicular to the web of rail.
- F. Use a template as a drilling guide to locate holes both vertically from bottom of rail and horizontally from rail end. In no case shall a joint bar be used for this purpose.
- G. Remove all rough edges from holes.

3.9 TIE PLATES - RESILIENT AND STANDARD

- A. Timber crossties shall have resilient tie plates installed under each 132 RE rail and standard double shaller canted plates under all secondhand and existing rail.
- B. Prior to installation of tie plates, clean contact surfaces to allow proper bearing of tie plate on tie and rail on tie plate.
- C. Locate tie plates on 8' 6" ties so that the line side of tie is 18 ½" from outer edge of base of rail. Tie plate shall be centered on the crosstie under rail.
- D. Locate tie plates on longitudinal centerline of each tie and place square to centerline of rail so that outside shaller of plate bears fully against rail base. Place plate with the downward cant toward center of track.
- E. Secure rail on line end of ties to tie, in proper relation to tie end, before securing opposite rail.
- F. Use line rail as reference in securing opposite rail to proper gauge.
- G. Tie Boring
 - 1. Field bore crossties and switch timber before fastening tie plates.
 - 2. Holes in crossties shall be 9/16" diameter and 6" deep for lock spikes and ½" diameter, 6" deep for cut spikes.
 - 3. Boring of holes in excess of number required will not be permitted.
 - 4. Do not bore holes entirely through tie.
 - 5. After drilling, brush drill chips from top surface of tie.
 - 6. Prior to locating position of holes to be bored for second rail to be placed on any tie or timber, position tie laterally so that field side base of first rail is in contact with shaller of plate and any tolerance between rail base width and plate seat width is on gauge side of rail. Position other plate similarly to ensure retention of gauge established.

3.10 SCREW SPIKES AND CUT SPIKES

- A. Start and drive spikes vertically and square with rail. Drive spikes straight.
- B. Spikes shall be driven in accordance with manufacturer's recommendations and specifications.
- C. Straightening spikes will not be permitted. Spikes bent during driving shall be withdrawn and replacement spike driven.
- D. Number of spikes used per tie shall conform to the MBTA Standard Plans.
- E. Avoid removal of spikes once driven. When necessary, pull spikes and plug hole using treated tie plugs.
- F. Under no circumstances shall gauge be adjusted by striking spikes, or plate edge after it is fixed to tie.
- G. Seat rail properly between tie plate shallers with outside base of rail tight against outside plate shaller.

3.11 JOINTED RAIL

- A. General
 - 1. Jointed rail shall be installed following the proper spacing of crossties, on double shaller canted tieplates, properly secured with spikes.
 - 2. Rails shall be laid one at a time, the rail ends brought squarely together and bolted.
 - 3. Rail joints in track will be staggered. The joints of one line of rails shall be opposite the middle of the rails in the other line, with a permissible variance of 18" either side of center.
 - 4. Rails shall be cut squarely and cleanly by means of a rail or abrasive disk saw. Cutting rails or burning holes in rails by means of a heat dependent device is prohibited.
 - a. Holes for bolting cut rails shall be drilled by an approved type of rail drill and with use of a template. Under no circumstances shall new holes be drilled between two existing holes.
- B. Compromise Joints
 - 1. Install compromise joints at the locations where rail section changes.
 - 2. The DB Entity is responsible for determining the proper size of the compromise joints which shall not exceed a 20 pound weight difference.
 - 3. Prior to the joint bar application, the DB Entity shall clean and coat the rail ends within the joint bar area, including webs, fishing surfaces, bolt holes and inside surfaces with an approved oil or grease as specified in AREMA Specification, Chapter 5, Part 5.
 - 4. The joint bars shall be positioned on the rail, bolts inserted and washers and nut applied by hand.
 - 5. The bars shall be in a vertical (uncocked) position as one of the center bolts is tightened.

6. All bolts shall be completely tightened when the rail is laid to a tension range of 20,000 to 25,000 pounds per bolt and in the proper sequence to properly seat the rail joint, beginning at the center and working in both directions toward the end. To assure that the joint bars maintain their vertical position the toes of the bars shall be tapped with a maul as the bolts are tightened.
7. After the rail has been laid, all bolts shall be tightened again.

C. Rail

1. If the compromise joint cross ties are not spaced properly at a joint location, the cross ties shall be re-spaced to properly support the joint bars as a suspended joint.
2. Tie plates shall be applied so the outside shaller is in contact with the rail base or a joint bar for the full length of the shaller. The tie plate shall be centered on the tie and the shaller shall not be under the rail base and shall be placed to cant the rail inward.
3. Mismatches on tread and gauge side of rail head will not be allowed and the DB Entity shall be required to properly build up rail ends to conform with adjacent rail to the satisfaction of the MBTA. Removal of mismatch by grinding rail head is prohibited.

3.12 TIE PLUGS

- A. Install treated tie plugs in holes where spikes have been pulled from ties.
- B. Drive plugs into tie to refusal and cut plug flush with top of tie, using an adze, before installing tie plate.

3.13 SURFACING AND ALIGNING

- A. Surface and align track as specified in Section 02854 – TRACK SURFACING AND ALIGNMENT.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY
COMMUTER RAIL MATERIAL SPECIFICATION NO. 9272

TIE PLATE - STANDARD

MATERIALS

New standard tie plate shall conform to AREA Manual For Railway Engineering, Chapter 5, Part 1 - "Specification For Low-Carbon Steel Tie Plates"

MANUFACTURE

Each new standard tie plate shall have AREA B-6 punching, 1:40 cant and shall be in accordance with MBTA Standard Plans.

Material order shall specify plan number required.

INSPECTION

Standard tie plates are subject to inspection at delivery for compliance with these specifications.

SHIPMENT

Standard tie plates shall be handled and shipped in accordance with currently accepted practices and as specified in the order.

DELIVERY

To be accepted, standard tie plates offered shall conform to this specification in all respects. Standard tie plates are subject to inspection at delivery and are at the supplier's risk until acceptance. Standard tie plates rejected for non-compliance with this specification will be returned at the supplier's expense.

APPLICABLE STANDARD PLANS

No. 1220

No. 1222

APPROVED:


ENGINEERING OFFICER

DATE: 10-28-92


CHIEF ENGINEERING OFFICER

ISSUE 10-28-92

TIE PLATES - STANDARD PAGE 1 OF 1

END OF SECTION

SECTION 02886

BALLAST MATS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies furnishing and installation of a vibration mitigating ballast mat where indicated on the Design Documents, complete with all necessary components in conformity with manufacturer's specifications, and to the lines and grades shown on the Design Documents.

1.2 REFERENCE STANDARDS

- A. Tensile Strength and Elongation at Break: ISO-37(2011) Rubber, Vulcanized or Thermoplastic – Determination of Tensile Stress-Strain properties; ASTM D4632 – Standard Test Method for Grab Breaking Load Elongation of Geotextiles.
- B. CBR Puncture Strength: ASTM D6241 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-related Products Using a 50-MM Probe.
- C. Compression Set: ISO-815-1(2008) Rubber, Vulcanized or Thermoplastic – Determination of Compression Set – Part 1: At Ambient or Elevated Temperatures.

1.3 SUBMITTALS

- A. Design:
 - 1. Submit drawings showing the limits of ballast mat installation in plan and cross section.
- B. Construction:
 - 1. Submit complete details of the ballast mat and appurtenant materials, including shop drawings and a detailed procedure for the storage, handling, transport, installation, and protection of the ballast mat (including procedures and equipment to be used for distribution, grading and compaction of initial layer of ballast) to the MBTA for review and acceptance.
 - 2. Submit complete details of the ballast mat performance qualification test, consistent with procedures described in Article 2.2 herein.
 - 3. Provide name and qualifications of proposed test consultants and/or lab as described in Paragraph 1.4(B).

1.4 QUALITY CONTROL

- A. A representative of the manufacturer of the ballast mat shall be present on the Project site(s) at least two days prior to the commencement of ballast mat installation and shall remain on the site(s) to supervise the ballast mat installation work for the duration of the installation or for a period of at least one week, as deemed necessary by the MBTA to ensure proper installation.
- B. Provide test results conducted by a recognized independent consultant and/or test lab that the performance specifications of the ballast mat to be installed on this Project is as specified herein and is compatible with substrates track system and rolling stock to be used on this Project.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Ballast mat shall be designed to provide reduction of ground or structure-borne vibrations, and the impact on structures and of the crushing of ballast.
- B. The upper surface of the mat shall be textured to permit ballast to nest for track bed stability and be designed for protection against attack by contaminants that may filter through ballast over time. The subsurface shall contain fabric reinforcement for strength and load distribution. The underside shall provide for subsurface drainage under the mat.

2.2 QUALIFICATION TEST

- A. Ballast mat material shall display minimum required performance characteristics for reducing measured vibration levels when tested (in-situ) for similar track installations and similar rolling stock, as specified below:

- 1. Insertion Loss Performance Requirement:

Measured ballast mat insertion loss will meet or exceed the following one-third octave band values, as measured using test procedures listed below.

1/3 Octave Band Center Frequency (Hz)	Insertion Loss (dB)
50	0
63	3.4
80	4.8
100	7.6
125	8.8
160	9.2
200	7.6
250	0.4
315	-0.9
400	0

- 2. Track Type and Rolling Stock Requirement:

Qualification testing shall be conducted (if possible) on a tangent and at-grade track installation (not on curves, in tunnels, or on bridges). Track type shall be continuously welded rail, with wood ties, with 12" minimum bottom ballast. Rolling stock used for test shall include a minimum 36.88-ton axle load locomotive.

- 3. Qualification Test Requirements, Ballast Mat Insertion Loss:

- a. Insertion loss is a measure of the difference in train-induced vibrations with and without the ballast mat installed.

- b. Measurements shall be made along a stretch of track where the soil conditions are substantially the same for the treated and untreated sections. A minimum of two vibration sensors shall be used, one next to the treated section and one next to an adjacent untreated section. In order to minimize flanking from the end of the ballast mat, the sensors shall be located approximately 200' from the treated/untreated junction (400 feet apart). Vibration data shall be recorded simultaneously at the two sites. The sensors shall be approximately 25' from the track centerline.
- c. Vibration spectra shall be measured for the same train passing each site, at the same speed. Vibration spectra shall be measured in one- third octave bands from 5 Hz to 500 Hz. Vibration spectra shall be measured using a "peak-hold" or "band-maximum" type average. Data from multiple passes shall be averaged using an energy averaging technique.
- d. Train speed shall be between 30 mph and 50 mph and shall be measured by both the cab recorder and by some other method such as GPS. Multiple train speeds are required. The measurements shall be made with rolling stock similar to that used on MBTA commuter rail lines, in particular with a 36.88-ton axle load locomotive.

2.3 BALLAST MAT PROPERTIES

A. Ballast mat material shall satisfy the following requirements:

- 1. Capacity: an axle load of 36.88 tons; speeds up to 70 mph.
- 2. Dimensions:
 - a. Width no less than 48" not including joint overlaps.
 - b. Thickness no greater than 2 inches.
- 3. Fabric:
 - a. Tensile strength $\geq 1,150$ lb/inch
 - b. Elongation at break ≥ 10 %
 - c. CBR- Puncture Resistance ≥ 725 lbf
- 4. Elastomer Properties:
 - a. Tensile strength ≥ 58 psi
 - b. Elongation at break ≥ 40 %
 - c. Compression Set < 4 %
- 5. Dynamics: dynamic to static stiffness ratio (related to a preload of 8.5 psi), $K_d = 1.3 (+0.1/-free)$.
- 6. Temperature Range: standard quality is suitable for service where ballast mat temperatures range between (-) 4 degrees F and (+) 158 degrees F.

- B. The material used for the sealing of ballast mat joints shall be an integral extension of the top surface of the mat or a separate material having strength characteristics equal to those of the top layer of the ballast mat and be accepted by the MBTA.

PART 3 – EXECUTION

3.1 INSTALLATION

- A. Installation shall be in accordance with:
 - 1. Manufacturer's guidelines
 - 2. Limits shown on accepted drawings.

END OF SECTION

SECTION 03300

CAST-IN-PLACE CONCRETE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items:
1. Cast-in-place concrete, including formwork, reinforcement, concrete materials, mixture design, placement procedures and finishes for the following applications:
 - a. Footings, mat foundations, grade beams
 - b. Pile caps: Including but not limited to caps for drilled shafts, mini-piles, driven piles and other deep foundation types
 - c. Slabs: Including but not limited to, slabs-on-grade, suspended slabs, slab on steel deck, approach slabs, topping slabs, and other slab types
 - d. Concrete toppings
 - e. Building frame members
 - f. Walls: Including but not limited to building walls, retaining walls, foundation walls, parapet walls, safety walls and other wall types
 - g. Cutting and patching of mechanical and electrical penetrations through cast-in-place concrete
 - h. Pedestrian Viaducts and Bridges:
 1. Abutments and abutment caps
 2. Piers and pier caps
 3. Deck slabs and parapet walls, curbs and haunches
 4. Approach slabs
 5. Footings
 6. Parapet walls
 - i. Viaduct Structures and Washington Street Bridge:
 1. Abutments and abutment caps
 2. Piers and pier caps
 3. Deck slabs
 4. Equipment platform slabs
 5. Approach slabs
 6. Approach retaining walls
 7. Drilled shafts
 8. Driven pile and drilled mini pile caps

- j. Storm drain manholes, structures, and headwalls
 - k. Sidewalks, curbs, gutters, and ramps
 - l. Foundations for fence posts
 - m. Foundations for bollards, benches, bicycle racks, and other miscellaneous site items
 - n. Footing for traffic signal structures
 - o. Concrete pavement structure at bus station
 - p. Underpasses at Walnut Street, Medford Street and School Street
 - q. Miscellaneous cast-in-place concrete item of varying types including but not limited to: ramps, service pits, sump pits, elevator and escalator pits, stairs and landings, pans, steps, concrete encasements, pole supports, corbels, haunches and other miscellaneous elements
2. Cast-in-place concrete with Integral Crystalline Waterproofing Admixture System: Furnish all materials, services, application instructions, testing guidelines, quality control requirements and supervision necessary for the supply and installation of crystalline integral waterproofing admixture in concrete. Add the crystalline waterproofing admixture to the concrete mixture at the time of batching. Design, batch, place, finish and cure concrete in accordance with the guidelines set out by the American Concrete Institute and the recommendations of the manufacturer written instructions
- B. Related Work: The following items are not included in this Section and shall be performed under the designated Sections:
- 1. Section 03301 –CAST-IN-PLACE CONCRETE FOR ROADWAY BRIDGES.
 - 2. Section 09900 – PAINTING
 - 3. Section 16125 – CATENARY POLES
 - 4. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION
 - 5. Section 16807 – CONCRETE AND OTHER FOUNDATIONS FOR THE LIGHT RAIL SIGNAL SYSTEM

1.2 DEFINITIONS

- A. Cementitious Materials: Portland cement alone or in combination with one or more of the following: blended hydraulic cement, fly ash and other pozzolans and ground granulated blast-furnace slag; subject to compliance with requirements.
- B. Mass Concrete requirements apply to the cast-in-place retaining wall, slabs, cap beams, bridge abutments and viaduct structures.
 - 1. Concrete slabs, footings, cap beams, bridge abutment, viaducts structures and other structures with thickness greater than three feet (3'-0") are considered mass concrete.
 - 2. Mass concrete also includes concrete placements of other dimensions where measures must be taken to mitigate cracking caused by heat of hydration.
- C. Lightweight Concrete as required by design shall consist of lightweight aggregate conforming to ASTM C330. Lightweight concrete shall achieve a 28-day oven-dry maximum unit weight of 110 pounds per cubic foot.

1.3 SUBMITTALS

- A. Product Data: Submit data for each type of product indicated, including but not limited to reinforcement, forming accessories, admixtures, patching compounds, waterstops, joint systems, curing compounds.
1. Include descriptive data, catalog cuts, laboratory test reports and any other information necessary to show acceptable materials and confirm Contract compliance.
- B. Design Mixtures: For each concrete mixture, submit proposed mix proportions and test results confirming mix meets requirements stated below. Submit alternate design mixtures when characteristics of materials, project conditions, weather, test results, or other circumstances warrant adjustments.
1. Indicate amounts of mixing water to be withheld for later addition at Project site.
 2. Indicate amount of fly ash or slag in the mix minimum of 25% of fly ash or slag is required in conformance with Volume 2 Technical Provisions Exhibit 2I.
 3. For mass concrete placements, submit a Temperature Control Plan. The temperature control plan shall follow the procedures outlined in Section 207 of the ACI Manual of Concrete Practice to formulate, implement, administer and monitor a temperature control plan, making adjustments as necessary to ensure compliance with the Contract Documents.
 4. As a minimum the Temperature Control Plan shall include the following:
 - a. Concrete mix design
 - b. Duration and method of curing
 - c. Procedures to control concrete temperatures at the time of placement
 - d. Methods of controlling temperature differentials
 - e. Temperature sensor types and locations
 - f. Temperature monitoring and recording system
 - g. Field measures to ensure conformance the maximum concrete temperature and temperature differential requirements
 - h. Methods for crack control
- C. Steel Reinforcement Shop Drawings: Submit steel reinforcement placing shop drawings that detail fabrication, bending, and placement. Include bar sizes, lengths, material, grade, bar schedules, stirrup spacing, bent bar diagrams, bar arrangement, splices and laps, mechanical connections, tie spacing, hoop spacing, and supports for concrete reinforcement.
1. Indicate coordination requirements for reinforcement locations with requirements of structural steel, steel joists and steel deck.
 2. Comply with ACI, "Manual of Standard Practice for Detailing Reinforced Concrete Structures".
- D. Formwork Shop Drawings: Prepared by or under the supervision of a qualified professional engineer licensed in the Commonwealth of Massachusetts detailing fabrication, assembly, and support of formwork
1. Submit complete and accurate shop drawings as required to adequately illustrate and control finished work. Show all dimensions, kind, type, quality of all material, applicable specification

references, and all information as may be necessary to detail finished construction of work covered.

2. Shoring and Reshoring: Indicate proposed schedule and sequence of formwork removal, shoring removal, and installing and removing reshoring. Submit camber and shoring calculations.
3. Blockouts for Architectural Joint Systems: Indicate blockouts and coordination with architectural joint systems.

E. Concrete Placement: Submit the following:

1. Written Cold-Weather Placement Plan: The Cold-Weather Placement Plan shall include detailed procedures to protect concrete during cold weather placements. Submit the Cold-Weather Placement Plan prior to concrete placement. The plan shall include:
 - a. Instructions for placing and protecting all concrete elements including but not limited to slabs on grade, walls, columns and elevated slabs
 - b. Provisions for monitoring the concrete temperature during placement, curing and immediately after protection is removed
 - c. Curing procedures to prevent undesirable drying of fresh concrete
 - d. Delivery coordination of redi-mix concrete trucks to avoid delays in concrete delivery
2. Written Hot-Weather Placement Plan: The Hot-Weather Placement Plan shall include detailed procedures to protect concrete during hot weather concrete placements. Submit the Hot-Weather Placement Plan prior to concrete placement. The plan shall include:
 - a. Instructions for placing and protecting all concrete elements to prevent rapid drying due to high temperature, low relative humidity and/or high wind velocity
 - b. The concrete producer's proposed methods of preventing the concrete from exceeding the maximum allowable temperature upon delivery
 - c. Detailed description for the use of chilled water, cooled aggregate, substitution of shaved ice in batching concrete or combination of methods
 - d. Detailed curing procedures including instructions to prevent drying-shrinkage cracking due to rapid loss of moisture as well as thermal cracking due to rapid temperature drop after placement
 - e. Delivery coordination of redi-mix concrete trucks to avoid delays in concrete delivery
3. Written Mass Concrete Placement Plan
4. Written lightweight Concrete Placement Plan, describing equipment and procedures to be used in the placement of the concrete and methods for consolidation

F. Reinforcement Placement: Comply with CRSI-WCRSI "Placing Reinforcing Bars"

- G. Material Test Reports: For the following, submit a test report from a qualified testing agency, indicating compliance with requirements:
1. Aggregate Soundness Test Reports (ASTM C88).
 2. Aggregate Staining Test Reports (ASTMC641).
 3. Preliminary Design Mix reports (ACI 301).
 4. Air Entrainment Test Reports (ASTM C260).

- H. Material Certificates: For each of the following, submit material certification signed by manufacturers:
1. Cementitious materials
 2. Lightweight Aggregate
 3. Admixtures
 4. Form materials and form-release agents
 5. Steel reinforcement and accessories
 6. Fiber reinforcement
 7. Waterstops
 8. Curing compounds
 9. Floor and slab treatments
 10. Bonding agents
 11. Adhesives
 12. Vapor Barriers/ Retarders
 13. Semirigid joint filler
 14. Joint-filler strips
 15. Repair materials
- I. Submit floor surface flatness and levelness measurements to determine compliance with specified tolerances and requirements for applied finishes and materials, except as noted for slope to drains.
- J. Submit for review and approval the name and qualifications of the proposed Independent Inspection and Testing Agency.
- K. Submit field quality-control test and inspection reports.
- L. Submit Minutes of pre-installation conference.
- M. Samples: Provide 3 samples, minimum 36" round by 3" thick, for the MBTA's evaluation of appearance and workmanship for each location type. If samples are not accepted, provide additional rounds of samples until approval is received.
- N. In-Place Mock-Ups: Using materials and mixes from approved samples, provide separate 10' x 10' mock-ups for each location type. Comply with procedural requirements for in-place mock-ups specified in Volume 2 Technical Provisions Exhibit 2I, including scheduling, shop drawings, photographs.
1. Submit proposed location of in-place mock-ups to the MBTA for review.
 2. Remove and replace rejected mock-ups until accepted by the MBTA.

1.4 QUALITY CONTROL /QUALITY ASSURANCE

- A. Manufacturer Qualifications: Furnish concrete from a plant experienced in manufacturing ready-mixed concrete products and that complies with ASTM C 94/C 94M requirements for production facilities and equipment. Select a plant that has recently furnished specified concrete for a large

- project, or furnish evidence of plant's capacity to produce and deliver concrete conforming to specified requirements at required rate and has laboratory capability to develop acceptable concrete mix designs and to control quality of concrete production, in accordance with a preapproved quality control plan.
- B. The DB Entity's selected Independent Testing Agency is required to perform all Testing and Inspection Services, Concrete Plant Inspection and Field Control and record keeping.
- C. The minimum number of test cylinders to be made for each class of concrete and for each placement shall be four for each 50 cubic yards or less and minimum of four extra cylinders for each additional 100 cubic yards or fraction thereof. When additional sets of test cylinders are required beyond the normal seven and twenty-eight day tests, each set shall consist of a minimum of two test cylinders. For Lightweight Concrete an additional three test cylinders are required in addition to those indicated above. Use the additional cylinders to help verify the final dry unit weight of the as placed mix.
- D. Independent Testing Agency Qualifications: An independent agency, acceptable to the MBTA, qualified according to ASTM C 1077 and ASTM E 329 for testing indicated, as documented according to ASTM E 548.
1. Personnel conducting field tests are required be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-01 or an equivalent certification program.
 2. Personnel performing laboratory tests are required be ACI-certified Concrete Strength Testing Technician and Concrete Laboratory Testing Technician - Grade I. Testing Agency laboratory supervisor is required to be an ACI-certified Concrete Laboratory Testing Technician - Grade II.
- E. Source Limitations: Obtain each type or class of cementitious material of the same brand from the same manufacturer's plant, obtain aggregate from one source, and obtain admixtures through one source from a single manufacturer.
- F. Welding: Qualify procedures and personnel according to AWS D1.4, "Structural Welding Code-- Reinforcing Steel".
- G. ACI Publications: Comply with the following unless modified by requirements in the Contract Documents:
1. ACI 116R "Cement and Concrete Terminology"
 2. ACI 207.1 "Guide to Mass Concrete"
 3. ACI 211.1 "Selecting Proportions for Normal, Heavyweight, and Mass Concrete"
 4. ACI 211.2 "Recommended Practice for Selecting Proportions for Structural Lightweight Concrete"
 5. ACI 214 "Recommended Practice for Evaluation of Compression Test Results of Field Concrete"
 6. ACI 117 "Specifications for Tolerances for Concrete Construction and Materials"
 7. ACI 301 "Specifications for Structural Concrete for Buildings"
 8. ACI 304 "Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete"
 9. ACI 304.2R "Placing Concrete by Pumping Methods"
 10. ACI 304.5R "Batching, Mixing, and Job Control of Lightweight Concrete"

11. ACI 305 “Hot Weather Concreting”
12. ACI 306 “Cold Weather Concreting”
13. ACI 309 “Consolidation of Concrete”
14. ACI 311 “Recommended Practice for Concrete Inspection”
15. ACI 315 “Manual of Standard Practice for Detailing Reinforced Concrete Structures”
16. ACI 318 “Building Code Requirements for Reinforced Concrete”
17. ACI 347 “Recommended Practice for Concrete Formwork”
18. ASTM C31 “Making and Curing Concrete Test Specimens in the Field”
19. ASTM C33 “Concrete Aggregates”
20. ASTM C39 “Compressive Strength of Cylindrical Concrete Specimens”
21. ASTM C40 “Organic Impurities in Fine Aggregates for Concrete”
22. ASTM C87 “Effect of Organic Impurities in Fine Aggregate on Strength of Mortar”
23. ASTM C88 “Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate”
24. ASTM C94 “Ready-Mixed Concrete”
25. ASTM C136 “Sieve Analysis of Fine and Coarse Aggregates”
26. ASTM C138 “Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete”
27. ASTM C143 “Slump of Hydraulic Cement Concrete”
28. ASTM C150 “Portland Cement”
29. ASTM C157 “Length Change of Hardened Hydraulic Cement Mortar and Concrete”
30. ASTM C173 “Air Content of Freshly Mixed Concrete by the Volumetric Method”

H. Construction Tolerances: Allowable deviations from as-designed or indicated dimensions and elevations - Do not allow adjacent units to have cumulative deviations:

1. Footings and Pile Caps
 - a. Misplacement and eccentricity, as measured from centroid of footing: Two percent of footing width in direction of misplacement but not more than two inches
 - b. Elevation of top: $\pm 1/4$ "
 - c. Other footing/cap dimensions: $- 1/4$ "
2. Concrete Substrate Surfaces
 - a. Slab to receive dry shake aggregate topping - Adjust to accommodate finished surface tolerances
 - b. Variation of other substrate surfaces from indicated elevation: $\pm 1/4$ "
3. Variations in thickness of finished monolithic slabs: $\pm 1/4$ "
4. Top of track slab (invert concrete) finish course: $\pm 1/4$ "
5. Horizontal distance from centerline of track to edge of station platform: $+ 1/8$ ", $- 1/4$ "
6. Concrete walkway dimensions: $\pm 1/4$ ".
7. Horizontal distance from edge of walkway to centerline of track: $+ \text{zero}$, $- 1/4$ "

8. Tops of slabs not otherwise specified: +/- 1/4"
 9. Variation from a 10' straightedge placed in all directions on horizontal and inclined surfaces: 1/4"
 10. Top elevation of columns, piers and walls: +/- 1/4"
 11. Flatness of wall and column surfaces in 10' in all directions: +/- 1/4"
 12. Out-of-plumb of columns, piers, walls, centerlines of elevator shafts, and joints not exposed to view in public areas of finished structure: 1/4" in 10'; do not exceed one inch total.
 13. Out-of-plumb of columns, piers, walls, vertical joints and grooves, openings for doors, windows, louvers, and other lines exposed to view in public areas of finished structure: 1/4" in 10'; do not exceed 1/2" total.
 14. Clearance between door, window and louver frames - Not less than 1/4" nor more than 3/8".
 15. Level and grades of exposed lintels, sills, parapets, horizontal grooves and other conspicuous lines: 1/4" in 20'; do not exceed 1/2" in entire line.
 16. Level and grade of slab soffits, ceilings, beam soffits and arises: 1/4" in any 10' length; 3/8" in any 20' length; do not exceed 3/4" for entire surface
 17. Cross Sectional dimensions of columns and beams and thickness of slabs: + 1/4", - 1/8".
 18. Elevation of bottom of slabs on grade: + zero, - has no minimum.
 19. Thickness of walls and pilasters: + 1/2", - 1/4"
 20. Position of linear building lines and distance from centerlines of columns, walls and partitions: 1/2"
 21. Rise of steps: +/- 1/16" in consecutive steps; do not exceed +/- 1/8" in total flight
 22. Tread of steps: +/- 1/8" in consecutive steps; do not exceed +/- 1/4" in total flight
 23. Size and location of sleeves and floor openings: +/- 1/4"
 24. Difference between diagonal dimensions of rectangular opening - Not more than two percent of sum of diagonal dimensions
 25. Escalator and elevator Sections - As required to fit approved equipment, determined by coordination with equipment subcontractor and actual measurements of equipment taken by DB Entity
 26. Horizontal distance form centerline of track to face of exterior concrete wall zero to plus one inch
 27. Fill Concrete: 1/4" of required elevation with variation in slope or plane not to exceed 1/4" in ten feet
- I. Concrete Testing Service: Engage a qualified independent testing agency to perform material evaluation tests and to design concrete mixtures.
- J. Pre-installation Conference: Conduct conference at Project site to address the following:
1. Before submitting design mixtures, review concrete design mixture and examine procedures for ensuring quality of concrete materials. Require representatives of each entity directly concerned with cast-in-place concrete to attend, including the following:
 - a. DB Entity's superintendent
 - b. Independent testing agency responsible for concrete design mixtures
 - c. Ready-mix concrete manufacturer
 - d. Concrete subcontractor

2. Review special inspection and testing and inspecting agency procedures for field quality control, concrete finishes and finishing, cold- and hot-weather concreting procedures, curing procedures, construction contraction and isolation joints, and joint-filler strips, semirigid joint fillers, forms and form removal limitations, shoring and reshoring procedures, vapor barrier/retarder installation, anchor rod and anchorage device installation tolerances, steel reinforcement installation, floor and slab flatness and levelness measurement, concrete repair procedures, and concrete protection
- K. Where the language in any of the documents referred to herein is in the form of a recommendation or suggestion, such recommendations or suggestions shall be deemed to be mandatory under this Contract.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Steel Reinforcement: Deliver, store, and handle steel reinforcement to prevent bending and damage. Avoid damaging coatings on steel reinforcement.
- B. Waterstops: Store waterstops under cover to protect from moisture, sunlight, dirt, oil, and other contaminants

PART 2 - PRODUCTS

2.1 CONCRETE MATERIALS

- A. Cement: Shall be American-made Portland Cement, free from water-soluble salts or alkalis which may cause efflorescence on exposed surfaces. Portland Cement shall be Type II, ASTM C 150 except as noted for Mass Concrete. Sulfate-resistant cement shall be Type V. Use only one brand of cement for each type of concrete throughout project. DB Entity shall be responsible for whatever steps are necessary to insure that no visual variations in color shall result in exposed concrete and shall place on order and secure in advance a sufficient quantity of this (these) cement(s) to complete concrete work specified herein.
 1. Fly Ash: ASTM C 618, Type F 15-35%
 2. Ground Granulated Blast-Furnace Slag: ASTM C 989, Grade 100 or 120, 25-50%
 3. A minimum of 25% of fly ash or slag is required in conformance with Volume 2 Technical Provisions Exhibit 2I Additional Project Requirements.

Maximum water/cement ratio shall conform to the following requirements:

1. All slabs that can be used as a walking surface; 0.40
2. All Stations safety walls/grade beams; 0.40
3. All walls, grade beams, beams, columns, roofs; 0.43
4. All drilled shafts for retaining walls; 0.43
5. All drilled shafts and foundation elements, columns, pier cap beams, approach structure walls, deck slabs and parapet walls for viaduct structure; 0.40

- B. Normal Weight Fine Aggregate: Shall be washed, inert, natural sand conforming to ASTM C 33 and the following additional requirements:

<u>Sieve</u>	<u>Percent Passing</u>
#4	95-100 (typical)
#16	50-85
#50	5-30
#100	0-10
Fineness Modulus	2.80 (Plus/Minus 0.20)
Organic	Plate 2 maximum
Silt	2.0 percent maximum
Mortar Strength	100 percent minimum compression ratio
Soundness	15 percent maximum loss, magnesium sulfate, five cycles

- C. Normal Weight Coarse Aggregate: Shall be well graded crushed stone or washed gravel conforming to ASTM C 33 and the following additional requirements:

Designated Size (inches)	3	2	1-1/2	1	3/4	1/2	3/8
F.M. (+/-0.20)	7.95	7.45	7.20	6.95	6.70	6.10	5.80
Organic	Plate 1 maximum						
Silt	1.0 percent maximum						
Soundness	5 percent maximum loss, magnesium sulfate, five cycles						

- D. Lightweight Aggregates: Expanded Shale, Clay, or Slate lightweight aggregate produced by the rotary kiln method, shall conform to ASTM C 330.
- E. Maximum designated sizes for normal weight coarse aggregate used in concrete sections shall conform to the requirements of ACI 211.1, except that sizes shall also be chosen in conjunction with required clearances and methods of placement.
- F. Concrete Fill for Steel Stair and Landing Pans: Composed of 1:2:2 mix with three-eighths inch maximum size normal weight aggregate and shall be placed with a 0" to 1" slump.
- G. Water: From approved source, potable, clean and free from oils, acids, alkali, organic matter and other deleterious material and complying with the requirements of ASTM C 94.
- H. Admixtures:
1. Water-reducing agent conforming to ASTM C494 Type A:
 - a. "WRDA" - W.R. Grace & Co.
 - b. "PDA25" - Protex Industries, Inc.
 - c. "Pozzolith 344H" - Master Builder's Co.
 - d. Or approved equivalent
 - e. Note: Water-reducing agent shall be by same manufacturer as air-entraining agent.
 2. Air-entraining agent conforming to ASTM C260:

- a. "DAREX AEA" - W.R. Grace & Co.
 - b. "PROTEX AEA" - Protex Industries
 - c. "MB-VR" or "MB-AE" - Master Builder's Co.
 - d. Or approved equivalent
3. Superplasticizer: High-range water-reducer conforming to ASTM C 494 / C 494M, Type A or Type F. ASTM C1017 Type I plasticizing selected to best meet application.
- a. "ADVA CAST 575" – W.R. Grace & Co.
 - b. "PLASTIFLOW R" – Nox-crete
 - c. "MasterGlenium 3400" – BASF US (Master Builders Solutions)
4. Corrosion inhibitor: Calcium Nitrite with a typical dosage rate of 3 gallons per cubic yard. For viaduct elements located within the detention pond use a dosage rate of 5 gallons per cubic yard. Calcium nitrite mix designs shall take into account the effect on concrete set times. Corrosion inhibitors shall be used on areas exposed to deicing salts, such as platforms, as called out in the DB Entity's accepted Shop Drawings

2.2 CONCRETE MIXTURES

- A. Design, on the basis of trial mixes and strength curves specified below, mixes for each type and strength of concrete. The Testing Agency shall verify that the proposed mix designs conform to all specification requirements.
- B. Furnish sufficient materials for concrete mix design not less than five weeks before use. Duplicate small samples plainly and neatly labeled with source, where proposed to be used, date, and name of collector shall be provided and presented to Testing Agency for permanent reference.
- C. Design concrete mixes in accordance with "Method 1" of ACI 301, and the requirements of this Section. All concrete is normal weight unless specifically designated otherwise; air-dry weight not to exceed 150 lbs. per cubic foot.
- D. Furnish Lightweight concrete in accordance with ACI 211.2 and the requirements of this section. Design Lightweight concrete mix to produce a 28-day oven-dry unit weight not to exceed 110 pound per cubic foot, plus or minus 2 percent. Mix lightweight coarse aggregate along with normal weight or lightweight fine aggregate, as required to obtain the unit weight indicated.
- E. All structural concrete shall be normal weight and have a minimum 28-day compressive strength of 4,000 psi and a maximum 28-day compressive strength of 6,000 psi. Deck slabs supporting railroad/light rail loads shall have a minimum 28-day compressive strength of 4,500 psi. The DB Entity may propose the use of higher strength concretes when feasible and as accepted by the MBTA.
- F. Exterior concrete shall contain air-entraining admixture when tested to ASTM C 231 at the point of discharge from the truck mixer:

<u>Aggregate Size</u>	<u>Air Content, %</u>
1-1/2 in.	4.5 - 7.5
3/4 in.	5.0 - 8.0
3/8 in.	6.0 - 9.0

Design Lightweight concrete mix to contain an Air Content between 3 and 4 percent as tested to ASTM C 231. Tremie concrete to contain an Air Content of 4 +/-1.5 percent.

- G. Furnish concrete to have the following slump, unless noted otherwise, when tested to ASTM C 143 at the point of discharge from the truck mixer:

<u>Condition</u>	<u>Slump, inches</u>
With Water-Reducing Agent	4-1/2 – 7
With High-Range W/R Agent	7-9
Without Water-Reducing Agent	2 - 5

- H. Design concrete mixes for slabs, including slabs on grade, to have a mid-range water reducer and have a maximum slump of 6”.
- I. The approved superplasticizer shall be used in all concrete walls.
- J. Design mix of concrete to be used in work shall correspond to following test strengths (TABLE A) obtained in laboratory trial mixtures.

TABLE A

Minimum Strength of Lab Trial Mixes (psi)

Design Trial Mix	Strength 7-days	Strength 28-days
4,000	3,400	5,200
5,000	4,200	6,200
6,000	5,100	7,500

- K. Exposed concrete: Provide corrosion admixture, such as DCI as manufactured by Grace Products, added to the mix design at a rate as indicated in Article 2.1-H.4 at locations noted below:
1. Slabs and concrete in contact with water
 2. Viaduct drilled shafts, columns, pile and shaft caps, and pier cap beams
- L. Mass Concrete: Provide cement complying with AASHTO M85 Type II, provided the specified temperature limitations are met. However, the DB Entity is allowed the option of using Type IV low heat cement in lieu of Type II.

2.3 FORM MATERIALS

- A. Construct formwork to shapes, lines, and dimensions required, plumb and straight, secured and braced sufficiently rigid to prevent deformation under load, and sufficiently tight to prevent leakage, all in conformance with ACI Standard 347, “Recommended Practice for Concrete Formwork”.
- B. Formwork for exterior concrete exposed to public view shall be high-density plastic overlaid plywood, 3/4” minimum thickness; for concealed concrete shall be “Plyform” plywood, 5/8” minimum thickness.

1. Chamfer Strips: At architectural concrete as required by design, use half-inch PVC radius former by BoMetals, Inc. At all other locations, use three quarter-inch, 45 degree poplar wood strips, nailed six inches on center, and installed in inside corners of all forms.
- C. Form Ties and Spreaders: Superior-ties by Superior Concrete Accessories, Inc.; or Sure-Grip Ties by Dayton Sure-Grip and Shore Co. Wire ties shall not be used. Ties for foundation walls shall be snap-ties or type specified above with removal cones and shall incorporate water seal washer. Ties shall be arranged in a symmetrical manner.
1. Provide units that shall not leave any metal closer than 1-1/2" to finished exposed surface.
 2. Provide tie that, when removed, shall not leave holes larger than 1-inch diameter in concrete surface, tie shall not be used for columns or exterior fascias.
- D. Form Release Agent: Crete-Lease 880-VOC-Xtra or Non-staining and non-emulsifiable type, or equal accepted by MBTA. Form release agent shall be biodegradable and shall not impart any stain to concrete nor interfere with adherence of any material to be applied to concrete surfaces.
- E. Form Liners: Units of face design, texture, arrangement, and configuration indicated. Furnish with manufacturer's recommended liquid-release agent that shall not bond with, stain, or adversely affect cast-in-place concrete surfaces and shall not impair subsequent surface or joint treatments of cast-in-place concrete.
1. Available Manufacturer: Available product by manufacture that may be incorporated into the Work include, but are not limited to, the following:
 - a. Greenstreak Group, Inc. or approved equal.
- F. Form-Facing Panels for Exposed-Aggregate Finishes: Steel, glass-fiber-reinforced plastic, or other approved non-absorptive panel materials that shall provide continuous, true, and smooth architectural concrete surfaces. Furnish in largest practicable sizes to minimize number of joints.
- G. Pan-Type Forms: Glass-fiber-reinforced plastic or formed steel, stiffened to resist plastic concrete loads without detrimental deformation.

2.4 REINFORCEMENT AND ACCESSORIES

- A. Reinforcing Steel Bars: Reinforcing bars shall be newly rolled billet steel conforming to ASTM A 615 Grade 60. Bars shall be bent cold.
1. All reinforcing bars shall be epoxy-coated, in accordance with ASTM D 3963, with the following exceptions:
 - a. Retaining walls reinforcing bars, other than viaduct approach structure retaining walls, shall be uncoated
 - b. Pile caps reinforcing bars, other than viaduct structure pile caps and drilled shaft caps, shall be uncoated
 - c. Reinforcing bars for mitigation of Stray Currents requirements per Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION shall be uncoated.
- B. Reinforcing Steel Bars for Welding: Shall be newly rolled billet steel conforming to ASTM A706 Grade 60, uncoated. Bars shall be bent cold.
1. Reinforcing bars for mitigation of Stray Currents requirements per Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION.

- C. Welded Wire Fabric: Shall conform to ASTM A 185 for interior concrete and ASTM A884, Class A for exterior concrete.
- D. Reinforcement Accessories: Shall conform to Product Standard PS7-766, National Bureau of Standards, Department of Commerce, Class C, as produced by Superior Concrete Accessories, Inc.; Dayton Sure-Grip Co.; or R.K.L. Building Specialties Co., Inc. Reinforcement accessories shall include spacers, chairs, ties, slab bolsters, clips, chair bars, and other devices for properly assembling, placing, spacing, supporting, and fastening reinforcement. Tie wire shall be galvanized, epoxy coated or stainless wire of sufficient strength for intended purpose, but not less than No. 18 gage. Metal supports shall be of such type as not to penetrate surface of formwork and show through surface of concrete. Provide epoxy coated supports for epoxy coated reinforcing steel. Accessories touching interior formed surfaces exposed to view shall have not less than 1/8" of plastic between metal and concrete surface. Plastic tips shall extend not less than 1/2" up on metal legs. Individual and continuous slab bolsters and chairs shall be of type to suit various conditions encountered and shall be capable of supporting 300 pound load without damage or permanent distortion.
- E. Mechanical Reinforcing Bar Splicers (Couplers): The completed splice, utilizing couplers, Dowel Bar Splicer and Dowel-In shall meet or exceed 125 percent of the yield of the reinforcing bars being spliced. Provide temporary plastic plugs in splicers, which shall be exposed for extended periods

2.5 MISCELLANEOUS MATERIALS

- A. Grout: Non-Shrink, Non-Metallic Grout: factory pre-mixed grout product complying with U.S. Army Corps of Engineers Handbook CRD-C-62 1. Ready-to-use aggregate product requiring only addition of water at job site such as "Embeco Pre-mixed Grout" by Master Builder's; "Vibro-Foil Ready-Mixed" by W.R. Grace & Co.; or "Ferrolith G" by Sonneborn Building Products, Inc. Grout shall be easily workable and shall have no drying shrinkage at any age. Compressive strength of grout (2" x 2" cubes) shall not be less than 5000 psi at 7 days, and 7500 psi at 28 days.
- B. Waterstops: Extruded virgin PVC containing no scrap or reclaimed material or pigment. Provide cross section as indicated, uniform along the length of the waterstop and symmetrical transversely so that the thickness at any given distance from either edge of the waterstop shall be uniform. The finished waterstop shall meet the requirements specified below for the average of five samples tested in each case. Report standard deviations of values in addition to averages. Condition and test samples in atmosphere of 73 (plus or minus 3) degrees F and 50 (plus or minus 10) percent relative humidity, except where other test conditions are specified.
 1. Tensile strength, per ASTM D 638. Die IV-: 2000 psi, minimum
 2. Ultimate elongation, per ASTM D 638. Die IV: 350 percent, minimum
 3. Tear resistance, per ASTM D 624. Die B: 350 pounds per inch of thickness, minimum
 4. Stiffness in flexure, samples reduced to 1/8-inch thickness, per ASTM D 747. 1/4" span: 600 psi. minimum
 5. Low temperature brittleness samples reduced to 1/8-inch thickness, per ASTM D 746: no cracking, chipping, or sign of failure at minus 35 degrees F
 6. Accelerated Extraction, samples reduced to 1/8-inch thickness, per Corps of Engineers CRDC-572: tensile strength, per ASTM D 412. Die C 1750 psi. minimum; ultimate elongation, per ASTM D 412. Die C: 300 percent, minimum.
 7. Effect of Alkali, samples reduced to 1/8-inch thickness, per Corps of Engineers CRDC-572: Change in weight. 7 days: minus 0.10 to plus 0.25 percent; Change in weight. 30 days minus

0.10 to plus 0 25 percent; Change in hardness. 7 days. per ASTM D 2240. Shore A-2: plus or minus 5 points; Change in thickness. 30 days: plus or minus 1.0 percent.

8. Tensile strength of samples taken across site-made and factory-made splices, per ASTM D 638 Die I \1000 psi. minimum
- C. Waterstop Grout: Where indicated on the drawings, provide continuous Waterstop Grout (Internal or External type as recommend by the manufacturer) and Waterstop Treatment system as manufactured by Kryton International Inc. or equal product accepted by the MBTA.
- D. Vapor Barrier/Retarder: Vapor Retarder: Minimum 15 mil polyethylene.
- E. Membrane Curing Compound: ASTM C 309, Type 1. Product used shall be shown to be compatible with the later application of coatings. Curing compound shall not be used on any floor slab scheduled to receive an adhered floor finish.
- F. Membrane Curing Compound for Architectural Concrete: Liquid membrane curing compound complying with AASHTO M148, Type 1D, except Type 2 if required to control temperature of mass concrete and hot weather concrete.
- G. Sheet Curing Materials: Waterproof paper (regular or white), polyethylene film (clear or opaque white), and white burlap-polyethylene sheet complying with AASHTO M171.
- H. Chemical Hardener: All exposed concrete floor slabs shall be hardened with three applications of fluosilicate chemical hardener followed by two applications of clear acrylic concrete sealer by Sonneborn Division, ChemRex Inc. "Lapidolith"; or equal products by W.R. Meadows Co. and Concrete Service Material Company or other manufacturers.
- I. Penetrating Sealer: Monomeric alkyalkoxy silane sealer which has demonstrated penetrability into dry low permeability concrete to a minimum of 1/4". Sealer shall have 20 to 25 percent solids when used on walls, and 40 to 50 percent solids when used on floors.
- J. Epoxy Bonding Compound: ASTM C881, Type V for load bearing applications, Grade 1 Class A (if placement temperature is below 40F); Class B (if placement temperature is above 60F). Provide Grade 1 or 2 for horizontal surfaces and Grade 3 for vertical surfaces.
- K. Epoxy Membrane Curing Compound/Concrete Sealer: The two- component, epoxy resin system shall act as a dual purpose material: A membrane compound for curing alone, plus a penetrating sealer. It shall provide protection for concrete exposed to de-icing salts, commercial acids and alkalis, gasoline, diesel fuel, and oil, and exposure to freeze/thaw cycles and to vehicular traffic. The epoxy resin compound shall be furnished in two components for combining immediately prior to use in accordance with the manufacturer's written instructions as specified herein. The components of the epoxy resin system shall conform to the following requirements.
 1. Component A: Poly (2 hydroxypropylene, P'p, isopropylidenephenolate) condensed with 1 chlorepropoxirane such that the ox content is 4% in aralkyl and hydroxylated solvents. Component B: The amido amine condensate of the Diels Alder adduct of polyunsaturated acids dissolved in suitable solvents. Ratio of components (A to B): 1:1 by volume.
 2. Properties of Mixed Material:
 - a. Viscosity: 75 to 125 cP's at 75°F
 - b. Pot Life: 8 hours minimum at 75°F

- c. Minimum Solids Content: 40 to 44% by weight
 - d. Recoat Time: 24 hours maximum
 - e. Dry Film Thickness: 2 to 3 mils per coat
 - f. Color: Clear, White tint, gray tint
3. Properties of Cured Material:
- a. The cured system shall exhibit no evidence of amine blushing or sweating which may inhibit bond of subsequent coats.
 - b. When tested according to ASTM D 968, specimens of coating cured for 14 days at 75°F shall exhibit an abrasion coefficient of at least 30 liters per mil.
 - c. When tested according to ASTM D 522, a 2 mil dry film thickness specimen cured for 14 days at 75° shall exceed 12% elongation when tested on the 1/4" mandrel.
 - d. Specimens cured for 14 days at 75°F and immersed for 48 hours shall exhibit less than 1% water absorption by weight.
 - e. Water Retentivity shall not exceed 0.055 grams per square centimeter when tested according to ASTM C 156.
- L. Compressible Filler: Closed Cell Foam Filler per MassDOT "Supplemental Specifications to the 1988 English Standard Specifications for Highways and Bridges and the 1995 Metric Standard Specifications for Highways and Bridges"

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine all work prepared by others to receive work of this Section. Commencement of work shall be construed as complete acceptance of preparatory work by others.
 - 1. Hold Point-A pre-placement inspection shall be performed by the DB Entity prior to placing concrete to assure that placement prerequisites have been accomplished.

3.2 HANDLING, STORAGE, AND PROTECTION OF MATERIALS

- A. Handle and store materials separately in such manner as to prevent intrusion of foreign matter, segregation, or deterioration. Do not use foreign materials or those containing ice. Remove improper and rejected materials immediately from point of use. Cover materials, including steel reinforcement and accessories, during construction period. Stockpile concrete constituents properly to assure uniformity throughout project.

3.3 ERECTION OF FORMWORK, SHORING AND RESHORING

- A. Set and maintain formwork to insure complete concrete work within tolerance limits listed in ACI 347 latest edition, "Recommended Practice for Concrete Formwork", and with following additional requirements:
 - 1. Maximum variations from plumb:

- a. In surfaces of columns, walls and beams:
 - 1. In any 10' of length: 1/4"
 - 2. Maximum for entire length: 1/2"
 - 2. Maximum variations from established position in plan required by design:
 - a. Column: 1/2"
 - b. Walls: 3/4"
 - 3. Variations in cross-sectional dimensions of columns and beams and in thickness of slabs and walls.
 - a. Minus: 1/8"
 - b. Plus: 1/4"
- B. Before form materials can be re-used, surfaces that shall be in contact with freshly cast concrete shall be thoroughly cleaned, damaged areas repaired and projecting nails withdrawn, as required in accordance with ACI 301 to return forms to acceptable surface condition. Re-use of form material shall be subject to acceptance by MBTA.
- C. Construct formwork so concrete members and structures are of size, shape, alignment, elevation, and position indicated, within tolerance limits of Article 1.4-I.

3.4 PLACING OF REINFORCEMENT

- A. Reinforcement shall be placed in accordance with requirements of CRSI 93, "Recommended Practice for Placing Reinforcing Bars" and CRSI 93, "Recommended Practice for Placing Bar Supports" and with further requirements below.
- B. Reinforcement shall be accurately placed as required by design and shall be firmly secured in position by wire ties, chairs, spacers, and hangers, each of type accepted by MBTA.
- C. Bending, welding or cutting reinforcement in field in any manner, is prohibited, unless specific approval for each case is given by MBTA.
- D. Reinforcement shall be continuous through construction joints unless otherwise required by design.
- E. Reinforcement shall be spliced only in accordance with requirements of the design. Splices of reinforcement at points of maximum stress shall generally be avoided. Welded wire fabric shall lap six inches or one space plus two inches whichever is larger, and shall be wired together.
- F. Hold Point - Before concrete is cast, check all reinforcement after it is placed to insure that reinforcement conforms requirements of the design and accepted Design Documents. The MBTA shall be notified at least 36 hours prior to concrete placement and given opportunity to inspect completed reinforcement and formwork before concrete placement. Prior acceptance of shop drawings shall in no way limit MBTA's right to demand modifications or additions to reinforcement or accessories.

3.5 JOINTS

- A. Construction and control joints required by design are mandatory and shall not be omitted.

- B. Joints not required by design shall be placed to least impair strength of structure and shall be subject to acceptance of MBTA.
- C. Waterstops:
1. Protect waterstop from oil, dirt, concrete spatter, and damage, and leave clean to receive concrete forms. Exercise care during installation of waterstop to eliminate all possibilities that may cause leakage. Ensure reinforcing bars and slip dowels shall not interfere with positioning of waterstop during Installation.
 2. Install waterstops in accordance with manufacturer's recommendations and as indicated. Hold waterstops rigidly in place by extending through slots in keyways, by spilt bulkheads, by tying to reinforcing bars, or by such other adequate methods as are necessary to insure proper support and embedment during the concreting process. Secure waterstop between the last rib and the end of the waterstop when tying to reinforcing rods. Tie waterstop to reinforcing bars every 12 inches.
 3. Install waterstop so that half of the ribs of the waterstop material are embedded in the concrete on each side of the joint. When installed in an expansion joint, exercise care in pouring so that the closed hollow center-bulb remains in the gap between the first and second pour, to allow for maximum elongation with minimum stress on the portion of the waterstop embedded in the concrete.
 4. Install expansion joint material and a sealant in the joint, as indicated, to prevent foreign matter from accumulating in the joint area. When a sealant is used place a separator between the sealant and the waterstop to insure that both the waterstop and sealant best perform their respective functions.
 5. Sweep horizontal joints prior to pour to insure that foreign matter does not interfere with direct contact between the waterstop and concrete.
 6. Systematically and thoroughly vibrate concrete around waterstop to avoid honeycombs and voids in the concrete and to insure complete contact of waterstop to concrete.
 7. For the second pour on horizontal sections, secure waterstops to forms and/or reinforcing bars to prevent excessive movement of the waterstop and to provide positive insurance against honeycombing or voids. Use a thicker waterstop, 3/8" or 1/2", for heavy pour or larger aggregate.
 8. Where using split-ribbed waterstop spread open the split leg of the waterstop and nail it to the bulkhead between the last two ribs. Upon completion of the first pour and removal of the bulkhead, join the split leg together every 12" with hog rings and position it for the second pour.
 9. PVC waterstop may be butt-spliced on the job with an electrical splicing iron or a hot air welding gun and vinyl welding rod in accordance with the manufacturer's instructions.
 10. Do not drive nails through center of waterstop. Do not lap waterstop, splice joints. Do not embed center bulb in concrete. Position it in the center of the joint to insure freedom of movement. Do not secure waterstop except between the last rib and the end of the waterstop when tying to the reinforcing rod to hold in place for the pour. Where using split-ribbed waterstop, do not nail split legs to bulkhead adjacent to bulb.
- D. Integral Waterproofing System (Crystalline Admixture, Waterstop Grout and Waterstop Treatment):
1. The Waterstop System, consisting of Waterstop Grout and Waterstop Treatment, shall be installed in all non-moving construction joints and shrinkage control joints, according to the applicable manufacturer written instructions of Waterstop System.

2. All pipe penetrations shall be treated as per the crystalline admixture manufacturer's recommendations.
3. After completion of pour, all tie-holes shall be treated as per the admixture manufacturer's recommendations. Application Instruction 5.31 — Waterproofing Tie Holes and Concrete Defects.
4. Follow the manufacturer's recommendations for storage and handling.

3.6 INSTALLATION OF EMBEDDED ITEMS

- A. Conform to requirements of ACI 318, paragraph 6.3, "Conduits and Pipes Embedded in Concrete", and as specified below.
- B. Install galvanized steel sleeves, galvanized embedded wall plates and similar items, furnished by other trades, at locations shown on the drawings.
- C. Anchor bolts for column baseplates shall be galvanized and installed with templates provided.
 1. Vertical alignment shall be maintained within one-sixteenth inches of the elevations shown on the Contract Drawings.
 2. Horizontal alignment shall be maintained within one-eighth inches of the locations shown on the Contract Drawings.
 3. Verify depth of embedment and bolt projection prior to placement of concrete.
 4. Inspection shall be performed by a surveyor licensed in the Commonwealth of Massachusetts. Certify compliance with shop drawings.
- D. Temperature Sensors for Mass Concrete
 1. Install temperature sensors for each mass concrete placement as outlined in the Temperature Control Plan specified in Article 1.3B.3 of this Section.
 2. Furnish to the MBTA 8 1/2 x 11" record sketches showing dimensional temperature sensor locations in plan and section.

3.7 MIXING, CONSISTENCY, AND DELIVERY OF CONCRETE

- A. Concrete shall be ready-mixed, produced by plant acceptable to MBTA. Hand or site mixing shall not be done. Constituents, including admixtures except certain corrosion inhibitors and superplasticizers, shall be batched at central batch plant. Admixtures shall be premixed in solution form and dispensed as recommended by manufacturer.
- B. Central plant and rolling stock equipment and methods shall conform to Truck Mixer and Agitator Standard of Truck Mixer Manufacturer's Bureau of National Ready-Mixed Concrete Association, and Contract Documents. Consistency of concrete at time of deposit shall be as per Article 2.2.
- C. Ready mixed concrete shall be transported to site in watertight agitator or mixer trucks loaded not in excess of rated capacities. Discharge at site shall be within one and one-half hours after cement was first introduced into mix. Discard concrete not discharged within one and one-half hours and dispose of legally. Concrete with a temperature greater than 80 degrees F shall require the implementation of Hot Weather Placement Plan (per ACI 305). Central mixed concrete shall be plant mixed a minimum of five minutes. Agitation shall begin immediately after premixed concrete is placed in truck and shall

continue without interruption until discharged. Transit mixed concrete shall be mixed at mixing speed for at least ten minutes immediately after charging truck followed by agitation without interruption until discharged. Concrete shall be furnished by a single plant unless accepted by the MBTA in writing.

- D. Retempering of concrete which has partially hardened, that is, mixing with or without additional cement, aggregates, or water, shall not be permitted.
- E. The DB Entity shall determine the infield delivered un-cured fresh unit weight of all Lightweight concrete prior to placement and compare this value to that determined from the trail mix results. If infield un-cured fresh unit weight is not within plus or minus 2 percent of the trail mix results the concrete shall be rejected and not used in construction.

3.8 PLACING CONCRETE

- A. No concrete shall be placed until forms, reinforcing steel, pipes, conduits, sleeves, hangers, anchors, inserts, reglets, and other work required to be built into the concrete have been properly installed. Do not schedule concrete placements without prior acceptance of the MBTA.
- B. Remove water and foreign matter from forms and excavations and, except in freezing weather or as otherwise directed, thoroughly wet wood forms just prior to placing concrete. Place no concrete on frozen soil and provide adequate protection against frost action during freezing weather.
- C. Before placing concrete, verify that subgrade preparation, installation of formwork, reinforcement, and embedded items is complete, and that required inspections have been performed. Concrete placement shall not proceed until the required inspection has verified the work related to subgrade preparation, formwork, reinforcing, embedded items, and other related work has been performed satisfactorily.
- D. To secure full bond at construction joints, surfaces of concrete already placed, including vertical and inclined surfaces, shall be thoroughly cleaned of foreign materials and laitance. Provide standard shear key-way or roughen surface to ¼" minimum amplitude with suitable tools such as chipping hammers or bush-hammer, and re-cleaned by stream of water or compressed air. Alternatively for horizontal construction joints above grade, the DB Entity may use the natural roughness at top of pour within forms provided wall surface are patched to the satisfaction of the MBTA.
- E. Do not place concrete having slump outside of allowable slump range.
- F. Do not add water to concrete during delivery, at Project site, or during placement, unless accepted in writing by the MBTA. Only water withheld at the batching plant shall be added at the Project site upon the acceptance of the MBTA. No other water may be added.
- G. Do not add water to concrete after adding high-range water-reducing admixtures to mix.
- H. Transport concrete from mixer to place of final deposit as rapidly as practical by methods which prevent separation of ingredients and displacement of reinforcement, and which avoid rehandling. Deposit no partially hardened concrete. When concrete is conveyed by chutes, equipment shall be of such size and U-shaped design as to insure continuous flow in chute. Flat (coal) chutes shall not be employed. Chutes shall be of metal or metal lined and different portions shall have approximately same slope. Slope shall not be less than 25 degrees nor more than 45 degrees from horizontal and shall be such as to prevent segregation of ingredients. Discharge end of chute shall be provided with baffle plate or spout to prevent segregation. If discharge end of chute is more than five feet above

surface of concrete in forms, spout shall be used, and lower and maintained as near surface of deposit as practicable. When operation is intermittent, chute shall discharge into hopper. Chute shall be thoroughly cleaned before and after each run and debris and any water used shall be discharged outside forms. Concrete shall not be allowed to flow horizontally over distances exceeding five feet.

- I. Concrete shall be placed in such manner as to prevent segregation, and accumulations of hardened concrete on forms or reinforcement above mass of concrete being placed. To achieve this end, suitable hoppers, spouts with restricted outlets and tremies shall be used as required.
- J. During and immediately after depositing, concrete shall be thoroughly compacted by means of internal type mechanical vibrators or other tools, or by spading to produce required quality of finish. Vibration shall be done by experienced operators under close supervision and shall be carried on only enough to produce homogeneity and optimum consolidation without permitting segregation of constituents or "pumping" of air. Vibrators used for normal weight concrete shall operate at speed at not less than 7,000 vpm and be of suitable capacity. Do not use vibrators to move concrete. Vibration shall be supplemented by proper wooden spade puddling to remove included bubbles and honeycomb adjacent to visible surfaces. At least one active vibrator shall be on hand for every 10 cubic yards of concrete placed per hour, plus one spare vibrator in addition to the active vibrators. Vibrators shall be operable and on site prior to starting placement.
- K. Vertical lifts shall not exceed 18"es. Vibrate completely through successive lifts to avoid pour lines. Vibrate first lift thoroughly until top of lift glistens to avoid stone pockets, honeycomb, and segregation.
- L. Concrete shall be deposited continuously, and in layers of such thickness that no concrete shall be deposited on concrete which has hardened sufficiently to cause formation of seams and planes of weakness within section. If section cannot be placed continuously between planned construction joints, as specified, field joint and additional reinforcement shall be introduced so as to preserve structural continuity. MBTA shall be notified in any such case.
- M. Deposit and consolidate concrete for floors, slabs, and toppings in a continuous operation, within limits of construction joints, until placement of a panel or section is complete.
 - 1. Consolidate concrete during placement operations so concrete is thoroughly worked around reinforcement and other embedded items and into corners.
 - 2. Maintain reinforcement in position on chairs during concrete placement.
 - 3. Screed slab surfaces with a straightedge and strike off to correct elevations. Place concrete at mid-span of beams and girders prior to placement at the member supports. The slab thicknesses are theoretical minimum thicknesses, which shall be maintained.
 - 4. Slope surfaces uniformly to drains where required.
 - 5. Begin initial floating to form a uniform and open-textured surface plane, free of humps or hollows, before excess moisture or bleed water appears on the surface. Do not further disturb slab surfaces before starting finishing operations.
- N. Cold joints, particularly in exposed concrete, including "honeycomb", are unacceptable. If they occur in concrete surfaces exposed to view, MBTA shall require that entire section in which blemish occurs be removed and replaced with new materials at DB Entity's expense.
- O. When placing exposed concrete walls or columns, strike corners of forms rapidly and repeatedly from outside along full height while depositing concrete and vibrating.

- P. Chutes, hoppers, spouts, adjacent work, etc. shall be thoroughly cleaned before and after each run and water and debris shall be discharged outside form.

3.9 HOT WEATHER CONCRETE PLACEMENT

- A. The DB Entity shall be adequately prepared to protect the concrete from the adverse influence of hot weather before the placement of any concrete may begin. Placement of concrete when the air temperature exceeds 80° F, particularly when the work is exposed to direct sunlight, shall be done taking special precautions to avoid cracking of the concrete from rapid drying or setting. The concrete shall be placed in accordance with ACI 305, "Hot Weather Concreting" when hot-weather conditions exist.
- B. Cool ingredients before mixing to maintain concrete temperature below 90° F at time of placement. Chilled mixing water or chopped ice may be used to control temperature, provided water equivalent of ice is calculated into the total amount of mixing water.
- C. Cover steel reinforcement with water-soaked burlap so steel temperature shall not exceed ambient air temperature immediately before embedding in concrete.
- D. Fog-spray forms, steel reinforcement, and subgrade just before placing concrete. The temperature of the forms shall not exceed 100° F. Keep subgrade moisture uniform without standing water, soft spots, or dry areas.
- E. If requested by the DB Entity, deemed advisable by the Testing Agency, and accepted by the MBTA, a retardant may be used to delay the initial set of the concrete.
- F. Concrete shall be placed at a sufficient rate that cold joints are not formed by the rapid set of concrete.
- G. Moist curing shall be applied as soon as possible after placement to inhibit the development of shrinkage cracks due to the rapid drying of the surface.
- H. The specified requirements for curing shall be strictly adhered to.
- I. When high temperatures, low humidity and dry winds create conditions which may produce plastic cracking (when the rate of evaporation exceeds 2 lbs. per sf. per hr.), the evaporation retarder specified may be required to be applied by spray one or more times during the finishing operation. Placing under these conditions should be reviewed by the Testing Agency prior to placing any concrete.

3.10 COLD WEATHER CONCRETE PLACEMENT

- A. The DB Entity shall be adequately prepared to protect the concrete from the adverse influence of cold weather before the placement of any concrete may begin. Protect concrete work from physical damage or reduced strength that could be caused by frost, freezing actions, or low temperatures. The concrete shall be placed in accordance with ACI 306, "Cold Weather Concreting" when cold-weather conditions exist.
- B. When the average daily temperature falls below 50° F, special precautions shall be taken to assure adequate strength gain of the concrete.
- C. When air temperature has fallen to or is expected to fall below 40° F, uniformly heat water and aggregates before mixing to obtain a concrete mixture temperature of not less than 50°F and not more

than 80° F at point of placement. The forms shall be prewarmed to at least 40° F to prevent the rapid cooling of the concrete by their contact, and shall be free of all ice and snow.

- D. When heated materials are being used the water shall be combined with the aggregate in the mixer and the resulting temperature shall be below 90° F before cement is added to the mix.
- E. Do not use frozen materials or materials containing ice or snow. Do not place concrete on frozen subgrade or on subgrade containing frozen materials.
- F. Do not use calcium chloride, salt, or other materials containing antifreeze agents or chemical accelerators, unless otherwise specified and approved in mix designs.
- G. After placement all concrete shall be maintained at a temperature of 50° F for at least seven days. If high early strength concrete is used, this time requirement may be reduced to three days.
- H. All concrete shall be protected by the use of heated enclosures, which must be sufficiently strong and wind proof and within which adequate heaters are properly distributed to maintain all concrete at the required temperatures. Heaters shall not be allowed to locally heat or dry the concrete. Adequate fire precautions shall be maintained and sufficient ventilation shall be provided to dissipate the building of carbon dioxide or other gases detrimental to the development of strength and hardness at the exposed surface(s).
- I. Only the specified non-corrosive, non-chloride accelerator may be used. Calcium chloride, thiocyanates, or admixtures containing more than 0.05% chloride ions are not permitted.

3.11 MASS CONCRETE PLACEMENT

- A. Mass Concrete shall be placed in accordance with ACI 207.1 “Guide to Mass Concrete”.
 - 1. Temperature of concrete at time of placement is limited to a maximum of 85 degrees F.
 - 2. A combination of the mix design, components in the mix, methods of pre-cooling and post-cooling, if employed, and surface insulation, if used, shall limit the maximum concrete temperature and also the maximum temperature differential between any point in the interior of the concrete element and any surface of the concrete element, thereby preventing cracking.
 - 3. During the period following placing the concrete, the temperature differential between interior and surface shall be limited to a maximum of 35 degrees F unless an analysis submitted under the Temperature Control Plan, required under Article 1.3.B.3 of this Section demonstrates through calculation that the element is sufficiently reinforced to prevent crack widths in excess of 0.012”es.
 - 4. The maximum allowable temperature (peak heat of hydration) in any portion of the mass concrete shall not exceed 165 degrees F.
 - 5. Mix designs shall achieve the required design strength without unnecessary increase in cement content. Such mix designs may result in slower strength gain than normal and are thus allowed to fall below the required strength test results at 28 Days provided the full strength is reached by 56 Days, and slab spans are not subjected to superimposed loads before the full strength is reached. No individual strength test result shall be below 3200 psi at 28 Days.
 - 6. Pre-cooling may be used to prevent excessive heat build-up caused by heat of hydration. Acceptable means include use of chilled water; providing some mixing water in the form of chipped, shaved, or flaked ice; cooling the aggregate; and cooling the mix with liquid nitrogen.

prior to placing. Ice shall be completely melted in the mix prior to concrete arrival at the jobsite.

7. Post-cooling is acceptable if feasible within the parameters of the construction schedule. Piping within the concrete shall be non-corrosive, non-conductive, non-metallic, and the system shall be submitted for review of the MBTA.
8. Regardless of methods used, install temperature sensing devices within the concrete in each placement as specified in Article 3.6D of this Section. The devices shall operate in the range of 32 degrees F to 212 degrees F with an accuracy of ± 2 degrees F. The temperatures shall be recorded automatically by the DB Entity. Transmit to MBTA daily.
9. Provide adequate concrete delivery and suitable equipment to accomplish mass placements without segregation, and without formation of cold joints.
10. If the 165 degree F maximum allowable temperature or the allowable differential temperature has been exceeded, take immediate action to retard further temperature increases or further growth of the temperature differential.
11. The MBTA may, at its sole discretion, direct that the concrete that has exceeded the temperature limits defined above be removed or otherwise mitigated at no additional cost to the MBTA.

3.12 LIGHTWEIGHT CONCRETE PLACEMENT

1. Lightweight Concrete shall be placed in accordance with the recommendations of ACI 304R and ACI 304.5R "Batching, Mixing, and Job Control of Lightweight Concrete".

3.13 MISCELLANEOUS CONCRETE ITEMS

- A. Filling In: Fill in holes and openings left in concrete structures, unless otherwise required by design, after work of other trades is in place. Mix, place, and cure concrete, as specified, to blend with in-place construction. Provide other miscellaneous concrete filling indicated or required to complete Work.
- B. Curbs: Provide monolithic finish to curbs by stripping forms while concrete is still green and by steel-troweling surfaces to a hard, dense finish with corners, intersections, and terminations slightly rounded.
- C. Equipment Bases and Foundations: Provide machine and equipment bases and foundations. Set anchor bolts for machines and equipment at correct elevations, complying with diagrams or templates of manufacturer furnishing machines and Equipment.
- D. Steel Pan Stairs: Provide concrete fill for steel pan stair treads, landings, and associated items. Cast-in inserts and accessories as required by design. Screeds, tamps, and provide slip-resistant aggregate finish.

3.14 FINISHING OF UNFORMED CONCRETE SURFACES

- A. General: Comply with ACI 302.1R recommendations for screeding, restraightening, and finishing operations for concrete surfaces. Do not wet concrete surfaces.
- B. Scratch Finish: While still plastic, texture concrete surface that has been screened and bull-floated or darbied. Use stiff brushes, brooms, or rakes to produce a profile amplitude of 1/4" in 1 direction.

1. Revise locations of scratch finish in subparagraph below to suit Project.
 2. Apply scratch finish to surfaces to receive mortar setting beds for bonded cementitious floor finishes.
- C. Float Finish: Consolidate surface with power-driven floats or by hand floating if area is small or inaccessible to power driven floats. Restraighten, cut down high spots, and fill low spots. Repeat float passes and re-straightening until surface is left with a uniform, smooth, granular texture.
1. Revise locations of float finish in subparagraph below to suit Project.
 2. Apply float finish to surfaces to receive trowel finish and where concrete flatwork is to receive waterproofing membranes or setting beds for finished materials.
- D. Trowel Finish: After applying float finish, apply first troweling and consolidate concrete by hand or power-driven trowel. Continue troweling passes and restraighten until surface is free of trowel marks and uniform in texture and appearance. Grind smooth any surface defects that would telegraph through applied coatings or floor coverings.
1. Revise locations of trowel finish in first subparagraph below to suit Project.
 2. Apply a trowel finish to all concrete surfaces unless noted otherwise.
 3. Finish surfaces to the following tolerances, according to ASTM E 1155, for a randomly trafficked floor surface:
 - a. Revise surface plane tolerances to suit Project. See Evaluations for description of F-number system. ACI 301 suggests that all residential floors and nonresidential floors less than 10,000 sq. ft. (929 sq. m) be measured by straightedge method and that other nonresidential floors be measured by F-number system.
 - b. Select floor flatness and levelness values required for Project from four subparagraphs below, or revise values to suit type of floor. ACI 302.1R suggests values in first subparagraph be used for carpeted slabs; those in second and third, for thin floor coverings; and those in fourth, for very flat floors for high-speed forklifts, air pallets, and ice and roller rinks.
 - c. Specified overall values of flatness, F(F) 35; and of levelness, F(L) 25; with minimum local values of flatness, F(F) 27; and of levelness, F(L) 20; for slabs-on-grade.
 4. Retain straightedge method in subparagraph below if deleting F-number system above.
 5. Finish and measure surface so gap at any point between concrete surface and an unleveled, freestanding, 10' long straightedge resting on 2 high spots and placed anywhere on the surface does not exceed 1/4".
- E. Broom Finish: Apply a broom finish to exterior concrete platforms, steps, and ramps, and elsewhere as indicated.
1. Immediately after float finishing, slightly roughen trafficked surface by brooming with fiber-bristle broom perpendicular to main traffic route. Coordinate required final finish with MBTA before application.
- F. Slip-Resistive Finish: Before final floating, apply slip-resistive aluminum granule finish where indicated and to concrete stair treads, platforms, and ramps. Apply according to manufacturer's written instructions and as follows:

1. Uniformly spread 25 lb/100 sq. ft. of dampened slip-resistive aluminum granules over surface in 1 or 2 applications. Tamp aggregate flush with surface, but do not force below surface.
2. After broadcasting and tamping, apply float finish.
3. After curing, lightly work surface with a steel wire brush or an abrasive stone and water to expose slip-resistive aluminum granules.

3.15 REPAIRING OF UNFORMED CONCRETE SURFACES

- A. Repairs of concrete surfaces are not allowed below 40 degrees F without proper preheating of materials and substrate. Concrete repairs below 40 degrees F shall be allowed only if the repair material temperatures are maintained per manufacturer's recommendations and if the substrate is tented and pre-conditioned to 40 degrees F and rising.
- B. Tops of slabs and walls shall be repaired by using either same material as originally cast or by use of dry-pack material, as accepted by MBTA. Areas affected shall be chipped back square and to depth of one inch minimum. Hole shall then be moistened with water for a minimum of two hours, followed by brush coat of 1/16 inch thick cement paste. Immediately plug hole with concrete, or with dry pack material consisting of 1:1.5 mixture of cement and concrete sand mixed slightly damp to touch. Hammer dry-pack into hole until dense, and excess paste appears on surface. Finish patch flush and to same texture as surrounding concrete. For large repairs employ 1-1-2 mixture of cement, concrete sand and pea gravel at same dry-pack consistency.

3.16 CURING, SEALING AND PROTECTION

- A. When concrete is placed at or below ambient air temperatures of 40 degrees F. or whenever in opinion of MBTA, such or lower temperatures are likely to occur within 48 hours after placement of concrete, cold weather concreting procedures, according to ACI 306 and as specified herein, shall be followed. To this end, entire area affected shall be protected by adequate housing or covering, and heating. No salt, chemicals or other foreign materials shall be used in the mix to lower freezing point of concrete.
- B. Protect concrete work against injury from heat, cold, and defacement of any nature during construction operations.
- C. Concrete shall be treated and protected immediately after concreting or cement finishing is completed, to provide continuous moist curing above 50 degrees F. for at least seven days, regardless of ambient air temperatures.
- D. Curing compounds shall not be permitted for slab and beams.
- E. Keep permanent temperature record showing date and outside temperature for concreting operations. Thermometer readings shall be taken at start of work in morning, at noon, and again late in afternoon. Locations of concrete placed during such periods shall likewise be recorded, in such manner as to show any effect temperatures may have had on construction. Copies of temperature record shall be distributed daily to MBTA.
- F. Epoxy Curing Compounds/Hardener:
 1. Apply the first coat of epoxy to the plastic concrete as soon as the bleed water has totally disappeared. This application shall serve a dual function: a membrane curing compound which

shall retain 95% or more of the mixing water in the concrete for a minimum of seven days; and the first coat of a two-coat system to seal and protect the concrete.

2. After a minimum curing period of 30 days and before the structure is opened to general use, wash the concrete with cleaning and degreasing chemical solution applied in accordance with the manufacturer's instructions and as specified herein.
 3. Prepare the cleaning solution in accordance with the manufacturer's instructions. Dampen concrete surface with water. Apply the prepared solution over the area to be cleaned using a soft fibered but densely filled brush. Allow the solution to remain on the surface for 3 to 5 minutes. Reapply the cleaning solution and scrub vigorously. Rinse with fresh water applied at a pressure of 400-800 psi and a volume of water per minute 5 - 10 gallons. Protect all non-masonry surfaces.
 4. Allow concrete to dry a minimum of 24 hours and a maximum of 48 hours before application of the second coat of epoxy.
 5. Pour equal quantities of Components 'A' and 'B' into a clean container. Mix thoroughly with a low speed electric drill equipped with a steel paddle. Keep individual components and mixed compound covered when material is not being used.
 6. Application: Apply mixed epoxy compound in a uniform coat at the rate of approximately 200 sq. ft. per gallon. Mixed material may be sprayed with any equipment capable of spraying epoxy compounds, or it may be applied with a deep nap lamb's wool roller.
 7. Protect surface against vehicular and pedestrian traffic during curing period (24 hours at 75°F).
 8. Final Coat - Broom Finish and Wood Float Finish: Concrete is totally sealed against contaminants and resists the attack of de-icing chemicals. It may be applied at any time after the concrete has cured a minimum of 30 days and before the structure is opened to general use. Apply the epoxy compound by spray or roller at the rate of 275 to 325 sq. ft. per gallon being careful to avoid puddles or uneven application. The concrete shall exhibit a uniform gloss indicating it is totally sealed. Any areas that are dull or flat are not totally sealed. Any areas that are dull or flat are not totally sealed and shall be given a third coat.
 9. Final Coat - Steel Trowel Finish Concrete: Apply the second and final coat at any time after the concrete has cured a minimum of 30 days and before the structure is opened to general use. Apply mixed epoxy compound in a uniform coat at a rate not to exceed 200 sq. ft. per gallon. While the epoxy compound is still liquid, drop fine sand meeting the gradation requirements of ASTM C-109, vertically into the epoxy at a uniform rate of one lb. per sq. ft. Make sure entire epoxy surface is thoroughly covered. After epoxy has hardened so that it cannot be dented with a screwdriver, remove excess sand.
- G. Concrete Sealer: Apply to bridge copings, beam sets, parapets, vehicle barriers, boatwalls portal flank walls and other concrete surfaces as required. Apply in accordance with manufacturer's instructions and the following:
1. Application of the sealer shall not alter the surface texture and shall be compatible with the use of surface finish coatings and caulking. Surface shall dry to a tack-free condition in 4 hours or less.
 2. Preparation process shall not cause any undue damage to the concrete surface, remove or alter the existing surface finish, or expose the coarse aggregate of the concrete.
 3. Concrete sealer shall be used as supplied by the manufacturer and not altered in any way. Apply onto concrete surfaces at manufacturer's recommended rate of coverage.

4. Prevent the concrete sealer from coming in contact with open joints that have not yet been filled with joint sealant, so as to prevent any loss of bond of the joint sealant.

3.17 REMOVAL OF FORMWORK, SHORING AND RESHORING

- A. DB Entity shall be responsible for proper removal of formwork, shoring, and reshoring.
- B. Forms shall be removed only after concrete has attained sufficient strength to support its own weight, construction loads to be placed thereon and lateral loads, without damage to structure or excessive deflection.
- C. Forms and falsework shall not be removed unless the concrete has attained the minimum percentage compressive strength as listed in the following table:

<u>Structural Member</u>	<u>Minimum Percent of Design Strength (f'c)</u>
1. Invert Slabs; Slabs and Beams on Grade	25
2. Free Standing Walls, Columns and Piers	40
3. Retaining Walls	50
4. Soffits of Beams, Slabs and Girders Less Than 20' Span	80
5. Stairs	80
6. Soffits of Beams, Slabs and Girders Greater Than 20' Span	90
7. Cantilevered Beams, Slabs and Girders	90

- D. Acceptance for form removal shall be based on field-cured concrete cylinders tested by the MBTA Lab.
- E. Clean and repair surfaces of forms to be reused in the Work. Do not use split, frayed, delaminated, or otherwise damaged form-facing material. Apply new form-release agent.
- F. When forms are reused, clean surfaces, remove fins and laitance, and tighten to close joints. Align and secure joints to avoid offsets. Do not use patched forms for architectural concrete surfaces.
- G. Fabricate forms for easy removal without hammering or prying against concrete surfaces. Provide crush or wrecking plates where stripping may damage cast-in-place surfaces. Provide top forms for inclined surfaces steeper than 1.5 horizontal to 1 vertical. Kerf wood rustications, keyways, reglets, recesses, and the like, for easy removal.
 1. Seal form joints and penetrations at form ties with form joint tape or form joint sealant to prevent cement paste leakage with eased edge on internal corners.
 2. Do not use rust-stained steel form-facing material.

3.18 REPAIRING AND FINISHING OF FORMED CONCRETE SURFACES

- A. In accordance with the provisions of ACI 301, Chapter 10, all concrete shall have "smooth form finish".

- B. Intent of this Specification is to require forms, mixtures of concrete, and workmanship so that concrete surfaces shall require no patching, except for plugging of tie holes. However, where patching is acceptable to MBTA, procedure described below shall be followed.
- C. Defective concrete and honeycombed areas shall not be patched unless examined and acceptance is given by MBTA. If such acceptance is received by DB Entity, areas involved shall be chipped down square and at least one inch deep to sound concrete by means of cold chisels or pneumatic chipping hammers. If honeycomb exists around reinforcement, chip to provide clear space at least three-quarter inch wide all around steel to afford proper ultimate bond thereto. For areas less than one and one-half inches deep, patch shall be made in same manner as described above for filling unformed concrete surfaces, care being exercised to use crumbly-dry (nontrowelable) mixtures and to avoid sagging. Thicker repairs shall require build-up in successive days, each layer being applied as described. To aid strength and bonding of multiple layer repairs, non-shrink, non-metallic aggregate shall be used as an additive to the mixture in proportions as follows:

Materials	Volumes (proportions)	Weights (proportions)
Cement	1.0	1.0
Non-Metallic Aggregate	0.15	0.25
Sand	1.5	1.55

For very heavy (generally, formed) patches, pea gravel may be added to mixture and proportions modified as follows:

Materials	Volumes (proportions)	Weights (proportions)
Cement	1.0	1.0
Non-Metallic Aggregate	0.2	0.33
Sand	1.0	1.0
Pea Gravel	1.5	1.55

- D. After hardening, rub lightly as described above for form tie holes.
1. Mortar for patching shall be same mix as above except aggregate shall pass a No. 14 sieve.
 2. For all concrete to receive "smooth" finish, remove formwork fins and clean entire surface of grease, form oil, laitance, dust, and other foreign matter.
 3. "Smooth" finish shall consist of having all fins removed, joint marks smoothed off, blemishes removed, and surfaces left smooth and unmarred.
 4. Begin finishing operations as soon as practicable after removal of forms, continue with curing operations after finishing is completed. After concrete has been well cured, carefully inspect surfaces. Remove any fins, rough spots, streaks, hardened mortar or grout and other foreign material. Patch defects with finishing mortar as specified above, to satisfaction of MBTA.
- E. Patches which become crazed, cracked, or sound hollow upon tapping shall be removed and re-placed with new material at DB Entity's expense.

3.19 CLEANING

- A. Concrete surfaces shall be cleaned of objectionable stains as determined by the MBTA. Materials containing acid in any form or methods which shall damage "skin" of concrete surfaces shall not be employed, except where otherwise specified.

END OF SECTION

SECTION 03301

CAST IN PLACE CONCRETE FOR ROADWAY BRIDGES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. Cast-in-place concrete, including formwork, reinforcement, concrete materials, mixture design, placement procedures, and finishes for the roadway bridges and underpasses in the following applications:
 - a. Footings and drilled shaft caps.
 - b. Foundation walls and wingwalls.
 - c. End diaphragms.
 - d. Approach slabs.
 - e. Deck slabs and sidewalks.
 - f. Underpasses (walls, roof slab, base slab)
 - g. Cutting and patching of mechanical and electrical penetrations through cast-in-place concrete.
 - h. Other bridge elements as shown on the Contract Documents.
- B. Related Work:
1. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION.
- C. For Cast-In-Place HP Cement Concrete Deck requirements, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 901, and the following:
1. At least 30 calendar days prior to the proposed start of placing the concrete bridge deck, the DB Entity shall submit to the MBTA for acceptance, a submittal (herein called the Placement and Curing Plan) specifying the method of concrete conveyance, placement, type and number of finishing machines and work bridges, rate of pour, estimated time of completion, screed and rail erection plan, sequence of concrete pours, and the concrete curing procedure. The Placement and Curing Plan shall take into consideration weather conditions. It shall also include details and a complete description of equipment to be used in the handling, placement, finishing and curing the concrete including the number and type of personnel who will be engaged in the operation. The personnel shall consist exclusively of persons with the experience and skill appropriate to their working assignment. acceptance of this plan will not relieve the DB Entity of the responsibility for the satisfactory performance of his/her methods and equipment. The Placement and Curing Plan shall include, but not be limited to, the following:
 - a. Proof of the following minimum operator qualifications for the bridge deck finishing machine(s):

1. Five years' experience operating machines of similar type and manufacturer as that proposed.
 2. Proof of no less than five bridge decks of similar size, placed using a machine of the same manufacturer as that proposed.
 3. Or as a substitute for a. and b., a representative of the manufacturer of the bridge deck finishing machine shall be present on the site a minimum of 24 hours in advance of the proposed deck placement to approve the setup of the machine and rail system, and the representative shall be present for the entire duration of the placement of the deck concrete using the bridge deck finishing machine.
- b. Provisions for consolidation of cement concrete. At least one vibrator shall be in service per each 30 cubic yards per hour of cement concrete placed with at least 2 vibrators in service at all times.
 - c. Curing method. At least two workers shall continuously place wet burlap curing materials from a dedicated work bridge from the start of the deck placement until the deck is completely covered with wet burlap.
 - d. When cold weather is reasonably expected during the 14 day wet curing period, or has occurred within 7 days of anticipated concrete placement, the DB Entity shall include detailed procedures for the production, transporting, placing, provisions for enclosures, protecting, curing, and temperature monitoring of concrete during cold weather, including a plan of heating devices, types and locations around structure.
 - e. Method of monitoring temperature of hardened concrete. The method of monitoring concrete temperatures shall be submitted regardless of whether cold weather is expected during the 14 day wet cure period.
 - f. Letter certifying that the fogging equipment attached to the finishing machine produces atomized water droplets with an average droplet diameter of 0.003 inches (76 μm) or less that are uniformly distributed at a rate of at least 0.10 gallons/square foot/hour.
 - g. Backup systems as required.
2. Before concrete placement operations begin, the DB Entity shall make all necessary arrangements and have all materials on hand for curing and protecting the concrete deck. Concrete placement shall not proceed until all necessary steps have been taken to insure adequate compliance with these Mandatory Specifications and that completion of the operation can be accomplished within the required scheduled time. The DB Entity shall allow sufficient time for inspection. The DB Entity shall review all aspects of the proposed deck slab concrete placement, as documented in the approved Placement and Curing Plan, including, but not limited to, the following:
 - a. Equipment proposed for use and for back-up
 - b. Planned workforce and assigned tasks of each designated position, based on experience and expertise
 - c. Proposed construction techniques
 - d. Safety considerations
 - e. Concrete mix design

- f. Admixtures and performance data; dosage rates shall be as approved
- g. Proposed placement rate, provisions for adverse weather, curing and loading schedules
- h. Curing Practices to be employed as well as the workforce designated to the curing process
- i. Delivery / conveyance equipment, including deck finishing machine setup and operation
- j. Traffic control

3. No concrete shall be placed until the environmental conditions are deemed favorable and satisfactory means to mitigate adverse environmental conditions exist. Favorable environmental conditions are defined as an expected weather forecast suitable for concrete placement during the entire placement duration with an evaporation rate not to exceed 0.15 lbs./ft²/hr, or suitable equipment and appropriate actions are taken to limit the evaporation rate of the exposed concrete surface to less than 0.15 lb/ft²/hr and acceptable curing temperatures are expected for the duration of the curing period.

The DB Entity shall provide any necessary means to mitigate adverse weather conditions and curing temperatures. Failure to maintain acceptable environmental conditions will result in the concrete placement being stopped and a bulkhead put in place. Concrete temperature will be taken from the same sample used for slump and air content tests. These measurements will be taken prior to commencement of concrete placement. If, in the MBTA's opinion, significant changes occur in atmospheric conditions, additional atmospheric measurements and calculations by the DB Entity will be required. The DB Entity will supply all instruments necessary to make the required calculations, will perform the tests, and will document the results on the attached "Bridge Deck Placement Environment" table which shall be submitted to the MBTA.

A trial placement of at least 3 cubic yards using the approved HP Cement Concrete mix design shall be required a minimum of two weeks before the intended date of the deck slab placement. The DB Entity shall demonstrate proper mix design, batching, placement, finishing and curing of the HP Cement Concrete deck slab. The trial placement shall simulate the actual job conditions in all respects including plant conditions, transit equipment, travel conditions, admixtures, forming, placement equipment, and personnel.

If there are problems, the MBTA may require the DB Entity to conduct more trial batches and trial placements. Removal of the trial placement concrete from the job site is the responsibility of the DB Entity.

In addition to the requirements contained herein, all weather and concrete temperature requirements contained in Subsection 901.64 of the MassDOT Standard Specifications shall be satisfied. Cement concrete for bridge decks shall not be placed when the ambient air temperature exceeds 85°F or is expected to exceed 85°F during the placement of the deck. When placing concrete, the DB Entity must provide suitable equipment and take appropriate actions to limit the evaporation rate of the exposed concrete surface to less than 0.15 lb/ft²/hr. The deck surface evaporation rate shall be determined in accordance with the paper "Plastic Cracking of Concrete" by Delmar Bloem for the National Ready Mixed Concrete Association and published in ACI 305R-89. and all data contained in the Bridge Deck Placement Environment table below shall be determined by the DB Entity

prior to and after casting the bridge deck. To maintain the deck surface evaporation rate below 0.15 lb/ft²/hr the DB Entity shall take one or more of the following actions:

- a. Misting the surface of the concrete with pressurized equipment attached to the finishing machine until the curing cover is applied. The water mist shall be distributed at a rate of at least 0.10 gallons/square foot/hour. For example, on a deck that is 30 feet wide, the system must be able to apply at least 3.0 gallons of water per linear foot per hour. The fog spray must be produced from nozzles that produce an atomized fog mist that will maintain a sheen of moisture on the concrete surface without ponding. The atomized water droplets shall have an average droplet diameter of 0.003” or less. The area of coverage from each nozzle shall overlap all adjacent coverage areas by at least 12”. Water that drips from the nozzles shall not be allowed to fall onto the concrete that is being cured.
- b. Reduce the temperature of the concrete.
- c. Reschedule the placement until such time as the environmental conditions are acceptable, such as at night or during early morning hours.

Bridge Deck Placement Environment						
City/Town:				Date:		
Bridge Number:				Contract Number:		
Start Station:				End Station:		
 	Time Measured	Air Temp.	Relative Humidity (%)	Concrete Temp.	Wind Velocity	Evaporation Rate
Prior to Casting						
After Casting						
Signature – DB Entity’s Authorized Representative:				Printed Name:		
Signature – MassDOT Resident Engineer:				Printed Name:		

4. Cement Concrete crack sealing requirements defined herein are for the repair and sealing of cast-in-place cement concrete to prevent water infiltration to the steel reinforcement bars. The width of cracks shall be determined using a width indicating comparator card made of clear plastic with lines of specified width on the cards. The crack width comparator cards shall be held on concrete surfaces to allow the widths of any concrete cracks to be determined by direct visual comparison of the crack width with the widths of the lines marked on the card surface. These cracks are assumed to be non-moving and to have been caused by inadequate control of shrinkage or temperature

stresses during curing. Cracks that are of structural concern shall be repaired by other methods determined by the DB Entity.

All required crack sealing and crack repairs shall be performed by the DB Entity without additional compensation. The DB Entity shall be required to seal cracks even if the environmental conditions during placement and curing satisfied specification requirements.

Cracks shall be sealed after construction movement is substantially stable and before waterproofing, pavement, or other construction covers the cracked surface. Crack sealing materials shall be applied by skilled applicators under a supervisor with proven successful experience in applications with similar scope of work. Crack sealing materials shall be applied when the concrete and the ambient air temperatures are above 40°F. If a heated enclosure is used to accomplish this, the heating units shall be properly vented to the outside of the enclosure to prevent products of combustion from exhausting within the enclosure.

Before containers of sealing materials are opened, the labels shall be checked and the label information shall be documented. If multi-component systems are used, mixing shall be completed prior to application. Manufacturer's instructions shall be followed. An initial crack sealing application demonstration shall be satisfactorily made before the application is continued.

Before sealing, the concrete must be clean, sound, and free of contaminants and surface moisture. Any curing compounds, sealers, oils, greases, coatings, or other impregnations shall be removed by sandblasting. Once any concrete surface contaminants are removed, the concrete shall be swept clean and blown off using oil free compressed air immediately prior to applying the sealer.

Methacrylate crack sealing shall be performed in accordance with the manufacturer's instructions within the allowable ambient temperature range. The cracks shall be v-notched to a minimum depth of 1/2" and shall be cleaned with compressed air. The notch shall then be inspected to confirm that the crack was intercepted. If the crack was not intercepted, the notch shall be expanded to intercept the crack and shall then be re-cleaned with compressed air. Methacrylate shall then be poured into the crack. The crack shall then be observed for seepage of methacrylate and shall be refilled as necessary to ensure the crack is completely filled. If large quantities of methacrylate are used and the crack is not getting filled, the crack should be filled with pre-bagged dried silica sand filler and the crack shall then be re-filled with methacrylate.

Methacrylate crack sealer shall consist of a high molecular weight low viscosity methacrylate monomer that when catalyzed will produce a crack-healer/penetrating-sealer that is a rapid-curing, modified-methacrylate resin. The methacrylate material shall, as a minimum, provide the following as applied properties:

Property	Value	Test
Viscosity	< 25 cps	ASTM D2393

Bond Strength	> 1500 psi	ASTM C882
Tensile Elongation	> 3%	ASTM D638

In addition, the methacrylate material shall demonstrate full penetration of concrete cracks in mock-up testing. Mock-up testing shall consist of preparing the deck surface, applying the methacrylate sealer, and removing cores to evaluate the depth and quality of methacrylate sealer penetration. Successful methacrylate penetration of the concrete cracks shall be demonstrated visually in nominal 3” deep cores that intersect crack widths in the 7 to 20 mil width range. The cores shall be sliced longitudinally, perpendicular to the crack, and examined in an AASHTO accredited laboratory using ultraviolet light in order to fluoresce the methacrylate to determine the methacrylate penetration depth (the deepest point to which the methacrylate reached) and the sealer-filled crack depth (the depth to which the crack was filled wall-to-wall). The results of mock-up testing shall be documented in a report prepared by the AASHTO accredited laboratory.

Epoxy injection crack sealing shall be performed in accordance with the manufacturer’s instructions within the allowable ambient temperature range. Epoxy-Resin for Cement Concrete Crack Injection shall conform to AASHTO M235, Type IV, Grade I. The cracks shall be cleaned with compressed air. Surface mounted injection ports shall then be installed over the centers of the cracks. The spacing of these ports shall be contingent upon the material and the injection equipment chosen. Socket porting shall be allowed provided that a hollow drill bit and vacuum system is used to prevent debris from entering the cracks. Surface ports shall be mounted with rapid setting epoxy material. The crack widths shall be noted during port installation. After the ports are installed, the crack surfaces shall be sealed with high modulus, 100% solids, moisture tolerant epoxy paste adhesive. This material shall be capped with fine sand before it is cured. After the capping material has cured, the cracks shall be injected with an epoxy resin compound. The injection pressure used to seal the cracks shall be based upon a number of factors including crack width, crack depth, and the epoxy material used. Injection shall be accomplished using a metered system. The system shall be equipped with a pressure gauge accurate for the pressures anticipated for this work. Injection shall start at the widest point of the crack and shall continue until the narrowest portions of the crack have been filled. Injection shall continue until refusal. If epoxy is observed at adjacent ports, the adjacent port shall be capped and injection shall continue until refusal occurs. Once refusal occurs, injection shall continue at the next wet port until refusal is reached.

Silane Crack Sealer shall consist of a clear, breathable, high-performance, 100 percent solids by weight Silane sealer for protecting new and existing concrete surfaces. It must penetrate deeply, sealing out water, chloride ions, and acids, and prevent damage from freeze/thaw cycles. Silane Crack Sealer material shall provide, as a minimum, the following as applied properties:

Property	Value	Test
Water Weight Gain at 250 ft ² /gal	88 percent reduction	NCHRP 244 Series II-Cube test
Absorbed Chloride at 250 ft ² /gal	89 percent reduction	NCHRP 244 Series II-Cube test

Absorbed Chloride at 250 ft ² /gal	94 percent reduction	NCHRP 244 Series IV - Northern Climate
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The type of Cement Concrete crack sealing required shall be determined as a function of the surface type and maximum crack width as follows:

- a. Bridge decks, either with membrane waterproofing and hot mix asphalt wearing surface or left exposed, and other non-overhead surfaces sloped less than or equal to 15%:
 1. Cracks less than 0.006" wide shall be ignored
 2. Cracks greater than or equal to 0.006" wide and less than 0.012" wide shall be sealed with an approved methacrylate
 3. Cracks greater than or equal to 0.012" wide shall be sealed using either epoxy injection or methacrylate with a sand filler
 - b. Overhead surfaces, vertical surfaces, and non-overhead surfaces sloped greater than 15%:
 1. Cracks less than 0.006" wide shall be ignored
 2. Cracks greater than or equal to 0.006" wide and less than 0.016" wide shall be sealed with an approved silane sealer
 3. Cracks greater than or equal to 0.016" wide shall be sealed using epoxy injection
- D. For all other Roadway Bridge Cast-in-Place Concrete requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 901, amended as follows:
1. For Roadway Bridge Cast-in-Place Concrete submittal requirements, including, but not limited to, shop drawings, working drawings, Requests For Information, Non Conformance and testing reports, see Volume 2.
 2. The DB Entity is responsible for all sampling and testing as outlined in their approved Quality Management Plan and Testing Plan. The DB Entity is also responsible for all costs related to the sampling, testing and related work.

PART 2 – PRODUCTS

2.1 ACCEPTANCE SAMPLING AND DOCUMENTATION REQUIREMENTS

- A. The following samples and documents must be submitted to the Program Manager per MassDOT Research and Materials assurance requirements:
 1. For Cement Concrete
 - a. Sampling Frequency: A minimum of one test per 100 (sublot) CY or fraction thereof for each pour of each class, minimum one test a day.
 2. For Rebar

- a. Sampling Frequency: One for each grade and size from each source with heat number.

PART 3 – EXECUTION

Not used.

END OF SECTION

SECTION 05122

STRUCTURAL STEEL FOR RAIL STRUCTURES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Structural steel for all Viaduct Structures.
 - 2. Structural steel for the Washington Street Rail Bridge.
- B. Items to Be Furnished Only: Furnish the following items for installation by the designated Sections:
 - 1. Section 03300 - CAST-IN-PLACE CONCRETE: Lintels, sleeves, anchors, inserts, embedded wall plates, loose leveling plates, and similar items.
- C. Related Work: See Volume 2 for other technical provisions.
 - 1. SUSTAINABILITY REQUIREMENTS - Volume 2 Technical Provisions Exhibit 2I "Additional Project Requirements".

1.2 DEFINITIONS

- A. Structural steel: Elements of structural-steel frame, as classified by AISC's "Code of Standard Practice for Steel Buildings and Bridges", that support design loads.
- B. Fracture Critical Members: A steel member in tension, or with a tension element, whose failure would probably cause a portion of the bridge or the entire bridge to collapse.

1.3 PERFORMANCE REQUIREMENTS

- A. Connections: Provide details of all connections to withstand loads determined by analysis of required load combinations.
 - 1. Connections shall be designed in accordance with the AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO), Standard Specifications for Highway Bridges, 17th Edition, Section 10.
 - 2. Connections shall be fully detailed or designed by the DB Entity or the DB Entity's subcontractor/fabricator for the design of the Viaduct Structures and or Washington Street Rail Bridge. The DB Entity shall provide all loads on the final Design Documents for the Fabricator's use in design of the final connections. The Fabricator shall utilize the services of a qualified professional engineer Registered in the Commonwealth of Massachusetts, to prepare structural analysis data for structural-steel connections.

1.4 SUBMITTALS

- A. Product data: For each type of product indicated.

- B. Erection Procedure and Erection drawings, see requirements within Article 3.3 Erection below.
- C. Shop drawings: Show fabrication of structural-steel components.
 - 1. Include details of cuts, connections, splices, camber, holes, and other pertinent data.
 - 2. Include embedment drawings.
 - 3. Indicate welds by standard American Welding Society (AWS) symbols, distinguishing between shop and field welds, and show size, length, and type of each weld.
 - 4. Indicate type, size, and length of bolts, distinguishing between shop and field bolts. Identify pre-tensioned and slip-critical high-strength bolted connections.
 - 5. For structural-steel connections indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer Registered in the Commonwealth of Massachusetts, responsible for their preparation.
- D. Welding Certificates: Certificate from AWS indicating certification in type of welding required for each welder and welding operator.
- E. Welding Records and Data:
 - 1. Before welding, submit the procedure which will be used for qualifying welders and welding procedures. For procedures other than those pre-qualified in accordance with AWS D1.1 and AWS D1.5, submit a copy of procedure qualification test records.
 - 2. Submit certified copy of qualification test records for each welder, welding operator, and tacker who will be employed in the work.
 - 3. Where field welding is permitted, submit descriptive data for field welding equipment.
 - 4. Submit all NDE records (radiographs, ultrasonic, magnetic particle) and visual inspection reports upon completion or when otherwise requested by the MBTA.
- F. Qualification Data: For installer, fabricator, DB Entity or fabricator professional engineer, testing agency, welding inspectors, NDE inspectors and galvanizer. Submit prior to starting work.
- G. Mill Test Reports: Signed by manufacturers certifying that the following products comply with requirements:
 - 1. Structural steel including chemical and physical properties.
 - 2. Bolts, nuts, and washers including mechanical properties and chemical analysis.
 - 3. Direct-tension indicators.
 - 4. Tension-control, high-strength bolt-nut-washer assemblies.
 - 5. Shear stud connectors.
 - 6. Shop primers and finished paint systems.
 - 7. Nonshrink grout.

1.5 QUALITY ASSURANCE

- A. Fabricator qualifications: A qualified fabricator who participates in the AISC Quality Certification Program and is certified for: Major Steel Bridges (CBR).

- B. Galvanizer qualifications: Engage the services of a qualified galvanizer who has demonstrated a minimum of five years' experience in the successful application of galvanized coatings specified in this Section in the facility where the work is to be performed and who will apply the coatings within the same facility.
- C. Installer qualifications: A qualified installer with previous experience in installing structural steel.
- D. Welding: Qualify procedures and personnel according to AWS D1.1 "Structural Welding Code -Steel" and AWS D1.5 " Bridge Welding Code".
- E. Comply with applicable provisions of the following specifications and documents:
 - 1. AASHTO "Standard Specification for Highway Bridges, 17th Edition"
 - 2. American Railway Engineering and Maintenance-of-way Association (AREMA), "Manual for Railway Engineering"
 - 3. AISC's "Code of Standard Practice for Steel Buildings and Bridges"
 - 4. AISC's "Seismic Provisions for Structural Steel Buildings" and "Supplement No. 2"
 - 5. AISC's "Specification for Structural Steel Buildings"
 - 6. AISC's "Specification for the Design of Steel Hollow Structural Sections"
 - 7. AISC's "Specification for Allowable Stress Design of Single-Angle Members" and "Specification for Load and Resistance Factor Design of Single-Angle Members"
 - 8. RCSC's "Specification for Structural Joints Using High-Strength Bolts"
- F. Tests and Inspection
 - 1. The DB Entity shall test and inspect all high-strength bolted connections and welded connections and prepare test reports for submission to the MBTA. Specialty tests shall be performed by an independent testing laboratory accepted by the MBTA. Costs of specialty tests shall be borne by the DB Entity. Test reports shall be submitted to the MBTA for review and acceptance.
 - 2. The MBTA reserves the right to inspect high-strength bolted connections and weld connections. The DB Entity shall provide access to places where structural steel work is being fabricated or erected so that required inspection and testing can be accomplished. Costs for providing access shall be borne by the DB Entity. At times, inspection may require moving or handling of steel to permit proper inspection, costs for handling and moving steel shall be borne by the DB Entity. Notify the MBTA not less than 48 hours prior to start of fabrication.
 - 3. The MBTA may inspect structural steel at the plant before shipment; the MBTA reserves the right, at any time before final acceptance, to reject material not complying with specified requirements.
 - 4. Correct deficiencies in structural steel work that inspections and laboratory test reports have indicated to be not in compliance with requirements at the DB Entity 's expense. Perform additional tests, at DB Entity's expense, as may be necessary to reconfirm any non-compliance of the original work, and as may be necessary to show compliance of corrected work.
 - 5. For Fracture Critical Members, acceptable Charpy V-Notch (CVN) tests shall be performed as required by ASTM A673, Temperature Zone 2.

6. Specialty Tests: Nondestructive examination of welds in accordance with provisions of AWS D1.1 and AWS D1.5 and ASTM Standards noted shall be made in accordance with the following schedule:
 - a. Radiographic Examination of Welds, per ASTM E94 and E142:
 - 1) Field, complete joint penetration groove welds:
 - a) 10%, of all complete joint penetration groove welds.
 - 2) Shop, complete joint penetration groove welds:
 - a) 10%, of all complete joint penetration groove welds.
 - b. Ultrasonic Examination, per ASTM E164: Complete joint penetration groove butt welds not accessible for radiographic examination shall be subjected to ultrasonic testing. The extent shall be the same as noted for radiographic examination. Ultrasonic examination shall be made 48 to 72 hours after welding at locations on weldments or welded joints subject to high restraint as indicated in order to check for lamellar tearing. The exact location of the areas to be inspected shall be determined with the MBTA at the time of fabrication. This examination shall be made according to the following schedule unless conditions of tearing require a greater number of tests, as directed:
 - 1) 100%, for all welds.
 - c. Magnetic Particle Examination, per ASTM E709, field and shop:
 - 1) 1 out of 5 (20%) of complete joint penetration groove welds of tee and corner joints.
 - 2) 1 out of 10 (10%) of partial joint penetration groove and fillet welds.
 - d. Penetrant Examination, per ASTM E165: Shall be used for detecting discontinuities that are open to the surface use as appropriate. 100% for all welds.
 7. Visual Examination: All welds, whether otherwise examined or not, shall be visually examined and faulty joints shall be marked for correction.
 8. When any testing, examination, or inspection reveals faulty welds, all joints of the same type shall be checked at the expense of the DB Entity, until the integrity of the weld is assured before resuming examination.
 9. After faulty welds have been corrected or repaired, they shall each be re-examined at the expense of the DB Entity, in the manner specified for the original joint.
 10. It is intended that inspections shall be performed to permit an orderly flow of completed material from the shop. Work with the MBTA to establish a schedule that will permit this.
 11. Test result information shall be forwarded to the MBTA immediately after test results are available stating the acceptance or rejection of fabricated pieces in order that the repairs and re-inspection may be made as soon as possible.
- G. Pre-Installation Conference: DB Entity shall schedule a meeting to be attended by DB Entity, MBTA, fabricator, erector and galvanizer. Agenda shall include the following: Project schedule, source for each fabrication, coordination between fabricator and galvanizer and adjacent Work, finish of surfaces, application of coatings, submittals, and approvals.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Store materials to permit easy access for inspection and identification. Keep steel members off ground and spaced by using pallets, dunnage, or other supports and spacers. Protect steel members and packaged materials from erosion and deterioration.

1. Store fasteners in a protected place. Clean and re-lubricate bolts and nuts that become dry or rusty before use.
2. Do not store materials on a structure in a manner that might cause distortion, damage, or overload to members or supporting structures. Repair or replace damaged materials or structures as directed by the MBTA.

1.7 COORDINATION

- A. Furnish anchorage items to be embedded in or attached to other construction without delaying the Work. Provide setting diagrams, sheet metal templates, instructions, and directions for installation.

PART 2 - PRODUCTS

2.1 STRUCTURAL STEEL MATERIALS

- A. ASTM A709, Grade 50
- B. ASTM A709, Grade 50W
- C. ASTM A709, Grade 50 Fracture Critical
- D. Welding Electrodes: Comply with AWS requirements.

2.2 BOLTS, CONNECTORS, AND ANCHORS

- A. High-Strength Bolts, Nuts, and Washers for Non-Weathering steels: ASTM F3125, Grade A325, Type 1, heavy hex steel structural bolts; ASTM A563 Grade DH heavy hex carbon-steel nuts; and ASTM F436 hardened carbon-steel washers.
 1. Finish: Hot-dip zinc coating, ASTM A153, Class C.
- B. High-Strength Bolts, Nuts, and Washers for weathering steels: ASTM F3125, Grade A325 Type 3.
- C. Tension-Control, High-Strength Bolt-Nut-Washer Assemblies: ASTM F3125, Grade F1852, Type 1, steel structural bolts with splined ends; ASTM A563 heavy hex carbon-steel nuts; and ASTM F436 hardened carbon-steel washers. Finish, mechanically deposited zinc coating, ASTM B695, Class 50.
- D. Shear Connectors: ASTM A 108, Grades 1015 through 1020, headed-stud type, cold-finished carbon steel; AWS D1.1 and AWS D1.5, Type B.
- E. Anchor Rods and or Anchor Bolts: ASTM F1554, Grade 55 minimum, hot-dip zinc coating, ASTM A123 and A153, Class C.
- F. Threaded Rods: ASTM A193, grade as required by design, hot-dip zinc coating, ASTM A153, Class C.
- G. Eye Bolts and Nuts: ASTM A108, Grade 1030, cold-finished carbon steel.
- H. Sleeve Nuts: ASTM A108, Grade 1018, cold-finished carbon steel.

2.3 MISCELLANEOUS MATERIALS

- A. Galvanizing Repair Paint: Coatings meeting requirements of ASTM A780.
- B. Nonmetallic, Shrinkage-Resistant Grout: ASTM C1107, factory-packaged, nonmetallic aggregate grout, noncorrosive, nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

2.4 FABRICATION

- A. Structural Steel: Fabricate and assemble in shop to greatest extent possible. Fabricate according to AASHTO Standard Specification, 17th Edition Division II, Section 11, AREMA Chapter 15 Part 3, AISC's "Code of Standard Practice for Steel Buildings and Bridges".
 - 1. Camber structural-steel members where indicated.
 - 2. Identify high-strength structural steel according to ASTM A6/A6M and maintain markings until structural steel has been erected.
 - 3. Mark and match-mark materials for field assembly.
 - 4. Complete structural-steel assemblies, including welding of units, before starting shop-priming and painting operations.
- B. Thermal Cutting: Perform thermal cutting by machine to greatest extent possible. Plane thermally cut edges to be welded to comply with requirements in AWS D1.1 and AWS D1.5.
- C. Bolt Holes: Cut, drill, or punch standard bolt holes perpendicular to metal surfaces.
- D. Finishing: Accurately finish ends of columns and other members transmitting bearing loads.
- E. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1 and AWS D1.5 and manufacturer's written instructions.
- F. Holes: Provide holes required for securing other work to structural steel and for passage of other work through steel framing members.
 - 1. Cut, drill, or punch holes perpendicular to steel surfaces. Do not thermally cut bolt holes or enlarge holes by burning.
 - 2. Base-Plate Holes: Cut, drill, mechanically thermal cut, or punch holes perpendicular to steel surfaces.
 - 3. Weld threaded nuts to framing and other specialty items indicated to receive other work.

2.5 SHOP CONNECTIONS

- A. High-Strength Bolts: Shop install high-strength bolts according to RCSC's "Specification for Structural Joints Using High-Strength Bolts" for type of bolt and type of joint specified.
- B. Weld Connections: Components requiring fabrication will be made in accordance with ANSI/AASHTO/AWS Bridge Welding Code D1.5. Comply with procedure specifications, tolerances, appearance and quality of welds and for methods used in correcting welding work. Complete welds in accordance with the design requirements.

1. Remove backing bars or runoff tabs, back gouge, re-weld, and grind steel smooth.
2. Assemble and weld built-up sections by methods that will maintain true alignment of axes without exceeding tolerances of AISC's "Code of Standard Practice for Steel Buildings and Bridges" for mill material.
3. Insufficient welds shall be rejected and corrected until required profiles are met.
4. Verify that weld sizes, fabrication sequence, and equipment used for exposed structural steel will limit distortions to allowable tolerances. Prevent weld show-through on exposed steel surfaces.
 - a. Grind butt welds flush.
 - b. Grind or fill exposed fillet welds to smooth profile. Dress exposed welds.
5. No skip welds will be permitted for steel connections to be coated.

2.6 STEEL PAINTS AND FINISHES

- A. Where required by the Contract Documents, structural steel for rail structures shall be fully shop painted. All paint coats shall conform to the requirements of MassDOT approved materials for New and 100% Bare Existing Steel for Bridges, per Northeast Protective Coating Committee (NEPCOAT) product list. Prepare uncoated ferrous-metal surfaces to comply with minimum requirements indicated below for The Society for Protective Coatings (SSPC) surface preparation specifications and environmental exposure conditions of installed metal fabrications:
 1. Exteriors (SSPC Zone 1B) and Items Indicated to Receive Zinc-Rich Primer: SSPC-SP 10/NACE No. 2, "Near White Metal Blast Cleaning"
 2. Apply coating to uncoated surfaces of metal fabrications, except those with galvanized finishes not indicated to be painted, and those to be field welded, or embedded in concrete or masonry, unless otherwise indicated. Extend priming of partially embedded members to a depth of 2 inches within the embedment.
 3. Comply with SSPC-PA 1, "Paint Application Specification No. 1: Shop, Field, and Maintenance Painting of Steel" for shop painting.
 4. Comply with SSPC-PA 2, "Measurement of Dry Coating Thickness with Magnetic Gages"
- B. Zinc-Rich Primer: Urethane zinc rich primer compatible with topcoat specified in Section 09900. Provide primer with a VOC content of 340 g/L (2.8 lb/gal.) or less per OTC ozone standards. Provide Tnemec Series 394 or Ameron 5105 or equal by DuPont or Carboline for exposed steel to be fireproofed, or Tnemec Series 901K97 Series or 90-97 or Ameron 68HS or equal by DuPont or Carboline for exposed steel to be finish painted at 3.0 mils DFT.
- C. Primer for Exposed Steel to Receive Multi-Coat Shop-Applied Coating: Tnemec Series 901K97 or 90-97 urethane zinc rich primer at 3.0 to 3.5 mils DFT, topcoated in shop with Tnemec Series V73 Endura-Shield, or use Ameron Series 68HS Primer at 3.0 to 5.0 mils DFT topcoated in shop with Ameron's Amercoat 450H, or use or equal primers and finish coats from DuPont or Carboline.
- D. Galvanizing: For steel to be galvanized, provide coating for iron and steel fabrications applied by the hot-dip process. Comply with ASTM A 123 for fabricated products and ASTM A 153 for hardware. Provide thickness of galvanizing specified in referenced standards. The galvanizing bath shall contain high grade zinc and other earthly materials. Fill vent holes and grind smooth after galvanizing.
- E. Hot-Dip Galvanizing and Factory-Applied Primer for Steel: Galvanized surfaces to be painted, provide hot-dip galvanizing and factory-applied prime coat, certified OTC/VOC compliant less than 2.8 lbs/gal.

and conforming to EPA and Commonwealth of Massachusetts requirements. Apply primer within 12 hours after galvanizing at the galvanizer's plant in a controlled environment meeting applicable environmental regulations and as recommended by the primer coating manufacturer. Blast cleaning of the surface is unacceptable for surface preparation. Primer shall have a minimum two year re-coat window for application of finish coat. Coatings shall meet or exceed the following performance criteria:

1. Abrasion: ASTM D 4060, CS17 Wheel, 1,000 gram load.
2. Adhesion: ASTM D 3359, Method B, 5 mm crosshatch.
3. Humidity Resistance: ASTM D 4585.
4. Salt Spray (Fog): ASTM B 117.

F. Hot-Dip Galvanizing and Factory-Applied Urethane Primer and Finish for Steel: Galvanized surfaces to be painted, provide factory-applied architectural coating over primed hot-dip galvanized steel matching approved samples.

1. Primer coat shall be factory-applied polyamide epoxy primer. Apply primer within 12 hours after galvanizing at the galvanizer's plant in a controlled environment meeting applicable environmental regulations and as recommended by the primer coating manufacturer.
2. Finish coat shall be factory-applied color-pigmented architectural finish. Apply finish coating at the galvanizer's plant, in a controlled environment meeting applicable environmental regulations and as recommended by the finish coating manufacturer.
3. Coatings shall be certified OTC/VOC compliant and conform to applicable regulations and EPA standards.
4. Apply the galvanizing, primer, and coating within the same facility and provide single-source responsibility for galvanizing, priming, and finish coating.
5. Blast cleaning of the galvanized surface is not acceptable.
6. Primer shall meet or exceed the following performance criteria:
 - a. Abrasion: ASTM D 4060, CS17 Wheel, 1,000 gram load.
 - b. Adhesion: ASTM D 3359, Method B, 5 mm crosshatch.
 - c. Humidity Resistance: ASTM D 4585.
 - d. Salt Spray (Fog): ASTM B 117.
7. Finish coat shall meet or exceed the following performance criteria:
 - a. Abrasion: ASTM D 4060, CS17 Wheel, 1,000 gram load.
 - b. Adhesion: ASTM D 3359, Method B, 5 mm crosshatch.
 - c. Graffiti Resistance: After drying for seven days, no staining from acrylic, epoxy, epoxy-ester and alkyd spray paints, ballpoint pen, crayons, magic marker, black shoe polish and lipstick.
 - d. Weathering: ASTM D 1014, 45 degrees facing south.
 - e. Surface Burning Characteristics: ASTM E 84
 - f. QUV: ASTM G53, ES-40 bulbs, 4 hours light, 4 hours dark.
 - g. Salt Spray (Fog): ASTM B 117.
8. Clearcoat over finish coat shall meet or exceed the following performance criteria:

- a. Abrasion: ASTM D 4060, CS17 Wheel, 1,000 gram load.
- b. Adhesion: ASTM D 3359, Method B, 5 mm crosshatch.
- c. Graffiti Resistance: After drying for seven days, no staining from acrylic, epoxy, epoxy-ester and alkyd spray paints, ballpoint pen, crayons, magic marker, black shoe polish and lipstick.
- d. Weathering: ASTM D 1014, 45 degrees facing south; and ASTM D 4141C EMMAQUANTW.
- e. QUV: ASTM G53, ES-40 bulbs, 4 hours light, 4 hours dark.
- f. Salt Spray (Fog): ASTM B 117.
- g. Flexibility: ASTM D 522, Method B, cylindrical mandrel.
- h. Hardness: ASTM D 3363 (Pencil).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify elevations of concrete- and masonry-bearing surfaces and locations of anchor rods and or bolts, bearing plates, and other embedments, with steel erector present, for compliance with design requirements. Elevations shall be verified by a surveyor licensed in the Commonwealth of Massachusetts.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Provide temporary shores, braces, and other supports during erection to keep structural steel secure, plumb, and in alignment against temporary construction loads and loads equal in intensity to design loads. Remove temporary supports when permanent structural steel, connections, and bracing are in place, unless otherwise required by design. Do not remove temporary shoring supporting composite deck construction until cast-in-place concrete has attained its design compressive strength.

3.3 ERECTION

- A. DB Entity shall submit an erection procedure. The submitted method of erection is subject to review, comment, and acceptance by the MBTA. The method shall be submitted with a detailed procedure which includes drawings and calculations sufficient to enable the MBTA to determine the adequacy of the proposed method. The method and all submissions shall be prepared under the supervision of a professional engineer, registered in the Commonwealth of Massachusetts, engaged by the DB Entity, who is familiar with these Mandatory Specifications, AASHTO, the work, and experienced in this technical field. All submitted sheets shall be stamped by the DB Entity. As a minimum the following information shall be included in the submittal:
 - 1. Plan showing the location of all roadways, utilities, railroad tracks and other appurtenances in areas of erection.
 - 2. The location of cranes, both horizontally and vertically, and their operating radii.

3. Lifting equipment information including rating data. Information shall include counter weights to be used and boom capability. The manufacturer's rated capacity of the crane and of all lifting and connecting devices shall be adequate for 125% of the total pick load including spreaders and other material except that in the areas within the potential influence area of the crane where railroad, vehicular or pedestrian traffic has access, the rated capacity shall be adequate for 150% of the total pick load. The limits of the potential crane influence area shall be taken as circular areas with radii matching the boom length and radius points located at the boom pivot point. Crane capacity rating charts and the rated capacity of all lifting and connecting devices shall be clearly shown in the submittal. The 125% or 150% factors of safety are to be used in addition to any factors of safety used by the manufacturer to calculate the rated capacity.
4. The type, size and arrangements of slings, shackles or other lifting and connecting devices including relative technical data.
5. The order of lifts, repositioning of equipment and counterweights, and location and method of attaching deadmen.
6. Methods and materials for temporary structures or the strengthening or bracing of a member(s) (either temporarily or permanently) for erection purposes.
7. Analysis of stresses shall be investigated at each stage of erection and the impact on construction of deck systems. Stresses shall take into consideration the non-composite nature of the girders when placing the concrete for the decks, in addition to other temporary construction loads from form work, personal, equipment. Allowance for wind pressure shall be included in the analysis of stresses based on the table below.

Height of Members Above Ground Feet	Wind Pressure Pounds per square foot
15	21.0
30	25.5
50	28.0

8. Curved girders and straight girders shall be stabilized with falsework, temporary braces, or holding cranes until a sufficient number of adjacent girders are erected with all diaphragms and cross frames connected to provide necessary lateral stability. The falsework and temporary braces shall provide for proper camber and alignment and shall be properly designed, constructed, and maintained for the loads that will be imposed upon it. Care shall be taken in the use of falsework and other temporary supports to ensure that the temporary elevation of structural steel provided by the falsework is consistent with the deflections that will occur as the structure is completed.
 9. In instances where falsework is required as part of the erection procedure, it shall be properly designed, constructed, and maintained for the loads that it will bear. Plans for falsework along with necessary engineering data shall be submitted to the MBTA for review, comment, and acceptance.
- B. Erection Drawings: Erection drawings shall show bolting or welding procedures necessary to complete erection. Procedures shall include sequence and method of connecting main members and secondary members. For stringer and girder spans, the following minimum information shall be included in the notes, modified as necessary to conform to design and erection requirements for each structure:
1. Splices and field connections of main stress carrying members shall be made with a minimum of 50% of the holes filled with approved high strength bolts and erection pins before the external

- support system is released. At least one-half of this percentage shall be bolts, tightened to specification requirements. The bolts and pins shall be installed uniformly throughout the connection except that erection pins shall be used in the extreme corners of all main connections.
2. Members to be assembled on the ground before erection shall be blocked to their proper "no load profile" and 100% of the approved high strength bolts shall be installed and tightened to specification requirements before erecting the member.
 3. All diaphragms and cross frames shall be installed between stringer lines as the work progresses.
 4. Dimensions indicated at expansion joints and similar construction shall be determined for a temperature of 50°F. Proper adjustments shall be made when the structure is placed at any other temperature.
 5. After the erection of beams and girders has been completed, expansion bearing sole plates shall be re-aligned so that they will be centered at 50°F.
- C. Set structural steel accurately in locations and to elevations indicated and according to AISC's "Code of Standard Practice for Steel Buildings and Bridges".
- D. Base and Bearing Plates: Clean concrete- and masonry-bearing surfaces of bond-reducing materials, and roughen surfaces prior to setting base and bearing plates. Clean bottom surface of base and bearing plates.
1. Set base and bearing plates for structural members on wedges, shims, or setting nuts as required.
 2. Weld plate washers to top of base plate.
 3. Snug-tighten or pre-tension anchor rods as applicable after supported members have been positioned and plumbed. Do not remove wedges or shims but, if protruding, cut off flush with edge of base or bearing plate before packing with grout.
 4. Where indicated promptly pack grout solidly between bearing surfaces and base or bearing plates so no voids remain. Neatly finish exposed surfaces; protect grout and allow to cure. Comply with manufacturer's written installation instructions for shrinkage-resistant grouts.
- E. Maintain erection tolerances of structural steel within AASHTO, AREMA and AISC's "Code of Standard Practice for Steel Buildings and Bridges", in the event of conflict between the referenced documents, the more stringent condition shall apply.
- F. Align and adjust various members forming part of complete frame or structure before permanently fastening. Before assembly, clean bearing surfaces and other surfaces that will be in permanent contact with members. Perform necessary adjustments to compensate for discrepancies in elevations and alignment.
1. Level and plumb individual members of structure.
 2. Make allowances for difference between temperature at time of erection and mean temperature when structure is completed and in service.
- G. Splice members only where indicated.
- H. Do not use thermal cutting during erection unless accepted by MBTA. Finish thermally cut sections within smoothness limits in AWS D1.1 and AWS D1.5.

- I. Do not enlarge unfair holes in members by burning or using drift pins. Obtain written acceptance from MBTA prior to reaming holes that are required to be enlarged to admit bolts.
- J. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1 and AWS D1.5 and manufacturer's written instructions.

3.4 FIELD CONNECTIONS

- A. High-Strength Bolts: Install high-strength bolts according to RCSC's "Specification for Structural Joints Using High-Strength Bolts" for type of bolt and type of joint indicated on the Drawings.
- B. Weld Connections: Comply with AWS D1.1 and AWS D1.5 for welding procedure specifications, tolerances, appearance, and quality of welds and for methods used in correcting welding work.
 - 1. Comply with AISC's "Code of Standard Practice for Steel Buildings and Bridges" for bearing, adequacy of temporary connections, alignment, and removal of paint on surfaces adjacent to field welds.
 - 2. Remove backing bars or runoff tabs, back gouge, and grind steel smooth.
 - 3. Assemble and weld built-up sections by methods that will maintain true alignment of axes without exceeding tolerances of AASHTO, AREMA and AISC's "Code of Standard Practice for Steel Buildings and Bridges" for mill material. In the event of conflict between the referenced documents, the more stringent tolerance condition shall apply.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: The DB Entity will engage a qualified independent testing and inspecting agency to inspect field welds and high-strength bolted connections.
- B. Bolted Connections: Bolted connections will be inspected according to RCSC's "Specification for Structural Joints Using High-Strength Bolts". When using bolted connections prime with "slip critical class B" primer as specified in this Section. All surfaces of bolted or bearing connections may be primed. When welding, hold back primer a minimum of 2" each side of weld.
- C. Welded Connections: Field welds will be visually inspected according to AWS D1.1 and AWS D1.5. In addition to visual inspection, specialty tests will be performed in accordance with AWS D1.1 and AWS D1.5 and at the frequency stated in Article 1.5.F.
- D. In addition to visual inspection, test and inspect field-welded shear connectors according to requirements in AWS D1.1 and AWS D1.5 for stud welding and as follows:
 - 1. Perform bend tests if visual inspections reveal either a less-than- continuous 360-degree flash or welding repairs to any shear connector.
 - 2. Conduct tests on additional shear connectors if weld fracture occurs on shear connectors already tested, according to requirements in AWS D1.1 and AWS D1.5.
- E. Correct deficiencies in Work that test reports and inspections indicate do not comply with the requirement of the Contract Documents.

3.6 REPAIRS AND PROTECTION

- A. Repair damaged galvanized coatings on galvanized items with galvanized repair paint according to ASTM A 780 and manufacturer's written instructions.
- B. Touchup Painting: After installation, promptly clean, prepare, and prime or reprime field connections, rust spots, and abraded surfaces of painted joists and accessories, bearing plates, and abutting structural steel.
 - 1. Clean and prepare surfaces by SSPC-SP 3 power-tool cleaning.
 - 2. Apply a compatible coating of same type as shop coating used on adjacent surfaces.

END OF SECTION

SECTION 07160

CRYSTALLINE WATERPROOFING

PART 1 - GENERAL

1.1 SUMMARY

- A. This Section includes crystalline waterproofing for application with concrete.
- B. Related Sections:
 - 1. Section 03300 - CAST IN PLACE CONCRETE.
 - 2. Section 07920 - JOINT SEALANTS.

1.2 PERFORMANCE REQUIREMENTS

- A. The DB Entity shall provide waterproofing that prevents passage of water under hydrostatic pressure and complies with physical requirements specified as demonstrated by testing performed by independent testing agency of manufacturer's current waterproofing formulation.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated. Include material descriptions and installation instructions for crystalline waterproofing. Indicate material interactions with substrate, accessories, or adjacent materials that could impair the performance of either item.
- B. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience.
- C. Product Certificates: For waterproofing, patching, and plugging materials, from manufacturer.
- D. Product Test Reports: Based on evaluation of comprehensive tests performed by manufacturer and witnessed by a qualified independent testing agency, for crystalline waterproofing.
- E. Field quality-control reports.

1.4 QUALITY ASSURANCE

- A. Qualification of Installer: A qualified installer who is authorized, approved, or licensed to install waterproofing manufacturer's products; and who is eligible to receive waterproofing warranty specified.
- B. Preinstallation Conference: Review requirements for waterproofing, including surface preparation specified under other Sections, substrate condition and pretreatment, minimum curing period, forecasted weather conditions, special details and sheet flashings, installation procedures, testing and inspection procedures, and protection and repairs.

1.5 PROJECT CONDITIONS

- A. Weather Limitations: Proceed with application only when existing and forecasted weather conditions permit crystalline waterproofing to be performed according to manufacturer's written instructions.
- B. Proceed with waterproofing work only after pipe sleeves, vents, curbs, inserts, drains, and other projections through the substrate to be waterproofed have been completed. Proceed only after substrate defects, including honeycombs, voids, and cracks, have been repaired to provide a sound substrate free of forming materials, including reveal inserts.
- C. Ambient Conditions: Proceed with waterproofing work only if temperature is maintained at 40 deg F (4.4 deg C) or above during work and cure period, and space is well ventilated and kept free of water.

1.6 WARRANTY

- A. Submit written warranty signed by manufacturer and Installer agreeing to repair or replace waterproofing, sheet flashings, and other components of waterproofing system that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 WATERPROOFING MATERIALS

- A. Crystalline Waterproofing: Prepackaged, blend of portland cement, specially treated sand, and active chemicals that, when mixed with water and applied, penetrates into concrete and concrete unit masonry and reacts chemically with the byproducts of cement hydration in the presence of water to develop crystalline growth within substrate capillaries to produce an impervious, dense, waterproof substrate; that has VOC content complying with limits of authorities having jurisdiction; with properties meeting or exceeding the criteria specified below.
 - 1. Available Products: Subject to compliance with requirements, provide one of the following:
 - a. Xypex Chemical Corporation; Xypex
 - b. AQUAFIN, Inc.; AQUAFIN-1C.
 - c. Vandex USA LLC; Vandex Super/Super White.
 - d. Or approved equal.
 - 2. Water Permeability: Maximum zero for water at 30 feet when tested according to CE CRD- C 48.
 - 3. Compressive Strength: Minimum 4000 psi at 28 days when tested according to ASTM C 109/C 109M.
- B. Crystalline Waterproofing Additive: Crystalline type that chemically controls and permanently fixes a non-soluble crystalline structure throughout the capillary voids of the concrete which causes the concrete to become sealed against the penetration of liquids and protects the concrete from deterioration due to harsh environmental conditions.

1. Available Products: Subject to compliance with requirements, provide one of the following:
 - a. Kryton International Inc.
 1. Krystol Internal Membrane (KIM)
 2. Krystol Waterstop Grout
 - b. Xypex Chemical Corporation
 1. Xypex Admix C-500 or Xypex Admix C-1000.

2.2 ACCESSORY MATERIALS

- A. Patching Compound: Factory-premixed cementitious repair mortar, crack filler, or sealant recommended by waterproofing manufacturer for filling and patching tie holes, honeycombs, reveals, and other imperfections; compatible with substrate and other materials indicated; and VOC content complying with limits of authorities having jurisdiction.
- B. Plugging Compound: Factory-premixed cementitious compound with hydrophobic properties and recommended by waterproofing manufacturer; resistant to water and moisture but vapor permeable for all standard applications (vertical, overhead, and horizontal surfaces not exposed to vehicular traffic); compatible with substrate and other materials indicated; and VOC content complying with limits of authorities having jurisdiction.
- C. Portland Cement: The DB Entity shall use ASTM C 150, Type I.
- D. Sand: The DB Entity shall use ASTM C 144.
- E. Water: The DB Entity shall use potable water.

2.3 MIXES

- A. Crystalline Waterproofing: Add prepackaged dry ingredients to water according to manufacturer's written instructions. Mix together with mechanical mixer or by hand to required consistency.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. The DB Entity shall examine substrates, areas, and conditions, with applicator present, for suitable conditions where waterproofing is to be applied.
- B. Proceed with application only after unsatisfactory conditions have been corrected.
- C. Notify Architect of Record in writing of active leaks or defects that would affect system performance.

3.2 PREPARATION

- A. Protect other work from damage caused by cleaning, preparation, and application of waterproofing.
- B. Provide temporary enclosure to ensure adequate ambient temperatures and ventilation conditions for application.

- C. Do not allow waterproofing, patching, and plugging materials to enter reveals or annular spaces intended for resilient sealants or gaskets, such as joint spaces between pipes and pipe sleeves.
- D. Stop active water leaks with plugging compound according to waterproofing manufacturer's written instructions.
- E. Repair damaged or unsatisfactory substrate with patching compound according to manufacturer's written instructions.
 - 1. At holes and cracks in substrate, remove loosened chips and cut reveal with sides perpendicular to surface, not tapered, and approximately 1 inch deep. Fill reveal with patching compound flush with surface.
- F. Surface Preparation: Comply with waterproofing manufacturer's written instructions to remove efflorescence, chalk, dust, dirt, mortar spatter, grease, oils, paint, curing compounds, and form-release agents to ensure that waterproofing bonds to surfaces.
 - 1. Clean concrete surfaces according to ASTM D 4258.
 - 2. Concrete Joints: Clean reveals according to waterproofing manufacturer's written instructions.

3.3 APPLICATION

- A. General: Comply with waterproofing manufacturer's written instructions for application and curing.
 - 1. Saturate surface with water for several hours prior to application and maintain damp condition until applying waterproofing. Remove standing water.
 - 2. Apply waterproofing to surfaces indicated on Design Documents.
 - 3. Number of Coats: Number required for specified water permeability.
 - 4. Application Method: Brush or spray. Apply to ensure that each coat fills voids and is in full contact with substrate or previous coat.
 - 5. Dampen surface between coats.
- B. Final Coat Finish: Smooth.
- C. Waterproofing admixture shall be added to concrete mix at time of batching.
- D. Curing: Moist-cure waterproofing for three days immediately after final coat has set, followed by air drying, unless otherwise recommended in writing by manufacturer.

3.4 FIELD QUALITY CONTROL

- A. After installation and prior to covering waterproofing system, arrange for system manufacturer's technical personnel to inspect waterproofing installation and submit report to Engineer of Record.

END OF SECTION

SECTION 08331

OVERHEAD COILING DOORS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Manually-operated and electrically-operated insulated service doors.
 - 2. Electrically-operated fire-rated, automatic-closing overhead coiling doors.
 - 3. Electrically-operated non-insulated overhead coiling doors.
 - 4. Electrically-operated high-speed insulated overhead coiling doors.
 - 5. Electrically-operated high-speed non-insulated vinyl overhead coiling doors (at car wash area).

- B. Related Work:
 - 1. Volume 2 Technical Provisions Exhibit 2I, Additional Project Requirements.
 - 2. Section 08711 - DOOR HARDWARE; lock cylinders and keying.
 - 3. Section 09900 - PAINTING; field-applied paint finish.
 - 4. Division 16 of Exhibit 2A.1 - ELECTRICAL; electrical service and connections for powered operators and accessories.

1.2 PERFORMANCE REQUIREMENTS

- A. Structural Performance: Provide overhead coiling doors capable of withstanding the effects of gravity loads and the following loads and stresses without evidencing permanent deformation of door components:
 - 1. Wind Load: Uniform pressure (velocity pressure) required by Code but not less than 20 lbf/sq. ft. acting inward and outward.

- B. Springs: 100,000 cycle springs.

1.3 SUBMITTALS

- A. Product Data: For each type and size of overhead coiling door and accessory. Include the following:
 - 1. Summary of forces and loads on walls and jambs.

- B. Shop Drawings: For special components and installations not dimensioned or detailed in manufacturer's product data.

- C. Qualification Data: For Installer.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for both installation and maintenance of units required for this Project.
- B. Source Limitations: Obtain overhead coiling doors through one source from a single manufacturer.
 - 1. Obtain operators and controls from overhead coiling door manufacturer.
- C. Fire-Test-Response Characteristics: Provide assemblies complying with NFPA 80 that are identical to door and frame assemblies tested for fire-test-response characteristics per UL 10b and NFPA 252, and that are listed and labeled for fire ratings indicated by UL, FMG, ITS, or another testing and inspecting agency acceptable to authorities having jurisdiction.
 - 1. Required Fire Rating for Unit at Employee Lounge/Lower Lobby Wall: 1 hour.
- D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100.
- E. Engineering Design: Engineering and structural analysis, as well as any necessary calculations shall be prepared under the supervision of, and signed and sealed by, a qualified professional engineer licensed in the Commonwealth of Massachusetts. Engineer shall have minimum 5 years experience performing work of similar scope and complexity. These calculations shall include gravity, wind and seismic loading. The internal structure, dimensions and specifications for all items shall be indicated in the DB Entity's shop drawings.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, Overhead Door Company, Raynor, Wayne-Dalton, Cornell and Rytek. Basis-of design models and performance as indicated below and on the Drawings:
 - 1. Insulated Coiling Doors: Insulated (R-9.3) 22 gauge galvanized steel insulated slats, 35 cycles per 24 hours; finished both sides; 12' per second open with window slot.
 - 2. Insulated Coiling Doors: Insulated (R-8) 22 gauge galvanized steel insulated slats, 10 cycles per 24 hours; finished both sides; 12' per second open with window slot.
 - 3. Non-Insulated Coiling Doors: Standard speed door, 10 cycles per day.
 - 4. High-Speed Coiling Doors: Interior high speed rubber or vinyl coiling door with 35 cycles per 24 hours (suitable for use in a car wash area); Spiral LH Door by Rytec Corporation.
 - 5. Fire-Rated Doors: Cornell Model ERD11 with M100 FireGard Tube Motor Operated System.

2.2 DOOR CURTAIN MATERIALS AND CONSTRUCTION

- A. Door Curtains: Fabricate overhead coiling door curtain of interlocking slats, designed to withstand wind loading indicated, in a continuous length for width of door without splices. Unless otherwise indicated, provide slats of thickness and mechanical properties recommended by door manufacturer for performance, size, and type of door indicated, and as follows:

1. Steel Door Curtain Slats: Zinc-coated (galvanized), cold-rolled structural steel (SS) sheet; complying with ASTM A 653/A 653M, G90 (Z275) coating designation.
 - a. Minimum Base-Metal (Uncoated) Thickness: 0.0209”.
 - b. Flat profile slats.
 2. Insulation at Exterior Units: Fill slat with manufacturer's standard rigid cellular polystyrene or polyurethane-foam-type thermal insulation complying with maximum flame-spread and smoke-developed indexes of 75 and 450, respectively, according to ASTM E 84. Enclose insulation completely within metal slat faces.
 3. Inside Curtain Slat Face: To match material of outside metal curtain slat.
- B. Endlocks and Windlocks for Service Doors: Malleable-iron casings galvanized after fabrication, secured to curtain slats with galvanized rivets or high-strength nylon. Provide locks on not less than alternate curtain slats for curtain alignment and resistance against lateral movement.
- C. Bottom Bar for Service Doors: Consisting of 2 angles, each not less than 1-1/2” by 1-1/2” by 1/8” thick; galvanized, stainless-steel, or aluminum extrusions to suit type of curtain slats.
- D. Curtain Jamb Guides for Service Doors: Fabricate curtain jamb guides of steel angles or channels and angles, with sufficient depth and strength to retain curtain, to allow curtain to operate smoothly, and to withstand loading. Build up units with not less than 3/16” (thick galvanized steel sections complying with ASTM A 36/A 36M and ASTM A 123/A 123M. Slot bolt holes for guide adjustment. Provide removable stops on guides to prevent overtravel of curtain, and a continuous bar for holding windlocks.

2.3 HOODS AND ACCESSORIES

- A. Hood: Form to act as weatherseal and entirely enclose coiled curtain and operating mechanism at opening head. Contour to fit end brackets to which hood is attached. Roll and reinforce top and bottom edges for stiffness. Provide closed ends for surface-mounted hoods and provide fascia for any portion of between-jamb mounting projecting beyond wall face. Provide intermediate support brackets as required to prevent sagging.
1. Fabricate hoods for steel doors of minimum 0.028” thick, hot-dip galvanized steel sheet with G90 zinc coating, complying with ASTM A 653/A 653M.
 2. Include automatic drop baffle to guard against passage of smoke or flame.
- B. Smoke Seals at Fire-Rated Unit: Combination smoke seal/sensing unit at bottom bar, replaceable UL listed nylon pile smoke seals sealing against fascia side of curtain at guides and head.
- C. Battery Back-Up System for Motor Operator at Fire-Rated Units: To provide 4 hours of door open holding time in the event of a power failure; powers local detectors and warning appliances. Allows for programming open/close obstruction cycling should the sensing edge encounter a stationary obstruction in the opening during AC power, alarm signal closing.
- D. Detector at Fire-Rated Units: UL listed photoelectric smoke/heat detector.
- E. Automatic Closing and Speed Governor Mechanism: Activation by central alarm system, local smoke and heat detectors or power outage greater than 4 hours with use of F-BBU back up device. Motor operator shall close door upon signal from central alarm system or local smoke and heat detectors or power outage. Closing speed not more than 9 inches per second. Reset Procedure; operation of control

station after alarm is cleared and/or power is restored; resetting of spring tension or mechanical dropouts shall not be required.

- F. Weatherseals at Exterior Units: Provide replaceable, adjustable, continuous, compressible weather-stripping gaskets fitted to bottom and top of exterior doors, unless otherwise indicated. At door head, use 1/8-inch-thick, replaceable, continuous sheet secured to inside of hood.
 - 1. Provide motor-operated doors with combination bottom weatherseal and sensor edge.
 - 2. In addition, provide replaceable, adjustable, continuous, flexible, 1/8" thick seals of flexible vinyl, rubber, or neoprene at door jambs for a weathertight installation.
- G. Fabricate locking device assembly with manufacturer's standard assembly which is compatible with project high-security lock cylinders and keyways installed under Section 08711 – DOOR HARDWARE.
- H. If door unit is power operated, provide safety interlock switch to disengage power supply when door is locked.
- I. Provide automatic-closing device that is inoperative during normal door operations, with governor unit complying with requirements of NFPA 80 and with an easily tested and reset release mechanism, and designed to be activated by building fire alarm and detection system and door-holder-release devices.

2.4 COUNTERBALANCING MECHANISM

- A. General: Counterbalance doors by means of adjustable-tension, steel helical torsion spring mounted around a steel shaft and contained in a spring barrel connected to door curtain with barrel rings. Use grease-sealed bearings or self-lubricating graphite bearings for rotating members.
- B. Counterbalance Barrel: Fabricate spring barrel of hot-formed, structural-quality, welded or seamless carbon-steel pipe, of sufficient diameter and wall thickness to support rolled-up curtain without distortion of slats and to limit barrel deflection to not more than 0.03 in./ft. (2.5 mm/m) of span under full load.
- C. Provide spring balance of one or more oil-tempered, heat-treated steel helical torsion springs. Size springs to counterbalance weight of curtain, with uniform adjustment accessible from outside barrel. Provide cast-steel barrel plugs to secure ends of springs to barrel and shaft.
- D. Fabricate torsion rod for counterbalance shaft of cold-rolled steel, sized to hold fixed spring ends and carry torsional load.
- E. Brackets: Provide mounting brackets of manufacturer's standard design, either cast iron or cold-rolled steel plate.

2.5 MANUAL DOOR OPERATOR

- A. General: Equip door with manual door operator by door manufacturer.
- B. Push-up Operation: Design counterbalance mechanisms so required lift or pull for door operation does not exceed 25-lbf.

2.6 ELECTRIC DOOR OPERATORS

- A. General: Provide electric door operator assembly of size and capacity recommended and provided by door manufacturer for door specified, with electric motor and factory-prewired motor controls, starter, gear-reduction unit, solenoid-operated brake, clutch, remote-control stations, control devices, integral gearing for locking door, and accessories required for proper operation.
- B. Comply with NFPA 70.
- C. Disconnect Device: Provide hand-operated disconnect or mechanism for automatically engaging chain and sprocket operator and releasing brake for emergency manual operation while disconnecting motor without affecting timing of limit switch. Mount disconnect and operator so they are accessible from floor level. Include interlock device to automatically prevent motor from operating when emergency operator is engaged.
- D. Design operator so motor may be removed without disturbing limit-switch adjustment and without affecting emergency auxiliary operator.
- E. Provide control equipment complying with NEMA ICS 1, NEMA ICS 2, and NEMA ICS 6, with NFPA 70 Class 2 control circuit, maximum 24-V, ac or dc.
- F. Door-Operator Type: Provide wall-, hood-, or bracket-mounted, jackshaft-type door operator unit consisting of electric motor, drive, and chain and sprocket secondary drive.
- G. Electric Motors: Provide high-starting torque, reversible, continuous-duty, Class A insulated, electric motors complying with NEMA MG 1; with overload protection; sized to start, accelerate, and operate door in either direction from any position, at not less than 2/3 fps and not more than 1 fps, without exceeding nameplate ratings or service factor.
 - 1. Type: Polyphase, medium-induction type.
 - 2. Service Factor: According to NEMA MG 1, unless otherwise indicated.
 - 3. Coordinate wiring requirements and electrical characteristics of motors with building electrical system.
- H. Remote-Control Station: Provide momentary-contact, three-button control station with push-button controls labeled "Open," "Close," and "Stop."
 - 1. Provide interior units, full-guarded, surface-mounted, heavy-duty type, with general-purpose NEMA ICS 6, Type 1 enclosure.
- I. Obstruction Detection Device: Provide each motorized door with indicated external automatic safety sensor capable of protecting full width of door opening. Activation of sensor immediately stops and reverses downward door travel.
- J. Limit Switches: Provide adjustable switches, interlocked with motor controls and set to automatically stop door at fully opened and fully closed positions.
- K. Provide electric operators with ADA-compliant audible alarm and visual indicator lights.
- L. Radio Control: Provide radio control system consisting of the following:
 - 1. Three-channel universal coaxial receiver to open, close, and stop door, one per operator.
 - 2. Multifunction remote control.

3. Remote antenna mounting kit.

2.7 FINISHES

- A. Appearance of Finished Work: Variations in appearance of abutting or adjacent pieces are acceptable if they are within one-half of the range of approved samples. Noticeable variations in the same piece are not acceptable. Variations in appearance of other components are acceptable if they are within the range of approved samples and are assembled or installed to minimize contrast.
- B. Powder-Coat Finish: Manufacturer's standard powder-coat finish consisting of primer and topcoat according to coating manufacturer's written instructions for cleaning, pretreatment, application, thermosetting, and minimum dry film thickness.
 1. Color and Gloss: As selected by DB Entity from manufacturer's full range.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. General: Install coiling doors and operating equipment complete with necessary hardware, jamb and head molding strips, anchors, inserts, hangers, and equipment supports.
 1. Install fire-rated doors to comply with NFPA 80.
 2. Test fire-rated unit to demonstrate proper operation. Adjust until proper operation is achieved.

3.2 ADJUSTING

- A. Lubricate bearings and sliding parts; adjust doors to operate easily, free of warp, twist, or distortion and with weathertight fit around entire perimeter.

3.3 STARTUP SERVICES

- A. Engage a factory-authorized service representative to perform startup service.
 1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Test door closing when activated by detector or alarm-connected fire-release system. Reset door-closing mechanism after successful test.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to train the Authority's maintenance personnel to adjust, operate, and maintain overhead coiling doors.

END OF SECTION

SECTION 08711

DOOR HARDWARE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies hardware for all operable doors for the purposes of coordination. This Section includes the following items.
1. Commercial door hardware.
 2. Hardware for doors specified in other Sections as listed below.
 3. Electrified door hardware.
 4. Electronic access control system (EACS) hardware
- B. Items to be Furnished Only: Furnish the following items for installation by others.
1. Lock cylinders and cores: Medico high security lock cylinders and non-removable cores with restricted keyways particular to the MBTA.
 - a. The Medico cylinders are Medico DR keyway M3.
 - b. These cylinders are additional to the cylinders and construction cores to be furnished and installed in each lock set as specified in Part 3 of this Section.
- C. Related Work - It shall be the DB Entity's option to assign the furnishing and installation of hardware for doors specified in Other Sections to the appropriate Subcontractor. Other Sections include, but are not limited to:
1. Volume 2 Technical Provisions for requirements for metal gates and station closure elements.
 2. Section 08331 – OVERHEAD COILING DOORS; lock cylinders and cores
 3. Section 16702– ELECTRONIC ACCESS CONTROL SYSTEM; card readers, audio/visual alarms, security terminal cabinets
- D. Related Work – Items Not Included: The following items are not included in this Section and will be performed under the designated Sections:
1. Division 16 of Exhibit 2A.1 – ELECTRICAL; power for electrified door hardware and interface with building control and security systems.
- E. Integration of EACS Work: The installation of electronic access control system (EACS) hardware requires coordination between trades. It shall be the DB Entity's option to assign the furnishing and installation of EACS hardware and components to the appropriate Subcontractor.

1.2 SUBMITTALS

- A. Product Data: Include installation details, material descriptions, dimensions of individual components and profiles, and finishes.
- B. Shop Drawings: Details of electrified door hardware, indicating the following:
 - 1. Wiring Diagrams: Detail wiring for power, signal, and control systems and differentiate between manufacturer-installed and field-installed wiring. Include the following:
 - a. System schematic.
 - b. Point-to-point wiring diagram.
 - c. Riser diagram.
 - d. Elevation of each door.
 - 2. Detail interface between electrified door hardware and fire alarm access control and building control and security systems.
- C. Door Hardware Schedule: Prepared by or under the supervision of supplier, detailing fabrication and assembly of door hardware, as well as procedures and diagrams. Coordinate the final Door Hardware Schedule with doors, frames, and related work to ensure proper size, thickness, hand, function, and finish of door hardware.
 - 1. Format: Comply with scheduling sequence and vertical format in DHI's "Sequence and Format for the Hardware Schedule."
 - 2. Organization: Organize the Door Hardware Schedule into door hardware sets indicating complete designations of every item required for each door or opening.
 - 3. Content: Include the following information:
 - a. Type, style, function, size, label, hand, and finish of each door hardware item. Note that the correct hand of the door
 - b. Manufacturer of each item.
 - c. Fastenings and other pertinent information.
 - d. Location of each door hardware set, cross-referenced to Drawings, both on floor plans and in door and frame schedule.
 - e. Explanation of abbreviations, symbols, and codes contained in schedule.
 - f. Mounting locations for door hardware.
 - g. Door and frame sizes and materials.
 - h. Description of each electrified door hardware function, including location, sequence of operation, and interface with other building control systems.
 - 1) Sequence of Operation: Include description of component functions that occur in the following situations: authorized person wants to enter; authorized person wants to exit; unauthorized person wants to enter; unauthorized person wants to exit.
 - i. Note that correct hand of door hardware is the responsibility of the hardware supplier.

4. Submittal Sequence: Submit the final Door Hardware Schedule at earliest possible date, particularly where approval of the Door Hardware Schedule must precede fabrication of other work that is critical in the Project construction schedule. Include Product Data, Samples, Shop Drawings of other work affected by door hardware, and other information essential to the coordinated review of the Door Hardware Schedule.
- D. Keying Schedule: Prepared by or under the supervision of supplier, detailing the Engineer's final keying instructions for locks. Include schematic keying diagram and index each key set to unique door designations.
 - E. Product Certificates: Signed by manufacturers of electrified door hardware certifying that products furnished comply with requirements.
 1. Certify that door hardware approved for use on types and sizes of labeled fire doors complies with listed fire door assemblies.
 - F. Qualification Data: For firms and persons specified in Part 1 "Quality Assurance" Article.
 1. Include lists of completed projects with project names and addresses of architects and Authorities, and other information specified.
 - G. Maintenance Data: Include maintenance manuals for each type of door hardware.
 - H. Warranties: Special warranties specified in this Section.
 - I. Closeout:
 1. Submit RECORD COPY of hardware schedule and product cuts, as indicated. Submission to contain contact information for Supplier and the DB Entity.
 2. Submit Manufacturers' warranties as listed below.
 - J. Proprietary Products: The MBTA has established the following as proprietary manufacturers of the specified items:
 1. All cylinders shall be Medico DR Keyway M3 high security lock cylinders with non-removable cores particular to the MBTA.

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: An experienced installer who has completed door hardware similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance.
- B. Supplier Qualifications: Door hardware supplier with warehousing facilities in Project's vicinity and who is or employs a qualified Architectural Hardware Consultant, available during the course of the Work to consult with the DB Entity about door hardware and keying.
 1. Electrified Door Hardware Supplier Qualifications: An experienced door hardware supplier who has completed projects with electrified door hardware similar in material, design, and extent to that indicated for this Project, whose work has resulted in construction with a record of successful in-service performance, and who is acceptable to manufacturer of primary materials.

- a. Engineering Responsibility: Prepare data for electrified door hardware, including Shop Drawings, based on testing and engineering analysis of manufacturer's standard units in assemblies similar to those indicated for this Project.
 2. Scheduling Responsibility: Preparation of door hardware and keying schedules.
- C. Architectural Hardware Consultant Qualifications: A person who is currently certified by the Door and Hardware Institute as an Architectural Hardware Consultant and who is experienced in providing consulting services for door hardware installations that are comparable in material, design, and extent to that indicated for this Project.
1. Electrified Door Hardware Qualifications: Experienced in providing consulting services for electrified door hardware installations.
- D. Source Limitations: Obtain each type and variety of door hardware from a single manufacturer, unless otherwise indicated.
1. Provide electrified door hardware from same manufacturer as mechanical door hardware, unless otherwise indicated. Manufacturers that are listed to perform electrical modifications, by a testing and inspecting agency acceptable to authorities having jurisdiction, are acceptable.
- E. Regulatory Requirements: Comply with provisions of the following:
1. Where indicated to comply with accessibility requirements, comply with Massachusetts Architectural Access Board and the Americans with Disabilities Act (ADA), "Accessibility Guidelines for Buildings and Facilities (ADAAG)," as follows:
 - a. Handles, Pulls, Latches, Locks, and other Operating Devices: Shape that is easy to grasp with one hand and does not require tight grasping, tight pinching, or twisting of the wrist.
 - b. Door Closers: Comply with the following maximum opening-force requirements indicated:
 - 1) Interior Hinged Doors: 5 lbf applied perpendicular to door.
 - 2) Sliding or Folding Doors: 5 lbf applied parallel to door at latch.
 - 3) Fire Doors: Minimum opening force allowable by authorities having jurisdiction.
 - c. Thresholds: Not more than ½" high. Bevel raised thresholds with a slope of not more than 1:2.
 2. NFPA 101: Comply with the following for means of egress doors:
 - a. Latches, Locks, and Exit Devices: Not more than 15 lbf to release the latch. Locks shall not require the use of a key, tool, or special knowledge for operation.
 - b. Delayed-Egress Locks: Lock releases within 15 seconds after applying a force not more than 15 lbf for not more than 3 seconds.
 - c. Door Closers: Not more than 30 lbf to set door in motion and not more than 15 lbf (67 N) to open door to minimum required width.
 - d. Thresholds: Not more than ½" high.
 3. Electrified Door Hardware: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction.

- F. Fire-Rated Door Assemblies: Provide door hardware for assemblies complying with NFPA 80(2007) that are listed and labeled by a testing and inspecting agency acceptable to authorities having jurisdiction, for fire ratings indicated, based on testing according to NFPA 252.
 - 1. Test Pressure: Test at atmospheric pressure.
- G. Field Measurement: The DB Entity shall verify all dimensions in the field, including, but not limited to, door and frame opening dimensions and wall thickness dimensions.
- H. Keying Conference: Incorporate keying conference decisions into final keying schedule after reviewing door hardware keying system including, but not limited to, the following:
 - 1. Function of building, flow of traffic, purpose of each area, degree of security required, and plans for future expansion.
 - 2. Preliminary key system schematic diagram.
 - 3. Requirements for key control system.
 - 4. Address for delivery of keys.
- I. Pre-installation Conference: Review methods and procedures related to electrified door hardware including, but not limited to, the following:
 - 1. Inspect and discuss electrical roughing-in and other preparatory work performed by other trades.
 - 2. Review sequence of operation for each type of electrified door hardware.
 - 3. Review and finalize construction schedule and verify availability of materials, Installer's personnel, equipment, and facilities needed to make progress and avoid delays.
 - 4. Review required testing, inspecting, and certifying procedures.

1.4 MARKING AND PACKING

- A. Door hardware shall arrive at the site in its original packaging. All packages shall be legibly labeled indicating manufacturer's numbers, types, sizes and hardware schedule reference number. All hardware shall be wrapped in paper and shall be packed in the same package as all screws, bolts and fasteners necessary for proper installation.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Inventory door hardware on receipt and provide secure lock-up for door hardware delivered to Project site. Do not store electronic access control hardware, software or accessories at Project site without prior authorization.
- B. Tag each item or package separately with identification related to the final Door Hardware Schedule, and include basic installation instructions with each item or package.
- C. Deliver permanent keys, cylinders, cores and related accessories directly to the MBTA via registered mail or overnight package service. Instructions for delivery to the MBTA shall be established at the "Keying Conference".

1.6 COORDINATION

- A. Coordinate layout and installation of recessed pivots and closers with floor construction. Cast anchoring inserts into concrete. Concrete, reinforcement, and formwork requirements are specified in Section 03300 - CAST-IN-PLACE CONCRETE.
- B. Templates: Obtain and distribute to the parties involved templates for doors, frames, and other work specified to be factory prepared for installing door hardware. Check Shop Drawings of other work to confirm that adequate provisions are made for locating and installing door hardware to comply with indicated requirements.
- C. Electrical System Roughing-in: Coordinate layout and installation of electrified door hardware with connections to power supplies, fire alarm system and detection devices, access control and building control system.

1.7 WARRANTY

- A. General Warranty: Special warranties specified in this Article shall not deprive the Authority of other rights the Authority may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by the DB Entity under requirements of the Contract Documents.
- B. Special Warranty: Written warranty, executed by manufacturer agreeing to repair or replace components of door hardware that fail in materials or workmanship within specified warranty period. Failures include, but are not limited to, the following:
 - 1. Structural failures including excessive deflection, cracking, or breakage.
 - 2. Faulty operation of operators and door hardware.
 - 3. Deterioration of metals, metal finishes, and other materials beyond normal weathering.
- C. Warranty Period: Three years from date of Contract Substantial Completion, unless otherwise indicated.
- D. Warranty Period for Manual Closers: Ten years from date of Contract Substantial Completion.

1.8 SPECIAL REQUIREMENTS

- A. Hardware Supplier shall determine conditions and materials for all doors and frames for the proper application of hardware.
- B. Hardware Supplier shall be responsible for the accuracy of the quantities, sizes, finish and proper hardware to be furnished, whether specifically mentioned or not.
- C. All lever trim for door locks to hazardous areas such as mechanical rooms shall have a tactile surface to comply requirements of the third-party involved.
- D. Tools for maintenance: All tools shall be packed with hardware items shall be saved and turned over to the MBTA upon completion of the work.
- E. Lock fronts, flush bolt faces and strikes shall be beveled in accordance with manufacturer's standards.

1.9 ATTIC STOCK

- A. Provide a minimum of one additional unit of each specified product item. Where the quantity of any specified item numbers more than 10, provide one additional unit for each additional 10 items specified.

1.10 MAINTENANCE SERVICE

- A. Maintenance Tools and Instructions: Furnish a complete set of specialized tools and maintenance instructions as needed for the MBTA’s continued adjustment, maintenance, and removal and replacement of door hardware.

1.11 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties with all agents whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS PREFERRED DOOR HARDWARE

- A. The MBTA has identified a number of specific door hardware items for which they have a preferred manufacturer.

Item	Preferred Manufacturer	Acceptable Manufacturers
Locksets & Deadlocks	Schlage (SCH), Sargent(SAR), Yale (YA)	As listed below
Electric Strikes	HES	As listed below
Cylinders & Keying	Medico (MED)	None
Exit Devices & Mullions	Von Duprin (VON)	As listed below
Door Closers	LCN	As listed below
Automatic Operators	RECORD (REC)	As listed below

2.2 SCHEDULED DOOR HARDWARE

- A. Scheduled and acceptable manufacturers must provide all the functions and features of the specified product or it will not be approved.

	Scheduled Manufacturer	Acceptable Manufacturers
Hinges (at typical doors)	Ives (IVE)	McKinney, Hager, Stanley
Continuous Hinges (at high-frequency doors)	SELECT (SEL)	McKinney, Stanley
Locksets & Deadlocks	Schlage (SCH)	Sargent, Yale
Electric Strikes	HES	Folger Adams, Von Duprin

Electromagnetic Locks	Schlage (SCH)	
Keypad Locks	Schlage (SCH)	Campus Standard
Cylinders & Keying	Medico (MED)	None
Exit Devices & Mullions	Von Duprin (VON)	Sargent, Yale
Door Closers	LCN (LCN)	Sargent,
Automatic Operators	RECORD (REC)	LCN, Stanley
Push & Pull Plates & Bars	Ives (IVE)	Rockwood, Burns
Flush Bolts & Coordinators	Ives (IVE)	Rockwood, Burns
Protection Plates	Ives (IVE)	Rockwood, Burns
Stops & Holders	Ives (IVE)	Rockwood, Burns
Overhead Stops	Glynn-Johnson (GLY)	Sargent, Rixson
Silencers	Ives (IVE)	Rockwood, Burns
Thresholds, Weatherstrip & Door Bottoms	National Guard (NGP)	Pemko, Reese
Door Position Switches	GE Sentrol (GE)	

- B. Hand of Door: Drawings show direction of slide, swing, or hand of each door leaf. Furnish each item of hardware for proper installation and operation of door movement as shown.
- C. Where the hardware specified is not adaptable to the finished shape or size of the members requiring hardware, furnish suitable types having the same operation and quality as the type specified, subject to the MBTA's acceptance.

2.3 MATERIALS

A. Fasteners

1. Provide hardware manufactured to conform to published templates, generally prepared for machine screw installation.
2. Furnish non-corrosive screws for installation with each hardware item. Finish exposed (exposed under any condition) screws to match hardware finish, or, if exposed in surfaces of other work, to match finish of this other work as closely as possible including "prepared for paint" surfaces to receive painted finish.
3. Provide concealed fasteners for hardware units that are exposed when door is closed except to the extent that no standard units of type specified are available with concealed fasteners. Do not use thru-bolts for installation where bolt head or nut on opposite face is exposed in other work unless their use is the only means of reinforcing the work adequately to fasten the hardware securely.
4. All hardware shall be installed with the fasteners provided by the hardware manufacturer.
5. Self-taping screws shall not be used to install hardware, except at continuous hinges.

B. Mortise Hinges

1. Material – Stainless steel (32D)
2. Design – 3-knuckle or 5-knuckle
3. Mortise hinges shall be of the same design

4. Bearings – ball bearing or concealed bearing
5. The width of hinges shall be 4 1/2" or as required for clearance.
6. Hinge Pins: Except as otherwise indicated, provide hinge pins as follows:
 - a. Steel Hinges: Steel pins
 - b. Non-Ferrous Hinges: Stainless steel pins
 - c. Out-Swinging Exterior Doors: Non-removable pins
 - d. Interior Doors: Non-rising pins
 - e. Electronic Access Control System (EACS) Doors: Non-removable pins
7. The following is a guide for hinge type required for this specification:
 - a. 1 3/4" thick doors up to and including 3'-0" wide:
Exterior: standard weight, 4 1/2" high
Interior: standard weight, 4 1/2" high
 - b. 1 3/4" thick doors over 3'-0" wide:
Exterior: heavy weight, 5" high
Interior: heavy weight, 5" high
8. Provide heavy weight HW hinges where indicated
9. Provide 3 hinges per door leaf for doors 90 inches or less in height, and one additional hinge for each 30 inches of additional door height.
10. Hinges meeting this specification: Ives 3BB1, 3BB1HW; 5BB1, 5BB1HW. McKinney TA 314, TA386HW; TA2314, T4A3386; Hager BB1191, BB1168; Stanley CB191, CB199; CB1960, CB1961.

C. Continuous Hinges

1. Concealed type geared heavy duty continuous hinges at high-frequency portals (unless otherwise noted). Material/Finish – clear aluminum
 - a. Preferred Manufacturer: SELECT – SL-11HD
 - b. Acceptable Manufacturers:
McKinney MCK-12 HD
Stanley 661 HD.
2. Continuous hinges at exterior gates shall be heavy duty 12 gauge stainless steel pin & barrel full mortise type, capable of carrying doors up to 600 pounds.
 - a. Products meeting this specification: Stanley 651, or equal
 - b. Continuous hinges at gates shall be installed with drilled and tapped fasteners.
3. Provide bearings at each hinge knuckle for quiet, smooth, self-lubricating operation.

4. Hinges shall be capable of supporting door weights up to 600 pounds, and shall be successfully tested for 1,500,000 cycles.
5. Install hinges with fasteners supplied by manufacturer. Hole pattern shall be symmetrically patterned.
6. Where indicated, provide hinge leaf cutouts to accommodate electric power transfers.

D. Flush Bolts

1. Automatic and manual flush bolts shall have forged bronze faceplates with extruded brass levers and with wrought brass guides and strikes. Doors up to 7'-6" in height shall have 12" steel or brass rods. Manual flush bolts for doors over 7'-6" in height shall be increased by 6" for each additional 6" of door height. Provide dust-proof strikes where scheduled.

E. Coordinators

1. Where pairs of doors are equipped with automatic flush bolts, an astragal, or other hardware that requires synchronized closing of the doors, provide a bar-type coordinating device, surface applied to the underside of the stop at the frame head.
2. Finish of the coordinator to be prime coat to receive the same finish paint as the door frame.
3. Provide a filler bar of the correct length for the unit to span the entire width of the opening, and appropriate brackets for parallel arm door closers and surface vertical rod exit device strikes. Factory-prep coordinators for vertical rod devices if required.

F. Mortise Locks

1. Mortise locks shall be certified as ANSI A156.13, Grade 1 Operational, Grade 1 Security, and shall be manufactured from heavy gauge steel, containing components of steel with a zinc dichromate plating for corrosion resistance. Lock case shall be multi-function and field reversible for handing without opening the case.
2. Locks are to have a standard 2 3/4" backset with a full 3/4" throw 2-piece stainless steel mechanical anti-friction latchbolt. Deadbolt shall be a full 1" throw, constructed of stainless steel.
3. Lever trim shall be solid brass, bronze, or stainless steel, cast or forged in the design specified, with wrought roses and external lever spring cages. Levers shall be thru-bolted to assure proper alignment, and shall have a 2-piece spindle. Lever trim on the secure side of doors serving rooms considered by the authority having jurisdiction to be hazardous shall have a tactile warning. Lever design shall be Schlage 07 or similar.
4. Locks meeting this specification: Schlage L9000 series, Sargent 8200 series, Yale 8800 series.

G. Keypad Locks

1. Locksets shall be mortise type with 3-piece, beveled, stainless steel latchbolts with 3/4" throw and equipped with an anti-friction latch.
2. Chassis shall accommodate ANSI standard mortise lock prep with a 2 3/4" nominal backset for 1 3/4" doors.
3. Locksets shall be provided from the factory with appropriate handing.
4. Levers shall operate independently of each other. Lock shall use patented clutch mechanism to deter vandalism and maximize durability. Disablement of secured levers shall not permit

latchbolt retraction from secure side, but shall allow egress. Lever trim on the secure side of doors serving rooms considered by the authority having jurisdiction to be hazardous, or where noted on the door schedule, shall be knurled to provide a tactile warning. Lever style to be Schlage 07.

5. Provide key cylinder for emergency key override, with Everest/Primus core.
6. Electrical operation shall be battery operated, capable of 80,000 operating cycles using four AA alkaline batteries. Lock shall be resistant to radio frequency and electrostatic discharge.
7. Outside escutcheon shall have keypad and iButton reader.
8. Visual red and green LED indicators shall indicate activation, operational systems status, system error conditions and low power conditions.
9. Locks meeting this specification: Schlage/Locknetics CM5596.

H. Exit Devices

1. Exit devices shall be touchpad type, fabricated of brass, bronze, stainless steel, or aluminum, plated to the standard architectural finishes to match the balance of the door hardware.
2. All exit devices shall incorporate a fluid damper or other device which eliminates noise associated with exit device operation. Touchpad shall extend a minimum of one half of the door width. End-cap will have two-point attachment to door. Touch-pad shall match exit device finish, and shall be stainless steel for US26, US26D, US28, US32, and US32D finishes. Only compression springs will be used in devices, latches, and outside trims or controls.
3. All devices to incorporate a security deadlatching feature.
4. Provide roller strikes for all rim and surface mounted vertical rod devices, ASA strikes for mortise devices, and manufacturer's standard strikes for concealed vertical rod devices.
5. Mechanism case shall sit flush on the face of all flush doors, or spacers shall be furnished to fill gaps behind devices. Where glass trim or molding projects off the face of the door, provide glass bead kits.
6. All non-fire-rated exit devices shall have cylinder dogging.
7. Where lever handles are specified as outside trim for exit devices, provide heavy duty lever trims with forged or cast escutcheon plates. Provide vandal-resistant levers that will travel to a 90-degree down position when more than 35 pounds of torque are applied, and which can easily be re-set. Lever styling will match the lever style of the locksets.
8. Exit devices shall be UL listed panic exit hardware. All exit devices for fire rated openings shall be UL labeled fire exit hardware.
9. Provide electrical options as scheduled.
10. All exit devices shall be supplied for cylinder dogging. Provide cylinder housings and cores for dogging function.
11. Exit devices meeting this specification for steel doors: Von Duprin 98 series, Sargent 80 series with dead latching, Yale 7100 Series.
12. Exit devices meeting this specification for aluminum doors: Von Duprin 33A series, Sargent 8500 series, Yale 7200 series.

I. Door Closers

1. Door closers shall have fully hydraulic, full rack and pinion action with a high strength cast iron or cast aluminum cylinder. Cylinder body shall be 1 1/2" in diameter, and double heat-treated pinion shall be 11/16" in diameter.
 2. Hydraulic fluid shall be of a type requiring no seasonal closer adjustment for temperatures ranging from 120 degrees F to -30 degrees F. Fluid shall be fireproof and shall pass the requirements of the UL10C "positive pressure" fire test.
 3. Spring power shall be continuously adjustable over the full range of closer sizes, and allow for reduced opening force for the physically handicapped. Hydraulic regulation shall be by tamper-proof, non-critical valves. Closers shall have separate adjustment for latch speed, general speed, and backcheck.
 4. Closers shall have solid forged steel main arms (and forged forearms for parallel arm closers).
 5. Closers shall not incorporate a pressure relief valve.
 6. All closers shall have metal covers.
 7. Closer cylinders, arms, and metal covers shall have a powder coating finish which has been certified to exceed 100 hours salt spray testing by an independent testing laboratory used by BHMA for ANSI certification. For metal components that can't be powder coated, a special rust inhibiting finish (SRI) must be used.
 8. Door closers shall be mounted on the least public side of the door.
 9. Door closers meeting this specification: LCN 4010/4110 series, Norton 7500/PR7560 (standard screws).
- J. Push Plates: 8" wide x 16" high x .050" thick. Where door stile does not allow 8" wide plates, 4" wide plates may be used.
- K. Door Pulls & Push Bars: Solid bar stock, diameter and length as scheduled. Push bars shall be of sufficient length to span from center to center of each stile.
1. Where Long Door Pulls are indicated provide 1-1/4" diameter offset pulls with smooth gripping surface and flat ends. Provide center bracket for pulls over 72" center-to-center (CTC) of top and bottom bracket.
 - a. Long door pulls meeting this specification: Burns VP4251, Ives 92641, Rockwood RM3311
- L. Protection Plates: Provide kick plates as scheduled, with 4 beveled edges. Furnish with machine or wood screws, finished to match plates. Plates shall be 8" high x 2" LWOD on single doors, 1" LWOD on pairs of doors.
- M. Door Stops and Holders
1. It shall be the responsibility of the hardware supplier to provide door stops for all doors in accordance with the following requirements:
 - a. Wall stops shall be used wherever possible.
 - b. Where wall stops cannot be used, provide dome type floor stops of the proper height.
 - c. At any opening where a wall or floor stop cannot be used, a heavy duty overhead stop must be used.

- N. Thresholds and Weatherstrip: Furnish as scheduled and per architectural details. Match finish of other items as closely as possible. Provide only those units where resilient or flexible seal strip is easily replaceable and readily available.
- O. Silencers: "Push-in" type silencers for each hollow metal or wood frame, 3 for each single frame, 2 for each pair frame. Omit where gasketing is scheduled.
- P. Automatic Operators:
1. Automatic Operators shall be heavy duty low energy surface mounted automatic swing door operators consisting of aluminum housing, electro-mechanical motor, operator assembly, swing arm, electronic control, wire harnesses, signage and push plate control devices.
 2. Units shall comply with the following:
 - a. Current ANSI A156.19 for Power Assist and Low Energy Power Operated Doors. Automatic operators shall comply with opening force and time to close standards required to be accessible to the disabled.
 3. Provide single and dual operators for doors swinging in the same direction, as specified.
 4. The operators shall be non-handed. Opening Force shall be adjustable.
 5. Electronic controls: Microprocessor controlled unit shall control the operation and switching of the swing power operator. The microprocessor control shall provide low voltage power supply for all means of actuation.
 6. Door opening: The door connecting hardware shall accommodate up to a 12" reveal and opening angles to 120 degrees.
 7. Normal Open: The operator shall serve as a manual door closer in the direction of swing with or without electrical power. Full closing force shall be provided when the power operation cycle ends.
 8. Power Open: When an opening signal is received by the control unit, the door shall be opened at the operator-adjusted opening speed. Before the door is fully open at back check, it shall slow automatically to low speed. The motor shall stop with the selected door opening.
 9. External Control: A three position switch shall be mounted in the end cover of the housing, along with a "fault warning" LED. The switch shall be marked ON/OFF/HOLD OPEN. The LED shall flash if the microprocessor detects a fault of any kind.
 - a. Provide the capability for the three position switch to be remotely located.
 10. Power Close: Closing shall be provided by means of a spring and motor. When the hold open time has elapsed, the operator will close the door automatically, using spring force and motor. The door will slow to low speed at latch catch before it reaches the fully closed position. The door is kept closed by spring power or extended closing force by the motor.
 11. Power Assist: Operator can be adjusted to lower the forces when used manually. Power assist will be active only when applied while pushing or pulling the door and will allow the door to close when an opening force is no longer applied to the door.
 12. Electronic dampening: Operator shall include standard electric dampening system which automatically counteracts additional forces applied to the door during the opening or closing cycle by reducing door speed.

13. Stack Pressure Feature: The electronic control allows for increases of forces to overcome stack pressure issues. The control automatically compensates for lower manual push forces when the door is used in manual mode. The door must comply with ANSI A156.19, when using this feature.
14. Lock Engage Circuit: Not used.
15. Push Plate Control Devices: Provide hard wired push plate switches. Switches shall be remotely mounted on stanchions.
16. Signage: Provide signage in accordance with ANSI/BHMA A156.19.
17. Locate power unit and exhaust away from door to minimize noise and vibration in pedestrian areas. Provide two low voltage 18 gauge stranded wires from automatic operator to activation devices (50 ft max).
18. All power operator systems shall include the following features and functions:
 - a. Provisions for separate conduits to carry high and low voltage wiring in compliance with the National Electric Code, section 725-31.
 - b. When an obstruction or resistance to the opening swing is encountered, the operator will continue attempting to open the door. If the obstruction or resistance remains, the operator will pause the door again.
 - c. The operator will be designed to prevent damage to the mechanism if the system is actuated while the door is latched or if the door is forced closed during the opening cycle.
 - d. Power consumption must be less than or equal to the following: Nominal power 67 watts, Nominal current .08A at 120VAC. Peak power consumption 2.9A. standby .02A with
 - e. Power consumption of 13watts.
 - f. Electric motor shall be equipped with built-in thermal overload protection.
19. Provisions in the control box or module shall provide control (inputs and outputs) for: electric strike delay, auxiliary contacts, sequential operation, fire alarm systems, actuators, swing side sensors, and stop side sensors.
20. Operators at Electronic Access Control System(EACS) doors:
 - a. The EACS shall be interconnected through the push plate control device so that a valid card transaction is required to enable the push plate control device to send a signal to the operator to open the door.
21. Provide safety sensors exterior and interior of automatic operating doors.
22. All exposed aluminum surfaces shall be clear anodized.
23. Preferred Manufacturer: Record 8200 Series
24. Acceptable manufacturers: LCN 9550 Series, Stanley Magic-Swing

Q. Electric Strikes

1. Provide electric strikes of configurations and with trim appropriate for the supplied lock sets and exit devices.
2. Standard Electric Strikes: Heavy duty mortise lock electric strikes conforming to ANSI/BHMA A156.31, Grade 1, UL listed for both Burglary Resistance and for use on fire rated door assemblies. Stainless steel construction with dual interlocking plunger design tested to exceed 3000 lbs. of static strength and 350 ft-lbs. of dynamic strength. Strikes tested for a minimum 1

million operating cycles. Provide strikes with 12 or 24 VDC capability and supplied standard as fail-secure unless otherwise specified. Provide faceplates appropriate for the operating hardware.

- a. Preferred Manufacturer: HES - 1006 Series
 - b. Acceptable Manufacturers:
Folger Adams (FO) – 310 Series
Von Duprin (VON) - 6000 Series.
 - c. Electric strikes shall be fail-secure unless otherwise noted.
3. Surface Mounted Rim Electric Strikes: Surface mounted rim exit device electric strikes conforming to ANSI/BHMA A156.31, Grade 1, and UL Listed for both Burglary Resistance and for use on fire rated door assemblies. Construction includes internally mounted solenoid with two heavy-duty, stainless steel locking mechanisms operating independently to provide tamper resistance. Strikes tested for a minimum of 500,000 operating cycles. Provide strikes with 12 or 24 VDC capability supplied standard as fail-secure unless otherwise specified.
- a. Preferred Manufacturer: HES - 9500/9600 Series.
 - b. Acceptable Manufactures:
Folger Adams (FO) – 310-4
Von Duprin (VON) - 6100 Series
 - c. Electric strikes shall be fail-secure unless otherwise noted.
 - d. Provide a Surface Mount Box accessory at door pairs with an active and an inactive leaf.
4. Hurricane and Tornado Resistance Compliance: Electric strikes to be U.L. listed for windstorm components where applicable. Provide the appropriate hurricane or tornado resistant products that have been independent third party tested, certified, and labeled to meet state and local windstorm building codes applicable to project.
5. Provide electric strikes with in-line power controller and surge suppressor by the same manufacturer as the strike with combined products having unlimited lifetime warranty.
6. Voltage shall be 24VDC.

R. Electromagnetic Gate Locks

1. Electromagnetic gate locks shall have magnetic bond sensors and gate status monitors.
2. Voltage – 24 volts
3. Electromagnetic gate lock to have compression fitting at cable connection and 24inch wire leads.
4. Finish shall be heavy-duty plating – nickel finish
5. Provide mounting brackets to accommodate frame mounting and misalignments
6. Acceptable manufacturers: Schlage M490G; or equal.

S. Miscellaneous

1. Silencers: "Push-in" type silencers for each hollow metal or wood frame, 3 for each single frame, 2 for each pair frame. Omit where gasketing is scheduled.
2. Electric Power Transfers (EPT): Provide Von Duprin EPT-10, or equal

3. Door Cords: Provide Von Duprin DL-18, or equal
4. Power Supplies and Transformers:
 - a. Provide power supplies and transformers appropriate for hardware requiring low voltage power.
 - b. Provide cabinets with key lock covers for power supplies and transformers.
5. Removable mullions. Provide keyed removable mullions (designated KR MULLION) where indicated in hardware sets. Provide appropriate model for adjacent door hardware. Preferred Manufacturer: Von Duprin models 1654, 4954, 9954.

T. Door Position Switches

1. Door Position Switches shall be by the same manufacturer.
2. Unless otherwise noted, door position switches shall be Steel Door Contacts, GE-Sentrol 1078C, or equal.
 - a. At doors with recessed channels at head, provide Rare Earth Magnets, GE-Sentrol 1840, or equal.
3. At grout-filled masonry frames and aluminum curtain wall or storefront frames, door position switches shall be Balance Magnetic Switches, GE-Sentrol 2702A, or equal. Provide brackets of shapes and sizes for installation and adjustment.
4. At overhead coiling doors, door position switches shall be wide gap Balanced Magnetic Switches, GE-Sentrol 2707AU, or equal. Provide brackets of shapes and sizes for installation and adjustment.

2.4 FINISHES

- A. With the exception of all items listed below, the finish of all hardware shall be US26D - satin chrome or US32D - satin stainless steel.
- B. Exceptions are as follows:
 1. Door Closers - aluminum powder coat finish.
 2. Coordinators - prime painted.
 3. Thresholds - mill finish aluminum.
 4. Weatherstrip & Sweeps - clear anodized aluminum.
 5. Silencers - grey.

2.5 KEYING

- A. All locks and cylinders shall be construction master keyed and master keyed per the Authority's instructions, to existing key system.
- B. All locks and cylinders, except cylinders for keypad locks will be interchangeable core type.
- C. Provide 3 keys per lock, 6 construction master keys, and a total of 6 master keys for each group.

- D. All master keys shall be delivered directly to the Authority by the hardware supplier, who shall obtain a receipt for delivery of same.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine doors and frames, with Installer present, for compliance with requirements for installation tolerances, labeled fire door assembly construction, wall and floor construction, and other conditions affecting performance.
- B. Examine roughing-in for electrical power systems to verify actual locations of wiring connections before electrified door hardware installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Steel Doors and Frames: Comply with DHI A115 series.
- B. Surface-Applied Door Hardware: Drill and tap doors and frames according to SDI 107.
- C. Wood Doors: Comply with DHI A115-W series.

3.3 INSTALLATION

- A. Mounting Heights: Mount door hardware units at heights indicated in following applicable publications, unless specifically indicated or required to comply with governing regulations:
 - 1. Standard Steel Doors and Frames: DHI's "Recommended Locations for Architectural Hardware for Standard Steel Doors and Frames."
 - 2. Custom Steel Doors and Frames: DHI's "Recommended Locations for Builders' Hardware for Custom Steel Doors and Frames."
- B. Install each door hardware item to comply with manufacturer's written instructions. Where cutting and fitting are required to install door hardware onto or into surfaces that are later to be painted or finished in another way, coordinate removal, storage, and reinstallation of surface protective trim units with finishing work specified in Division 9 Sections of Exhibit 2A.1. Do not install surface-mounted items until finishes have been completed on substrates involved.
 - 1. Set units level, plumb, and true to line and location. Adjust and reinforce attachment substrates as necessary for proper installation and operation.
 - 2. Drill and countersink units that are not factory prepared for anchorage fasteners. Space fasteners and anchors according to industry standards.
- C. Key Control System: Place keys on markers and hooks in key control system cabinet, as determined by final keying schedule.

- D. **Boxed Power Supplies:** Locate power supplies as indicated or, if not indicated, above accessible ceilings. Verify location with Engineer.
 - 1. **Configuration:** Provide the least number of power supplies required to adequately serve doors with electrified door hardware.
- E. **Thresholds:** Set thresholds for exterior and acoustical doors in full bed of sealant.
 - 1. Thresholds shall be full width of door opening.

3.4 SPECIAL INSTRUCTIONS

- A. **General**
 - 1. Prior to installation, the DB Entity is to test each electrified finish hardware device to verify that it is in working order, and ready for installation.
 - 2. Electrified hardware is to be installed with wiring concealed within door and/or door frame.
 - 3. Install construction cores in all locking hardware at time of installation. Replace construction cores with permanent cores when directed by the MBTA.
 - 4. The DB Entity shall retain responsibility for hardware installation until final acceptance. This includes control of hardware during and through the wiring of electrified devices. Coordinate installation of electrified door hardware with electrical trades.
 - 5. Provide a person on-site when access control door is brought on-line to accommodate replacement of mal-functioning hardware components.

3.5 ADJUSTING

- A. **Initial Adjustment:** Adjust and check each operating item of door hardware and each door to ensure proper operation or function of every unit. Replace units that cannot be adjusted to operate as intended. Adjust door control devices to compensate for final operation of heating and ventilating equipment and to comply with referenced accessibility requirements.
 - 1. **Spring Hinges:** Adjust to achieve positive latching when door is allowed to close freely from an open position of 30 degrees.
 - 2. **Electric Strikes:** Adjust horizontal and vertical alignment of keeper to properly engage lock bolt.
 - 3. **Door Closers:** Adjust sweep period so that, from an open position of 70 degrees, the door takes at least 3 seconds to move to a point 3 inches from the latch, measured to the leading edge of the door.
- B. **Six-Month Adjustment:** Six months after date of Contract Substantial Completion, Installer shall perform the following:
 - 1. Examine and readjust each item of door hardware as necessary to ensure function of doors, door hardware, and electrified door hardware.
 - 2. Consult with and instruct the MBTA's personnel on recommended maintenance procedures.

3. Replace door hardware items that have deteriorated or failed due to faulty design, materials, or installation of door hardware units.

3.6 CLEANING AND PROTECTION

- A. Clean adjacent surfaces soiled by door hardware installation.
- B. Clean operating items as necessary to restore proper function and finish.
- C. Provide final protection and maintain conditions that ensure door hardware is without damage or deterioration at time of Contract Substantial Completion.

3.7 HARDWARE SCHEDULE

- A. Provide hardware for each door to comply with requirements of Section “Door Hardware,” hardware set numbers indicated in door schedule, and in the following schedule of hardware sets.
- B. It is indicated that the following schedule includes complete items or finish hardware necessary to complete the work. If a discrepancy is found in the schedule, such as a missing item, improper hardware for a frame, door or fire codes, the preamble will be the deciding document.
- C. Abbreviations:
 - CR – card reader
 - EACS – electronic access control system
 - PR - pair
 - SGL – singleRefer to paragraphs 2.1 & 2.2 for manufacturer abbreviations used in this schedule

END OF SECTION

SECTION 09360

MODULAR TACTILE SURFACES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies modular tactile surface sheet tile and filled pavers at station platforms.
- B. Related Work:
 - 1. Volume 2 Technical Provisions Exhibit 2I, Additional Project Requirements.
 - 2. Section 03300 - CAST-IN-PLACE CONCRETE: Concrete substrate.
 - 3. Section 09300 - TILE: Tile adjacent to modular tiles.

1.2 SUBMITTALS

- A. Shop drawings: Include complete layout and fabrication details, composite structure, dimensions of tiled areas, and affected adjacent areas. Provide large scale plan details of the tiles at the curves, including fastener locations.
- B. Product Data: Manufacturer's catalog cuts, material specifications, installation and maintenance instructions, and other data pertinent to the work of this Section.
- C. Samples: One full-size sample of the type, size, pattern, and color of tile required, and five six by six inch samples for MBTA records.
- D. Material Certification: Manufacturer's certification that all products meet specified requirements, as verified by a certified independent testing agency. Submit certified test reports for all tests shown in Article 2.02 B, indicating for each test whether or not the tile passes or fails the passing criteria. Test report shall be current and shall not predate the notice to proceed date of this contract by more than two years.
- E. Installer Certification: Manufacturer's approval of installer if other than manufacturer, and detailed work history with the product proposed for installation.
- F. Extra Materials: After completion of the work, furnish a minimum of ten percent of the total amount of tile furnished, from the same manufactured lot as materials furnished for work of this Section, in sealed, protective packaging marked with Contract number, lot number and identification contents. Store in a location designated by the DB Entity.

1.3 QUALITY ASSURANCE

- A. **Manufacturer:** A company specializing in the manufacture of modular tactile surface tiles as used in transit systems for guidance of the sight impaired. Product must have been installed at other locations with successful records of performance and product durability.
- B. **Installer:** Manufacturer-approved installer with documented experience in work similar to that of this Section. The Installer must be accepted by the MBTA before installation of the tile may begin.
- C. **First Time Suppliers and Installers:** For first time installers and suppliers of tactile tile to the MBTA, a meeting with representatives of the MBTA, the DB Entity, Surface Preparation subcontractor, Manufacturer, and Installer in attendance is mandatory. The agenda shall include the review and clarification of the specification, installation procedures, quality control, inspection and acceptance criteria and installation schedules. In no case will installation be allowed to commence until this meeting is held.
- D. **Hold Point - Mock-Up:** After approval of materials, erect an eight foot long tile mock-up using specified materials, per Volume 2 Technical Provisions Exhibit 2I, Additional Project Requirements.
 - 1. Assign the same construction crew to both the mock-up and the permanent work.
 - 2. If not accepted, remove and replace mock-up at no additional cost to the MBTA. Repeat procedure until approval is granted.
 - 3. Accepted mock-up shall serve as the quality standard for appearance, tolerances, and workmanship.
 - 4. Accepted mock-up may be incorporated in the permanent work, with the following certification.
 - 5. Protect and maintain accepted mock-up in accepted condition throughout the construction period. When no longer required, remove and dispose of offsite, if not incorporated into the permanent work.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Deliver materials and products in unopened, factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Store under cover and protect from all damage and pilferage

1.5 WARRANTY

- A. **Warranty:** In addition to the requirements of the General Conditions, furnish a warranty jointly executed by the tile manufacturer and the installer. Warrant the work executed in this Section for a period of five years against failure of tile material, workmanship, and installation for the work performed under the supervision of the manufacturer of the tile. The Warranty shall include breakage, deformation, fading, chalking of finishes, loosening of tiles, and mechanical fasteners, which are used for securing the tiles to the platform.

PART 2 - PRODUCTS

2.1 MODULAR TACTILE SURFACE TILE

- A. Accessibility Requirements: The modular tactile tile surface system shall differ from adjoining surfaces in resiliency or sound-on-cane contact as set forth by the latest requirements of the Americans with Disabilities (ADA) and the Massachusetts Architectural Access Board (AAB). Such reference is intended to establish quality and performance characteristics and meet the legal definition of the law.
- B. Modular Tile: Provide fiberglass polymer platform edge surfaces with custom sheet size as indicated on Drawings. Provide 1/8" minimum to 3/16" maximum thicknesses of the non-domed surface. The tactile tile shall be fabricated with a solid dome and solid body. Tile shall have a truncated dome design in patterns conforming to Americans with Disabilities Act Architectural Guidelines (ADAAG) requirements. Tiles shall have integral safety yellow color throughout the entire thickness of material.
1. Modular Tactile Surface at Curb Ramps: 24" wide, 1-1/2" thick polymer-concrete- filled fiberglass tile, maximum slope of 8 percent, in contrasting color with curb. Unit shall be flush with roadway and be able to withstand AASHTO H-20 truck loading.
- C. Performance Requirements: Tiles shall be chemically test certified to resist corrosion by sand, salt, and salt substitutes and resist color change and be resistant to ultraviolet rays. Tiles shall exhibit the following properties, and be tested using the corresponding test method, and meet the respective passing criteria, as follows:
1. Property: Water Absorption.
 - a. Test Method: ASTM D570 - Standard Test Method for Water Absorption of Plastics.
 - b. Passing Criteria: No greater absorption than 0.35% of weight increase due to saturation.
 2. Property: Compressive Strength.
 - a. Test Method: ASTM D 695 - Standard Test Method for Compressive Properties of Rigid Plastics.
 - b. Passing Criteria: 13000 psi average compressive strength.
 3. Property: Slip Resistance.
 - a. Test Method: ASTM C1028 - Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method.
 - b. Passing Criteria: Minimum coefficient of friction of 0.80 with Neolite under wet and dry conditions.
 4. Property: Impact Resistance.
 - a. Test Method: ASTM D 5420 - Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling eight Gardner Impact).
 - b. Passing Criteria: No cracks at ambient temperature.

5. Property: Accelerated Weathering.
 - a. Test Method: ASTM G 26 - Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.
 - b. Passing Criteria: No deterioration, fading, or chalking of tile surface after 500 hrs. of exposure.
6. Property: Fire Resistance.
 - a. Test Method: ASTM E 136 - Standard Method for Behavior of Materials in a Vertical Tube Furnace at 750 degrees C.
 - b. Passing Criteria: Material shall conform to the contained criteria to be considered noncombustible.
7. Property: Flexural Strength.
 - a. Test Method: ASTM D 790 - Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
 - b. Passing Criteria: 15,000 psi average flexural strength.
8. Property: Stain and Chemical Resistance.
 - a. Test Method: ASTM D 543 - Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents.
 - b. Passing Criteria: No staining or dissolution of the material.

2.2 FASTENING SYSTEM

- A. Fasteners: The fastener system shall consist of stainless steel masonry nails anchored into predrilled holes in the concrete platform sections, meeting the following requirements:
 1. Nails: Supply stainless steel nails, oval head tamperproof, 1/8" diameter by 2" long. The head of the screw shall be powder coating finished to match the color of the tile or covered with a cap to match the tile finish. Nails shall be hammer driven into the concrete and shall be removable with the use of a special tool for the tamperproof head.
 2. Number: The number of fasteners used shall be as required to completely fasten the tile to the platform substrate, but in no case will less than 10 fasteners be installed in a 2' by 4' modular unit. Fasteners shall not be installed in the body of the tactile material.
 3. Adhesive: Urethane Adhesive as recommended by manufacturer of anchors, conforming to manufacture's installation instructions.

PART 3 - EXECUTION

3.1 INSPECTION OF SURFACES

- A. Carefully inspect substrates for conditions affecting application and performance of the work of this Section. Report defects in writing to MTBA. Do not proceed with tactile tile installation work until unsatisfactory conditions have been corrected.

- A. Beginning work shall constitute acceptance of its conditions and any defects in tactile tile installation work resulting from such accepted surfaces shall be corrected without further expense to the Authority.

3.2 PREPARATION

- A. Coordinate tile installation, working with prior and subsequent work of other trades.
- B. Ensure that concrete substrate is smooth, clean, cured and trowel finished or scarified, free from curing compounds or surface coatings. The tactile tile shall be installed on poured in place concrete, retractable edge units, or precast concrete units and not on leveling compounds or fillers.
- C. The platform surface shall be scarified or depressed during forming, except for 2' wide platform edge units, and preparation shall depend on the thickness of the modular tile/ The surface preparation shall also be as recommended by the manufacturer for installation of that particular product so the body of the tile is to be recessed flush with the finished platform surface so that only the domes project above the top of the finished surface.
- D. If applicable, any slurry or concrete dust produced by the scarifying procedure and/or drilling for mechanical anchors shall be vacuumed from the platform during the preparation process to prevent the slurry from cementing the ballast or fouling the track drains. The DB Entity shall provide protection as required to prevent any residue from entering the ballast area.
- E. If applicable, electrical or signal cables under the platform edges or mounted on the support walls shall be protected, as required, using polyethylene or similar waterproof material.

3.3 INSTALLATION

- A. Install tile in accordance with manufacturer's recommendations and as indicated on the Design Documents. Install anchors and adhesive in accordance with manufacturer's recommendations.
- B. Hold Point - The tiles shall be dry-fit prior to installation to ensure proper installation.
- C. At the platform radius, tiles shall be installed with the platform edge tangent to the radius with the ends trimmed to provide a joint tangent to the curve and square to adjoining tiles. Domes cut in the trimming shall be beveled and polished to match the finish of the tile.
- D. Apply sealant only at expansion joints in accordance with Section 07920 - JOINT SEALANTS.
- E. Fasteners, as required by the platform conditions, shall be used to fully fasten the tile to the platform to provide complete contact between the tile and the platform.

3.4 PROTECTION

- A. During construction and prior to opening the platform edge for public use, cover all tactile surfaces with an appropriate covering material, temporarily secured in place, to protect it from damage from construction activity. Remove covering when protection is no longer needed and dispose of it off-site in a manner conforming to all appropriate laws and regulations.

- B. Prohibit construction vehicle traffic from riding on newly tiled surfaces. Do not place or store construction equipment or tools directly on tiled surfaces.
- C. Provide snow removal as required using equipment that will not damage tile.

END OF SECTION

SECTION 09671

FLUID APPLIED DI-ELECTRIC EPOXY FLOOR TOPPING

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies furnishing and installing dielectric epoxy topping on the floor under and around the rectifier and dc switchgear and on all the exposed vertical walls of the floor openings.
- B. An area at minimum 6' from the DC switchgear and rectifier equipment shall require the installation of an epoxy insulated floor. Areas in between equipment requiring installation of epoxy floor shall be filled in to expand the area of coverage.

1.2 RELATED SPECIFICATIONS

- A. Section 16311 –TRACTION POWER ELECTRICAL EQUIPMENT

1.3 SUBMITTALS

- A. Submit a layout drawing showing the proposed epoxy floor area to be provided for acceptance by the MBTA.
- B. Submit the proposed method of epoxy floor insulated anchors to be used with the DC switchgear and rectifiers. Note the requirement that the anchors shall withstand the 40kV level required by the insulated floor.
- C. Submit the qualifications of the installers of similar flooring systems. Provide the experience list of the proposed installer demonstrating installation of similar system. Where possible, demonstrate that the installation personnel have completed training courses provided the material supplier to ensure product installation is professional and manufacturer's requirements and performance.
- D. Submit technical data and test data indicating conformance to the mechanical, dielectric, and water absorption properties specified herein. Tests shall represent the composition and thickness of the proposed topping.
- E. Submit manufacturer's application and installation procedures including the following:
 - 1. Surface preparation.
 - 2. Temperature, humidity and other environment condition prior to, during and after installation.
 - 3. Drying and curing requirements of concrete subsurface and each layer of topping.
 - 4. Method and rate of application including the minimum and maximum thickness of each layer.
 - 5. The submittal of manufacturer's application and installation procedure shall be site specific for each Substation site.

- F. Submit three (3) 12 inch square samples of epoxy floor topping on concrete paving blocks. Show installation proposed for the project.
- G. Submit the proposed test procedure to be used to prove the epoxy floor meets the specified values at the specified locations. The test procedure should include test equipment, test values, test locations (shown on a substation layout plan), pass/fail criteria, test record sheets and should address each stage of installation and testing. Testing should include the floor and the equipment anchors. The DB Entity shall consider the proposed test method within the testing procedure submittal, such that testing of the equipment anchors can be achieved at the specified value in 2.2.A without risk of damaging the equipment.

1.4 JOB SITE CONDITIONS

- A. Provide positive ventilation and conform to volatile organic content regulations.
- B. Apply topping only when substrate temperature is 55°F minimum and rising, 90°F maximum. Do not apply if humidity is greater than 90% or if the substrate temperature is 5°F above dew point of the work area.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The topping shall be dielectric, non-porous, seamless, 100% solid (no solvent resin and hardener) two component epoxy with silica added.

2.2 PERFORMANCE REQUIREMENTS

- A. Dielectric strength: 40,000 VDC minimum when tested per ASTM D-149 for 60 seconds without physical breakdown of epoxy.
- B. Insulation resistance: 10,000 megaohms at 2500 VDC.
- C. Water absorption: 0.8% maximum when tested per ASTM D-570.
- D. Hardness: Shore “D” hardness 75 minimum at 7 days.
- E. Durability: Ability to withstand steel-wheeled fork-lift traffic.

2.3 THICKNESS AND APPLICATION

- A. The topping shall be a trowel applied self-leveling system consisting of the following:
 - 1. A prime coat of neat epoxy of minimum 1/8” thickness.
 - 2. Apply thoroughly mixed epoxy mortar in proper thickness of 1/2”, unless otherwise indicated or directed by the MBTA.
 - 3. Non-slip shake applied prior to hardening of the epoxy topping.
 - 4. A final seal coat of neat epoxy.

2.4 ACCEPTABLE BRAND NAMES

- A. Any brand name and manufacturer that meet the specified performance requirement is acceptable.

Subject to the conformance of the requirements the following provide 100% solid epoxy topping systems:

1. Amazite: As manufactured by Halamite Inc., 28 Alhambra Road, Warwick, RI 02887 (800/272- 7752).
2. Duraltek: As distributed by Tamms Industries, 7405 Production Drive, Mentor, OH 44060 (800/21-TAMMS).
3. Dex-O-Tex Cheminert: As manufactured by Crossfields Products Corporation, 3000E Harcourt Street, Compton. (213/509-2016).

2.5 MOISTURE CONTENT

- A. Sand, shake material and all other constituents shall be dry.

PART 3 – EXECUTION

3.1 PREPARATION OF CONCRETE FLOOR SUBSTRATE

- A. Fill floor cracks by injecting epoxy grout under pressure.
- B. Evaluate levelness of floor with a straightedge. Grind highpoints. Patch floor imperfections.
- C. Cure floor slab and concrete filing and patching for 28 days minimum. Perform the “Visqueen Test” (ASTM D-4263), as necessary, to evaluate the moisture level of concrete.
- D. Saw cut 1/2" deep at all termination edges to insure adhesion of topping.
- E. Chip and roughen concrete floor to prepare substrate surface, removal of concrete shall not exceed a depth of 3/4". Adopt dust control measures during chipping and saw cutting to prevent dust infiltration into energized electrical equipment.
- F. No acid etching or solvent cleaning or sand blasting is permitted.
- G. Inspect the surface and correct unsatisfactory conditions. Starting of work by the applicator shall be construed as the applicator’s acceptance of the substrate.
- H. DB Entity shall verify the substrate floor has been prepared in a manner which will facilitate installation of a flat and level dielectric floor; unsatisfactory conditions shall be corrected. Starting of work by the applicator shall be construed as the applicator’s acceptance of the substrate.

3.2 TOPPING - GENERAL

- A. Apply in accordance with manufacturer’s instructions.
- B. Clean surface with industrial vacuum immediately prior to application of topping.

- C. Start topping work after MBTA's inspection of the substrate surface.
- D. Apply in a seamless manner to insure no holidays through cold joints.
- E. Top surface of the insulated floor shall be grouted with a finish coat insulated epoxy topping to smooth up and fill to give a smooth hard, easy to clean top surface.
- F. The top surface of the insulated floor shall mate flush with the top surface the concrete floor. All evaluation readings to be within a plane 1/16" above and a plane 1/16" or below an imaginary "perfectly level" zero reference plane.

3.3 PROTECTION

- A. After curing and before foot traffic commences, cover all finished surfaces with 1 inch thick construction grade plywood. Seal joints and edges with duct tape.

3.4 CLEANUP

- A. Clean all drips and spills, using care not to scratch or otherwise damage finished surfaces. Mask all termination edges.

3.5 TESTING

- A. DB Entity shall test the floor and the insulated anchors to assure that the dielectric strength is as specified. Dielectric strength to be achieved for the floor and the anchors is specified in 2.02.A above. Testing shall be completed in accordance with the accepted test procedure. The "Copper Plate Method" is the accepted method of testing the epoxy floor. The plate should cover at least 144 sq. inches of floor, comprised of 1/4" copper with an integrated test lead. The positive lead of the hi-pot shall be connected to the plate while the negative lead is connected to building ground. The use of liquid/void filling liquid for the testing will not be acceptable unless accepted by the MBTA.
- B. The testing shall be performed by an independent testing laboratory acceptable to MBTA.
- C. Tests shall be conducted after topping installation of each phase and prior to the installation of equipment for that phase. DB Entity shall propose the test locations. The DB Entity shall perform a test per every 4sqft of floor installed.
- D. After installation of all electrical equipment, DB Entity shall retest the entire area for dielectric strength. Testing at a minimum, shall be completed at the following locations. Test voltage shall be the di-electric strength identified in 2.02.A above.
 - 1. All equipment anchors – DB Entity may propose testing prior to equipment installation, subject to acceptance by the MBTA.
 - 2. At two locations at the rear of each DC switchgear cubicle. Test locations shall be 12" and 24" from the edge of the equipment.
 - 3. At three locations in front of each DC switchgear cubicle. Test locations shall be 12", 24" and 36" from the edge of the equipment.
 - 4. At two locations at each end of the DC switchgear, approximately 2' from the edge of the equipment.

5. Two on each side of each rectifier approximately 2' from the edge of the equipment.
 6. One test per every 4sqft of installed epoxy floor outside of the areas identified above.
- E. The areas which do not meet the dielectric strength specified shall be repaired and re-tested at no additional cost.
- F. Any areas which exhibit cracks or chipping shall be repaired and retested at no additional cost.

END OF SECTION

SECTION 09900

PAINTING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Field painting of exposed interior items and surfaces.
 2. Field painting of exposed exterior items and surfaces.
 3. Surface preparation for painting.
 4. Painted signage: Level ID markers on concrete columns, refer to Division 10.

1.2 DEFINITIONS AND EXTENT

- A. General: Standard coating terms defined in ASTM D 16 apply to this Section.
1. Flat refers to a lusterless or matte finish with a gloss range below 15 when measured at an 85-degree meter.
 2. Eggshell refers to low-sheen finish with a gloss range between 20 and 35 when measured at a 60-degree meter.
 3. Semi-gloss refers to medium-sheen finish with a gloss range between 35 and 70 when measured at a 60-degree meter.
 4. Full gloss refers to high-sheen finish with a gloss range more than 70 when measured at a 60-degree meter.
- B. This Section includes surface preparation and field painting of exposed exterior and interior items and surfaces.
1. Surface preparation, priming, and finish coats specified in this Section are in addition to shop priming and surface treatment specified in other Sections.
- C. Paint exposed surfaces, except where these Mandatory Specifications indicate that the surface or material is not to be painted or is to remain natural. If an item or a surface is not specifically mentioned, paint the item or surface the same as similar adjacent materials or surfaces. If a color of finish is not indicated, DB Entity will select from standard colors and finishes available.
1. Painting includes field painting of exposed bare and covered pipes and ducts (including color coding), hangers, exposed steel and iron supports, and surfaces of mechanical and electrical equipment that do not have a factory-applied final finish.
- D. Do not paint prefinished items, concealed surfaces, finished metal surfaces, operating parts, and labels.
1. Prefinished items include, but are not limited to the following factory-finished components:

- a. Elevator entrance doors and frames.
 - b. Elevator equipment.
 - c. Finished mechanical and electrical equipment.
 - d. Light fixtures.
2. Concealed surfaces include walls or ceilings in the following generally inaccessible spaces:
- a. Foundation spaces.
 - b. Furred areas.
 - c. Ceiling plenums.
 - d. Pipe spaces.
 - e. Duct shafts.
3. Finished metal surfaces include the following:
- a. Anodized aluminum.
 - b. Stainless steel.
 - c. Chromium plate.
 - d. Copper and copper alloys.
 - e. Bronze and brass.
4. Operating parts include moving parts of operating equipment and the following:
- a. Valve and damper operators.
 - b. Linkages.
 - c. Sensing devices.
 - d. Motor and fan shafts.
5. Labels: Do not paint over UL, FMG, or other code-required labels or equipment name, identification, performance rating, or nomenclature plates.

1.3 SUBMITTALS

- A. Product Data: For each paint system indicated, include block fillers and primers.
1. Material List: An inclusive list of required coating materials. Indicate each material and cross-reference specific coating, finish system, and application. Identify each material by manufacturer's catalog number and general classification.
 2. Manufacturer's Information: Manufacturer's technical information, including label analysis and instructions for handling, storing, and applying each coating material.
 3. If the product submitted is an equal to those listed, provide detailed comparison in at least five (5) material properties against each of the products listed.
- B. Samples for Verification: For each color and material to be applied, with texture to simulate actual conditions, on representative Samples of the actual substrate.
1. Provide stepped Samples, defining each separate coat, including block fillers and primers. Use representative colors when preparing Samples for review. Resubmit until required sheen, color, and texture are achieved.

2. Provide a list of materials and applications for each coat of each Sample. Label each Sample for location and application.
 3. Submit two 8" by 12" samples for each type of finish coating for MBTA's review of color and texture only.
- C. Qualification Data: For Applicator.

1.4 QUALITY ASSURANCE

- A. Applicator Qualifications: A firm or individual experienced in applying paints and coatings similar in material, design, and extent to those indicated for this Project, whose work has resulted in applications with a record of successful in-service performance.
- B. Source Limitations: Obtain block fillers and primers for each coating system from the same manufacturer as the finish coats.
- C. Mockups: Provide a full-coat benchmark finish sample for each type of coating and substrate required. Comply with procedures specified in Painting and Decorating Contractors of America PDCA P5. Duplicate finish of accepted sample Submittals.
1. DB Entity will select one room or surface to represent surfaces and conditions for application of each type of coating and substrate.
 - a. Wall Surfaces: Provide samples on at least 100 sq. ft.
 - b. Small Areas and Items: DB Entity will designate items or areas required.
 2. Apply benchmark samples, according to requirements for the completed Work, after permanent lighting and other environmental services have been activated. Provide required sheen, color, and texture on each surface.
 - a. After finishes are accepted, DB Entity will use the room or surface to evaluate coating systems of a similar nature.
 3. Final approval of colors will be from benchmark samples.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials to Project site in manufacturer's original, unopened packages and containers bearing manufacturer's name and label and the following information:
1. Product name or title of material.
 2. Product description (generic classification or binder type).
 3. Manufacturer's stock number and date of manufacture.
 4. Contents by volume, for pigment and vehicle constituents.
 5. Thinning instructions.
 6. Application instructions.
 7. Color name and number.
 8. VOC content.

- B. Store materials not in use in tightly covered containers in a well-ventilated area at a minimum ambient temperature of 45 deg F and a maximum ambient temperature of 95 deg F. Maintain storage containers in a clean condition, free of foreign materials and residue.
 - 1. Protect from freezing. Keep storage area neat and orderly. Remove oily rags and waste daily.

1.6 PROJECT CONDITIONS

- A. Apply waterborne paints only when temperatures of surfaces to be painted and surrounding air are between 50 and 90 deg F.
- B. Apply solvent-thinned paints only when temperatures of surfaces to be painted and surrounding air are between 45 and 95 deg F.
- C. Do not apply paint in snow, rain, fog, or mist; or when relative humidity exceeds 85 percent; or at temperatures less than 5 deg F above the dew point; or to damp or wet surfaces.
 - 1. Painting may continue during inclement weather if surfaces and areas to be painted are enclosed and heated within temperature limits specified by manufacturer during application and drying periods.

1.7 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by all interested parties whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 PAINT MATERIALS, GENERAL

- A. Material Compatibility: Provide block fillers, primers, and finish-coat materials that are compatible with one another and with the substrates indicated under conditions of service and application, as demonstrated by manufacturer based on testing and field experience.
- B. Material Quality: Provide manufacturer's best-quality paint material of the various coating types specified that are factory formulated and recommended by manufacturer for application indicated. Paint-material containers not displaying manufacturer's product identification will not be acceptable.
 - 1. Proprietary Names: Use of manufacturer's proprietary product names to designate colors or materials is not intended to imply that products named are required to be used to the exclusion of equivalent products of other manufacturers. Furnish manufacturer's material data and certificates of performance for proposed substitutions.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Applicator present, for compliance with requirements for paint application.
 - 1. Proceed with paint application only after unsatisfactory conditions have been corrected and surfaces receiving paint are thoroughly dry.
 - 2. Start of painting will be construed as Applicator's acceptance of surfaces and conditions within a particular area.
- B. Coordination of Work: Review other Sections in which primers are provided to ensure compatibility of the total system for various substrates. On request, furnish information on characteristics of finish materials to ensure use of compatible primers.

3.2 PREPARATION

- A. General: Remove hardware and hardware accessories, plates, machined surfaces, lighting fixtures, and similar items already installed that are not to be painted. If removal is impractical or impossible because of size or weight of the item, provide surface-applied protection before surface preparation and painting.
 - 1. After completing painting operations in each space or area, reinstall items removed using workers skilled in the trades involved.
- B. Cleaning: Before applying paint or other surface treatments, clean substrates of substances that could impair bond of the various coatings. Remove oil and grease before cleaning.
 - 1. Schedule cleaning and painting so dust and other contaminants from the cleaning process will not fall on wet, newly painted surfaces.
- C. Surface Preparation: Clean and prepare surfaces to be painted according to manufacturer's written instructions for each particular substrate condition and as specified.
 - 1. Provide barrier coats or tie-coats over incompatible primers or remove and reprime.
 - 2. Cementitious Materials: Prepare concrete, concrete unit masonry, cement plaster, and mineral-fiber-reinforced cement panel surfaces to be painted. Remove efflorescence, chalk, dust, dirt, grease, oils, and release agents. Roughen as required to remove glaze. If hardeners or sealers have been used to improve curing, use mechanical methods of surface preparation to remove.
 - a. Use abrasive blast-cleaning methods if recommended by paint manufacturer.
 - b. Determine pH of surfaces using pH indicating papers and distilled water and perform moisture vapor transmission testing for concrete floors in accordance with ASTM F 1869 and moisture tests on concrete walls in accordance with ASTM D 4263, Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method. For masonry walls, use a moisture meter approved by the coating manufacturer. Follow the selected and approved coating manufacturers recommendations for acceptable pH values, moisture vapor transmission values (in lbs. of moisture per 24 hours per 1,000 SF), and moisture meter values (for masonry). If these values are not acceptable, do not paint surfaces until

- moisture levels are acceptable or additional surface preparation has been performed and the pH values measured are acceptable.
- c. Clean concrete floors to be painted with shot blast equipment in accordance with SSPC-SP13 Surface Preparation of Concrete. Reference (ICRI CSP 3-5).
3. Wood: Clean surfaces of dirt, oil, and other foreign substances with scrapers, mineral spirits, and sandpaper, as required. Sand surfaces exposed to view smooth and dust off.
 - a. Scrape and clean small, dry, seasoned knots, and apply a thin coat of white shellac or other recommended knot sealer before applying primer. After priming, fill holes and imperfections in finish surfaces with putty or plastic wood filler. Sand smooth when dried.
 - b. Prime, stain, or seal wood to be painted immediately on delivery. Prime edges, ends, faces, undersides, and back sides of wood, including cabinets, counters, cases, and paneling.
 - c. If transparent finish is required, backprime with spar varnish.
 - d. Backprime paneling on interior partitions where masonry, plaster, or other wet wall construction occurs on back side.
 - e. Seal tops, bottoms, and cutouts of unprimed wood doors with a heavy coat of varnish or sealer immediately on delivery.
 4. Ferrous Metals: Clean ungalvanized ferrous-metal surfaces that have not been shop coated; remove oil, grease, dirt, loose mill scale, and other foreign substances. Use solvent or mechanical cleaning methods that comply with The Society for Protective Coatings' (SSPC) recommendations.
 - a. Exterior Exposed Steel surfaces shall be cleaned in accordance with SSPC-SP 6/NACE No. 3 Commercial Blast Cleaning. Abrasive blast cleaned surfaces shall exhibit a uniform, angular profile of 1.5-3.0 mils. Cleaned surfaces shall be primed within 8 hours of cleaning and prior to any surface rusting.
 - b. Interior Exposed Steel in humid environments shall be cleaned in accordance with SSPC-SP 6/NACE No. 3 Commercial Blast Cleaning. Abrasive blast cleaned surfaces shall exhibit a uniform, angular profile of 1.5-3.0 mils. Cleaned surfaces shall be primed within 8 hours of cleaning and prior to any surface rusting.
 - c. Interior Exposed Steel in dry environments shall be cleaned in accordance with SSPC-SP2 or SP3 Hand or Power Tool Cleaning.
 5. Galvanized Surfaces: Shall be cleaned in accordance with SSPC-SP16 Brush of Blast Cleaning of Galvanized Steel and Non-Ferrous Metals to achieve a minimum 1 mil anchor profile. (Including but not limited to Structural and Miscellaneous Metals, Galvanized Metal Deck, etc.)
- D. Material Preparation: Mix and prepare paint materials according to manufacturer's written instructions.
1. Maintain containers used in mixing and applying paint in a clean condition, free of foreign materials and residue.

2. Stir material before application to produce a mixture of uniform density. Stir as required during application. Do not stir surface film into material. If necessary, remove surface film and strain material before using.
 3. Use only thinners approved by paint manufacturer and only within recommended limits.
- E. Tinting: Tint each undercoat a lighter shade to simplify identification of each coat when multiple coats of same material are applied. Tint undercoats to match the color of the finish coat, but provide sufficient differences in shade of undercoats to distinguish each separate coat.

3.3 APPLICATION

- A. General: Apply paint according to manufacturer's written instructions. Use applicators and techniques best suited for substrate and type of material being applied.
1. Paint colors, surface treatments, and finishes are indicated in the paint schedules.
 2. Do not paint over dirt, rust, scale, grease, moisture, scuffed surfaces, or conditions detrimental to formation of a durable paint film.
 3. Provide finish coats that are compatible with primers used.
 4. The term "exposed surfaces" includes areas visible when permanent or built-in fixtures, grilles, convector covers, covers for finned-tube radiation, and similar components are in place. Extend coatings in these areas, as required, to maintain system integrity and provide desired protection.
 5. Paint surfaces behind movable equipment and furniture the same as similar exposed surfaces. Before final installation of equipment, paint surfaces behind permanently fixed equipment or furniture with prime coat only.
 6. Paint interior surfaces of ducts with a flat, nonspecular black paint where visible through registers or grilles.
 7. Paint back sides of access panels and removable or hinged covers to match exposed surfaces.
 8. Finish exterior doors on tops, bottoms, and side edges the same as exterior faces.
 9. Sand lightly between each succeeding enamel or varnish coat.
- B. Scheduling Painting: Apply first coat to surfaces that have been cleaned, pretreated, or otherwise prepared for painting as soon as practicable after preparation and before subsequent surface deterioration.
1. The number of coats and film thickness required are the same regardless of application method. Do not apply succeeding coats until previous coat has cured as recommended by manufacturer. If sanding is required to produce a smooth, even surface according to manufacturer's written instructions, sand between applications.
 2. Omit primer over metal surfaces that have been shop primed and touchup painted.

3. If undercoats, stains, or other conditions show through final coat of paint, apply additional coats until paint film is of uniform finish, color, and appearance. Give special attention to ensure that edges, corners, crevices, welds, and exposed fasteners receive a dry film thickness equivalent to that of flat surfaces.
 4. Allow sufficient time between successive coats to permit proper drying. Do not recoat surfaces until paint has dried to where it feels firm, and does not deform or feel sticky under moderate thumb pressure, and until application of another coat of paint does not cause undercoat to lift or lose adhesion.
- C. Application Procedures: Apply paints and coatings by brush, roller, spray, or other applicators according to manufacturer's written instructions.
1. Brushes: Use brushes best suited for type of material applied. Use brush of appropriate size for surface or item being painted.
 2. Rollers: Use rollers of carpet, velvet-back, or high-pile sheep's wool as recommended by manufacturer for material and texture required.
 3. Spray Equipment: Use airless spray equipment with orifice size as recommended by manufacturer for material and texture required.
- D. Minimum Coating Thickness: Apply paint materials no thinner than manufacturer's recommended spreading rate to achieve dry film thickness indicated. Provide total dry film thickness of the entire system as recommended by manufacturer.
- E. Mechanical and Electrical Work: Painting of mechanical and electrical work is limited to items exposed in equipment rooms and occupied spaces.
- F. Mechanical items to be painted include, but are not limited to, the following:
1. Uninsulated metal piping.
 2. Uninsulated plastic piping.
 3. Pipe hangers and supports.
 4. Tanks that do not have factory-applied final finishes.
 5. Visible portions of internal surfaces of metal ducts, without liner, behind air inlets and outlets.
 6. Duct, equipment, and pipe insulation having "all-service jacket" or other paintable jacket material.
 7. Mechanical equipment that is indicated to have a factory-primed finish for field painting.
- G. Electrical items to be painted include, but are not limited to, the following:
1. Switchgear.
 2. Panelboards.
 3. Electrical equipment that is indicated to have a factory-primed finish for field painting.
- H. Block Fillers: Apply block fillers to concrete masonry block at a rate to ensure complete coverage with pores filled.
- I. Prime Coats: Before applying finish coats, apply a prime coat, as recommended by manufacturer, to material that is required to be painted or finished and that has not been prime coated by others. Recoat primed and sealed surfaces where evidence of suction spots or unsealed areas in first coat appears, to ensure a finish coat with no burn-through or other defects due to insufficient sealing.

- J. Pigmented (Opaque) Finishes: Completely cover surfaces as necessary to provide a smooth, opaque surface of uniform finish, color, appearance, and coverage. Cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness, or other surface imperfections will not be acceptable.
- K. Transparent (Clear) Finishes: Use multiple coats to produce a glass-smooth surface film of even luster. Provide a finish free of laps, runs, cloudiness, color irregularity, brush marks, orange peel, nail holes, or other surface imperfections.
 - 1. Provide satin finish for final coats.
- L. Completed Work: Match approved samples for color, texture, and coverage. Remove, refinish, or repaint work not complying with requirements.

3.4 CLEANING

- A. Cleanup: At the end of each workday, remove empty cans, rags, rubbish, and other discarded paint materials from Project site.
 - 1. After completing painting, clean glass and paint-spattered surfaces. Remove spattered paint by washing and scraping without scratching or damaging adjacent finished surfaces.
- B. Cleaning of Galvanized Ductwork, Conduit and Similar Items: Prepare surfaces of galvanized items in accordance with SSPC-SP 16 (The Society for Protective Coatings) – Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels and Non-ferrous Metals.

3.5 PROTECTION

- A. Protect work of other trades, whether being painted or not, against damage from painting. Correct damage by cleaning, repairing or replacing, and repainting.
- B. Provide "Wet Paint" signs to protect newly painted finishes. After completing painting operations, remove temporary protective wrappings provided by others to protect their work.
 - 1. After work of other trades is complete, touch up and restore damaged or defaced painted surfaces. Comply with procedures specified in Painting and Decorating Contractors of America PDCA P1.

3.6 PAINT SCHEDULE

- A. Schedule: Provide products and number of coats specified. Use of manufacturer's proprietary product names to designate colors, materials, generic class, standard of quality and performance criteria and is not intended to imply that products named are required to be used to the exclusion of equivalent performing products of other manufacturers.
- B. Exterior Paint Schedule:
 - 1. Exterior Masonry and Concrete to be Painted:
 - One Coat
 - 1. Tnemec Series 156 Enviro-Crete at 6.0 to 10 mils DFT
 - 2. PPG PMC Amercoat 147 at 6.0 to 10.0 mils
 - 3. RD Coatings – RD Elasto-Flex at 6.0 to 10 mils DFT

- One Coat
1. Tnemec Series 156 Enviro-Crete at 8 to 10 mils DFT
 2. PPG PMC Amercoat 147 at 6.0 to 10.0 mils DFT
 3. RD Coatings – RD Elasto-Flex at 6.0 to 10 mils DFT
2. Exterior Concrete and Masonry in Right of Way:
- Two Coats
1. TextureDot Smooth by ChemMasters or equal by Tnemec or PPG AMC; application rate of 125-150 square feet per gallon. Complies with ASTM C309, Type 2, Class B and ASTM C1315 Class B for curing/sealing efficiency.
3. Exterior Ferrous Metals: (Railings, Polyurethane System) (Surface Preparation: SSPC-SP6)
- One Coat
1. Tnemec 90-1K97 at 3 mils DFT; shop applied under other Sections; use for touch up
 2. PPG PMC 68 at 3 mils DFT; shop applied under other Sections; use for touch up
 3. International Interzinc 315 at 2.0 to 3.0 mils DFT
- One Coat
1. Tnemec N69 Hi-Build Epoxoline II at 3.0 mils DFT
 2. PPG PMC Amerlock 400 Hi-Build Epoxy at 3.0 to 5.0 mils DFT
 3. International Intergard 475 HS at 4.0 to 8.0 mils DF
- One Coat
1. Tnemec 1075 Endura-Shield at 3.0 mils DFT
 2. PPG PMC Amerlock 400 Hi-Build Epoxy at 3.0 to 5.0 mils DFT
 3. International Interthane 990 HS at 2.0 to 3.0 mils DFT
4. Exterior Galvanized Metal: Refer to specification section 05041 – Hot Dip Galvanizing for shop finished galvanized metal. Paint system below is for galvanized and shop-primed steel items that is not hot-dip galvanized. Surface Preparation SSPC-SP7 Brush-Off Blast.
- One Coat
1. Tnemec 66HS Hi-Build Epoxoline at 3.0 mils DFT
 2. PPG PMC Amerlock 400 Hi-Build Epoxy at 4.0-5.0 mils DFT
 3. International Intergard 475 HS at 5.0 to 10.0 mils DFT
- One Coat
1. Tnemec 1080 /1081 Endurashield at 3.0 – 4.0 mils DFT
 2. PPG PMC AmerShield VOC at 2.0 to 3.0 mils DFT
 3. International Water Borne Urethane at 3.0 to 4.0 mils DFT
5. Yellow Pavement Marking Paint.
- One Coat
1. S-W Pro-Park Waterborne Traffic Marking Paint Latex Flat
 2. Moore Super Spec HP Latex Flat
 3. PPG Olympic Latex Flat
6. Exterior Existing Prepainted Painted Steel, for Overcoat Painted Finish:
- a. Surface Preparation: Water Blast 5000 psi and SSPC-SP3 Power Tool Clean.
 - b. One Coat:
 - 1) Tnemec 394 Omnithane at 3.0 to 3.5 mils DFT.
 - 2) PPG PMC Amerlock 400 Hi-Build Epoxy at 3.0 to 4.0 mils DFT.
 - 3) RD Coatings Elasto Metal at 3.0 mils DFT.

- c. And One Coat:
 - 1) Tnemec 66HS Hi-Build Epoxoline at 3.0 to 5.0 mils DFT.
 - 2) PPG PMC Amerlock 400 at 3.0 to 4.0 mils DFT.
 - 3) RD Coatings Elasto Metal at 7.0 mils DFT.
- d. And One Coat:
 - 1) Tnemec 1080 /1081 Endurashield at 3.0 – 4.0 mils DFT.
 - 2) PPG PMC AmerShield VOC at 2.0 to 3.0 mils DFT.
 - 3) International Water Borne Urethane at 3.0 to 4.0 mils DFT.

C. Interior Paint Schedule for Standard Performance Coatings:

1. Interior Gypsum Wallboard for Latex Eggshell Finish:

- One Coat
- 1. Moore Ecospec Interior Latex Primer Sealer (231)
 - 2. Duron Genesis Latex Primer
 - 3. S-W Health Spec Latex Wall Primer
 - 4. PPG Pure Performance Latex Primer

- Two Coats
- 1. Moore Pristine Ecospec Interior Latex Eggshell (223)
 - 2. Duron Genesis Latex Eggshell
 - 3. S-W Health Spec Latex Eggshell
 - 4. PPG Pure Performance Latex Eggshell

2. Interior Finish Carpentry for Latex Semi-Gloss Paint Finish (softwoods, paint grade hardwoods, MDO, and hardwood veneers):

- One Coat
- 1. Moore Eco Spec WB Interior Latex Primer (372)
 - 2. Duron Genesis Latex Primer
 - 3. PPG Pure Performance Latex Primer

- And Two Coats
- 1. Moore Eco Spec WB Interior Latex Semi-Gloss (376)
 - 2. Duron Genesis Latex Semi-Gloss
 - 3. PPG Pure Performance Latex Semi-Gloss

D. Interior Paint Schedule for High Performance Coatings:

1. Interior Concrete Ceiling Surfaces for Acrylic – Semi-Gloss Finish for Garage Ceilings:

- One Coat
- 1. Tnemec 27WB Typoxy at 4.0-6.0 mils DFT
 - PPG PMC Amerlock Sealer at 1.0 mils DFT
 - International Intercryl 520 at 3.0 mils DFT

- Two Coats
- 1. Tnemec 1028/1029 Tufcryl at 2.0 to 3.0 mils DFT per coat min.
 - 2. PPG PMC Amercoat 220 at 3.0 mils DFT
 - 3. International Intercryl 530 at 3.0 mils DFT

2. Interior Concrete Block, Epoxy/Urethane Coating:
(Surface Preparation: Cured, clean and dry, free of surface contaminants)

One Coat 1. Tnemec 130 Envirofil at 100 sq/ft/gal
PPG PMC Amercoat 965 at 100 sq/ft/gal

One Coat 1. Tnemec 27WB Typoxy at 6.0 8.0 mils DFT
PPG PMC Amercoat 133 at 6-8 mils DFT

One Coat: 1. Tnemec 1080 /1081 Endurashield at 3.0 – 4.0 mils DFT
PPG PMC AmerShield VOC at 2.0 to 3.0 mils DFT

3. Interior Concrete Walls Exposed to View, Urethane Coating:
(Surface Preparation: Cured, clean and dry, free of surface contaminants)

One Coat 1. Tnemec 27WB Typoxy at 3.0- 4.0 mils DFT
2. PPG PMC Amercoat 133 at 6-8 mils DFT

One Coat 1. Tnemec 27WB Typoxy at 6.0 to 8.0 mils DFT
2. PPG PMC Amercoat 133 at 6-8 mils DFT

One Coat 1. Tnemec 1080 / 1081 Endura-Shield WB at 3.0 to 3.5 mils DFT
2. PPG PMC AmerShield VOC at 2.0 to 3.0 mils DFT

4. Interior Concrete Walls Exposed to View, Epoxy Coating for Non-Immersion Service:
(Surface preparation- Cured, clean, dry and free of contaminants)

One Coat 1. Tnemec 27WB Typoxy at 3.0- 4.0 mils DFT
2. PPG PMC Amercoat 133 at 6-8 mils DFT

One Coat 1. Tnemec 27WB Typoxy at 6.0 to 8.0 mils DFT
2. PPG PMC Amercoat 133 at 6-8 mils DFT

One Coat 1. Tnemec 1080 / 1081 Endura-Shield WB at 3.0 to 3.5 mils DFT
2. PPG PMC AmerShield VOC at 2.0 to 3.0 mils DFT

5. Interior Metals, Epoxy (Not specified to receive other coating systems/not shop finished/intended to be painted):

One Coat 1. Approved primer, in shop under other Sections (where specified). If not shop primed, provide primer recommended by finish coating manufacturer

One Coat 1. Tnemec 27WB Typoxy at 2.0 to 3.0 mils DFT
2. PPG PMC Amerlock 400 at 2.0 to 4.0 mils DFT
3. International Interseal 670 HS at 3.0 mils DFT

One Coat 1. Tnemec 1081 EnduraShield WB at 2.0 to 3.0 mils DFT
2. PPG PMC Amerlock 400 at 2.0 to 4.0 mils DFT
3. International Intercryl 530 at 3.0 to 4.0 mils DFT

6. Interior Steel, Joists, Ductwork, Conduit and Similar Items Not Galvanized:

One Coat 1. Tnemec Series 115 WB Unibond at 2.5 to 3 mils DFT
2. PPG PMC Amercoat 220 Acrylic Series at 3.0 mils DFT
3. RD Muracryl at 2.5 to 3.0 mils DFT

7. Interior Galvanized Metal: Refer to specification section 05041 – Hot Dip Galvanizing for shop finished galvanized metal. Paint system below is for galvanized and shop-primed steel items that are not hot-dip galvanized. Surface Preparation SSPC-SP7 Brush-Off Blast.
- One Coat
1. Tnemec 66HS Hi-Build Epoxoline at 3.0 mils DFT
 2. PPG PMC Amerlock 400 Hi-Build Epoxy at 4.0-5.0 mils DFT
 3. International Intergard 475 HS at 5.0 to 10.0 mils DFT
- One Coat
1. Tnemec 1080 /1081 Endurashield at 3.0 – 4.0 mils DFT
 2. PPG PMC AmerShield VOC at 2.0 to 3.0 mils DFT
 3. International Intergard 475 HS at 5.0 to 10.0 mils DFT
8. Mechanical and Electrical Work; Paint all exposed items that are located on surfaces that are to be painted only except factory finished items with factory-applied baked enamel finishes which occur in mechanical rooms or areas, and excepting chrome or nickel plating, stainless steel, and aluminum other than mill finished. Paint all exposed ductwork and inner portion of all ductwork: Same as specified for other interior metals, hereinabove. Note: Do not paint exposed mechanical and electrical work inside of garage that are installed on unpainted surfaces.

END OF SECTION

SECTION 10100

DISPLAY CASES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies all display cases as indicated on the Design Documents and specified herein.
- B. Transportation: Deliver all display cases and related elements, including mounting hardware, to the job site.
- C. Temporary: Provide fabrication, erection, and removal of any and all temporary safety barricades, temporary holding, retaining or storage structures necessary as described herein.

1.2 PERFORMANCE REQUIREMENTS

- A. Design Criteria: Design, fabricate, and install display cases to withstand normal exposure to weather, temperature variation, wind loads and building movement; provide units resistant to vandalism and theft.
- B. Field Measurements: Check actual locations of construction - to which metal fabrications must fit - by accurate field measurements before fabrication; show recorded measurements on final shop drawings.
- C. Thermal Movements: Allow for thermal movement resulting from the following maximum change (range) in ambient temperature in engineering, fabricating, and installing cases to prevent buckling, opening of joints, over stressing of components and connections, and other detrimental effects. Base engineering calculation on actual surface temperatures of materials due to both solar heat gain and nighttime sky heat loss.
 - 1. Temperature Change (Range): 0 - 180 deg F ambient, material surfaces.
- D. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials.

1.3 SUBMITTALS

- A. All submittals shall be provided to the MBTA for review.
- B. Product Data: Manufacturer's product data, any limitations and recommendations for each material used, installation instructions, and manufacturer's certification (stating that materials comply with requirements) for the MBTA's review and acceptance.
 - 1. Include material details for each display case specified.

- C. Shop drawings: Submit shop drawings showing layout, profiles, and product components, including dimensions, anchorage, all details, plans and sections required to indicate all conditions. Provide shop drawings for review by the MBTA.
- D. Samples for Approval: Submit suppliers standard color chart for selection purposes and selected colors to the MBTA for verification.

1.4 QUALITY ASSURANCE

- A. Reference Standards: The work shall conform to the codes and standards of the following regulatory Agencies and Authorities as further cited herein:
 - 1. ADAAG: Americans with Disabilities Act Accessibility Guidelines
 - 2. ANSI: American National Standards Institute.
 - 3. ASTM: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 as published in "Compilation of ASTM Standards in Building Codes".
 - 4. MAAB: Massachusetts Architectural Access Board.
- B. Source: Obtain all products in this section from a single supplier.
- C. Qualifications: The approved manufacturer shall have a minimum of 5 years of successful experience with similar work, and shall have a reputation for doing satisfactory work on time.
- D. Engineering: The DB Entity is responsible for the proper engineering of all items. The internal structure, dimensions and specifications for all items shall be indicated in the DB Entity's shop drawings. The DB Entity to engineer display cases to proper level to withstand their environment.
- E. Coordination: The work in this Section shall be completely coordinated with the work of other Sections. Verify dimensions and work of other trades that adjoin materials of this Section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all work under this Contract.
- F. Project Meetings: Subcontractors are required to attend project meetings at the Project site.
- G. Certification: Submit manufacturer's certification that materials furnished comply with requirements specified.
- H. Maintenance Instructions: Submit manufacturer's printed instructions for maintenance of each display case installed to the MBTA, including precautions for use of cleaning materials.
- I. Warranty:
 - 1. Submit a written Manufacturer's warranty for MBTA acceptance, signed by the manufacturer, agreeing to repair or replace display cases that fail due to defects in material or workmanship during the specified warranty period.
 - 2. Warranty Period: 1 Year Limited

1.5 DELIVERY, STORAGE AND HANDLING

- A. Installer: Installer specialized and experienced in work similar to that required for this project shall perform Installation.
- B. Deliver work under this Section to the site in ample time to avoid delay in job progress and at such times as to permit proper coordination of the various parts.
- C. Installation of this work shall be scheduled to occur near time of Contract Substantial Completion.

1.6 PROJECT CONDITIONS

- A. Inspection of Site: The DB Entity shall visit the site of the proposed work and become fully acquainted with existing conditions, and fully informed as to the facilities involved and the difficulties and restrictions attending the requirements of the Contract Documents, prior to submitting a price quotation.
- B. Substrates: Proceed with work of this Section only when substrate construction and penetration work have been completed.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Manufacturers products must meet or exceed the specifications approved for use on the Project. Provide products of one of the following vendors or approved equal:
 - 1. Access Display Group
 - 2. SwingFrame
 - 3. Outdoor Display Cases

2.2 MATERIALS

- A. Materials
 - 1. Aluminum Extrusions: Meeting ASTM B221, alloy 6063-T6.
 - 2. Aluminum Panels: Meeting ASTM B209, minimum 0.032" thick.

2.3 FABRICATION

- A. General:
 - 1. Comply with requirements indicated for materials, thickness, finishes, colors, designs, shapes, sizes and details of construction.

2. Welded Connections: Comply with AWS standards for recommended practices in shop welding. Provide welds behind finished surfaces with distortion or discoloration of exposed side. Clear exposed welded surfaces of welding flux and dress on exposed and contact surfaces.
 3. Mill joints to a tight, hairline fit.
 4. Pre-assemble display cases in the shop. No visible fasteners.
 5. Form panels to required size and shape. Comply with requirements indicated for design, dimensions, finish, color and details of construction.
 6. Display cases to be fabricated based on dimensions as shown on Design Documents.
 7. Coordinated dimensions and attachment methods to produce display panels with closely fitting joints. Align edges and surfaces with one another in the relationship indicated.
 8. Increase metal thickness or reinforce with concealed stiffeners or backing materials as required to produce surfaces without distortion, buckles, warp or other surface deformations.
 - a. Fabricate frame from extruded aluminum. Corners to have hairline miters and be braced by means of internal aluminum angels. If welding is necessary, none should be visible. Frames shall have a continuous back-up member behind door.
 - b. Venting: Provide venting as recommended by the manufacturer to prevent condensation.
- B. Display Case Construction:
1. Casing: Aluminum extrusion mitered and reinforced with locking corner brackets.
 2. Exterior Backing: 0.032" weather resistant aluminum with silicone sealant.
 3. Interior Backing: 1/32" cork laminated to 7/16" fiberboard.
 4. Weep Holes: on bottom.
 5. Lock: security cam lock.
- C. Finishes:
1. Aluminum with anodized finish: Black.
 2. Aluminum with a satin polyurethane coating. Faces shall be smooth, free of scratches, blemishes or other imperfections.
- D. Door Profile:
1. Hinged aluminum extruded door, mitered and assembled with concealed corner angles, 1/4" shatter resistant acrylic window, and cam lock.
- E. Background:
1. Vinyl (grey) over Cork/Fiberboard.
- F. Mounting:
1. Sign Frame Mounting: Mount display case to sign frame structure through case sides.
 - a. Maintain a minimum 3/16" open joint to allow for venting.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The DB Entity shall examine substrates, supports, and conditions under which this Work is to be performed, and notify the MBTA in writing of conditions detrimental to the proper completion of the Work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means DB Entity accepts substrates and conditions.
- B. Notification Point: MBTA will be given 72 hour notice to perform field inspection at the start of installation. If work does not meet project requirements, the DB Entity must remove and replace deficient work.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. Strictly comply with accepted shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
- B. Install work plumb, level, and in true plane and alignment and at heights indicated in accordance with manufacturer's recommendations.
- C. Install products at heights to conform to Americans with Disabilities Act Accessibility Guidelines (ADAAG) and applicable local amendments and regulations.
- D. Follow manufacturer's instructions for storage and handling of units before installation.
- E. Protect adjacent or adjoining surfaces and work from damage during installation in this Section.
- F. Work shall be designed and anchored so that work will not be distorted nor the fasteners overstressed from expansion and contraction of metal or other materials as applicable.

3.3 CLEANING AND PROTECTION

- A. Touch-up damaged finishes and eliminate any evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned.
- B. Provide temporary protection to ensure work is delivered without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.
- C. Manufacturer shall provide Authority with information on cleaning and maintenance recommendations for all display cases.
- D. Names, stamps and decals of manufacturers, installers or maintainers of display cases shall not be visible in the finished work.

END OF SECTION

SECTION 10400

FIXED SIGNAGE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies all fixed signage as indicated on the Design Documents and specified herein. The work of this section includes, but is not limited to, the fabrication and installation of the following:
1. Station Identification and Wayfinding signs as indicated – porcelain enamel on steel
 2. Maps – Line, RTL, Neighborhood, Bus Neighborhood– porcelain enamel on steel
 3. Historic Interpretive Murals – porcelain enamel on steel
 4. Regulatory, Informational signage - Aluminum
 5. Sign frames and mounting accessories as indicated and required
- B. Custom software to be used by the MBTA for generating all custom sign content as digital files. No other method of creating graphic files or content is permitted.
- C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
1. Section 09900 – PAINTING
 2. Section 10100 – DISPLAY CASES
 3. Section 10401 – METAL SIGN FRAMES
 4. Section 10426 – TACTILE /BRAILLE SIGNAGE
 5. Division 16 of Exhibit 2A.1 – ELECTRICAL - “Exit” signs; and “Variable Message Signs”
- D. Transportation: Deliver all signs and related elements, including frames and mounting hardware, to the job site.
- E. Temporary: Provide fabrication, erection, and removal of any and all temporary safety barricades, temporary holding, and retaining or storage structures necessary as described herein.
- F. Permits: Obtain permits required by Authority Having Jurisdiction for installation of signs and frames.
- G. Coordination between the DB Entity and MBTA on signage requires Pre-Design meeting: DB Entity required meeting with MBTA to discuss signage specs, process, and signage guidelines.
- H. Pre-Construction meeting: The DB Entity and signage/frame sub (same source for porcelain enamel signage and framing to ensure quality.) required to meet with MBTA to discuss signage specs and schedules.
- I. FIXED SIGNAGE SUBMITTAL PROCESS SUMMARY (Details found in 1.2 Submittals)
1. Submittals must include a dated transmittal form and be provided to MBTA

2. Pre-Construction meeting with MBTA, the DB Entity, and sign/framing fabricator:
 - a. Review scope for signage and frames, submittal process, schedule, expected fabrication lead times, overall fabrication process and critical path to completion.

1.2 SUBMITTALS

- A. All submittals shall be provided to both the MBTA for review.
- B. Product Data: Manufacturer's product data, any limitations and recommendations for each material used, installation instructions, and manufacturer's certification (stating that materials comply with requirements) shall be provided to the MBTA for review and acceptance.
- C. Shop Drawings: Submit shop drawings for fabrication and installation of each sign assembly. This includes, but is not limited to; sign frames and associated sign panel drawings, plans and elevations, sign content elevations, and large-scale details of each sign frame and sign panel showing all required mounting holes, slots, clips, flanges, and other integral fastener components and accessory items. Provide date stamped digital copies of shop drawings for review by the MBTA.
- D. Sign Schedules: Submit complete sign schedule for each sign. Use same designations as indicated on the Design Documents. Notify the MBTA, in writing, of any size variances from the construction documents so that adjustments can be made to the final sign fabrication files.
- E. Samples for Approval: Sample Submittals are in addition to quantities shown in sign schedule. They are record project samples to be kept on file at the MBTA.
 1. Samples and Proofs: To be provided to the MBTA within 30 business days from the MBTA's submittal of digital artwork. All samples and proofs must be produced by the fabricator and submitted to the MBTA by the DB Entity for acceptance.
 2. Fabricator proofs:
 - a. For each sign assembly/content type listed on the signage schedule, provide digital proofs on all files and full size paper proofs on selected files as determined by the MBTA; the DB Entity shall request graphic artwork from the MBTA.
 - b. Submit 3" x 4" samples of each color on all signage substrates specified.
 - c. For art and mural panels (if indicated), provide full size paper proofs; the DB Entity shall request graphic artwork from the MBTA.
 3. For porcelain enamel signage, art panels, and murals provide 15" x 15" sample with flanges on all four sides of the sample (area of sign determined by MBTA). Samples and proofs will be resubmitted until they meet quality standards outlined in the next section.
 4. Provide samples and proofs to the MBTA at no extra charge.
 5. acceptance is required from the MBTA for all samples and proofs prior to final signage production.
 6. Mock-ups: Provide a full-size mock-up in place of each type of sign, for locations, to verify selections made under sample submittals and to demonstrate aesthetic effects and quality of

materials and execution. Build mock-ups to comply with the specified requirements, using materials indicated for final unit of Work.

- a. If the MBTA determines mock-ups do not comply with requirements, provide new corrected sign(s) until mockups are accepted.
- b. Accepted mock-ups may become part of the completed work if undisturbed at time of Contract Substantial Completion.

1.3 SUPPLIED GRAPHICS

- A. Digital Graphics files: The MBTA will prepare and supply all digital sign content to the DB Entity.
 1. Elevation drawings of all signs at $\frac{1}{2}'' = 1'$ scale will be provided in raster format for the DB Entity use in preparing shop drawings.
 2. Full size sign layouts will be provided in vector format for direct fabrication from digital files.
 3. The DB Entity is responsible for verifying that each sign frame and sign panel is coordinated with the dimensions and content of supplied digital sign files, and for fabricating and installing all signs based on the MBTA's supplied graphic layouts of signs, historic interpretive panels and associated panels.
- B. Formats: Digital files are provided in vector format (.EPS) for use in final fabrication of signs, and in raster format (.PNG) at $\frac{1}{2}'' = 1'$ scale for insertion in to shop drawings. Vector graphics do not contain editable fonts. Any typographic editing must be done by the MBTA and returned to the DB Entity.
- C. Colors: Match all spot colors using the Pantone Matching System (PMS) or as per file designation in the digital files and in compliance with the standard colors as identified in the MBTA Signage Guidelines. Color samples, PMS color swatches, and proofs are to be provided to the MBTA at no extra charge. Standard PMS Colors by Line:

<u>Line</u>	<u>PMS Color</u>
Blue Line	293 C
Green Line	348 C
Orange Line	152 C
Red Line	485 C
Silver Line	430 C
Commuter Rail (purple)	249 C
Amtrak (brand color)	302 C
Bus (Yellow)	1235 C
Commuter Boat	3135 C

- D. Mural Panels: The DB entity shall request the final digital artwork for the mural panels from the MBTA. The DB Entity shall be responsible for the fabrication of the artwork, adhering to industry standards of quality and procedures. When one image spans several panels, either a larger sized porcelain panel will be required or margins shall be minimized to reduce white seams.
 1. The DB Entity to provide name of sign, art, and mural manufacturer.

2. Resolution of final sign output by fabricator must be in vector format (not raster format) with a minimum resolution of 150- 300 LPI. Final output shall match EPS digital files for accurate layout, smoothness of contours and letter forms, and evenness of colors.
3. Fabricator must provide written documentation of their capabilities/specs to the MBTA to show resolution output capability of equipment - line screens (LPI).

1.4 PERFORMANCE REQUIREMENTS

1. Design Criteria: Design, fabricate, and install sign items to withstand normal exposure to weather, temperature variation, wind loads and building movement; provide units resistant to vandalism and theft.
2. Field Measurements: Check actual locations of construction - to which metal fabrications must fit - by accurate field measurements before fabrication; show recorded measurements on final shop drawings.
3. The drawings indicate minimum dimensions and thicknesses for components. Where performance requirements necessitate thickness of material to be increased or additional reinforcing to be added such revisions shall be made without changing the visible profiles of inlay elements. Where changes cannot be made without changing visible profiles they shall be made only with acceptance by the MBTA.
4. Thermal Movements: Allow for thermal movement resulting from the following maximum change (range) in ambient temperature in engineering, fabricating, and installing signs to prevent buckling, opening of joints, over stressing of components and connections, and other detrimental effects. Base engineering calculation on actual surface temperatures of materials due to both solar heat gain and nighttime sky heat loss.
 - a. Temperature Change (Range): 0 - 180 deg F ambient, material surfaces.
5. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials.

1.5 QUALITY ASSURANCE

- A. MBTA Reference Standards: Comply with the MBTA Signage Guidelines V 03.2015.
- B. Reference Standards: The work shall conform to the codes and standards of the following regulatory Agencies and Authorities as further cited herein:
 1. ADAAG: Americans with Disabilities Act Accessibility Guidelines
 2. ANSI: American National Standards Institute.
 3. ASTM: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 as published in "Compilation of ASTM Standards in Building Codes".
 4. MAAB: Massachusetts Architectural Access Board.
 5. PEI: Porcelain Enamel Institute, Inc., 1900 L Street N.W., Washington, DC, 20036 – “Specifications for Architectural Porcelain Enamel,” PEI-1001 (S-100); and “Standard Tests for Special Properties and Classifications.”

6. Structural Code:
 - a. Mass Building Code
 - b. AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals
- C. Source: For each material type required for the work in this Section, provide Single-Source Responsibility. This local Single-Source supplier will control coordination and installation of Frames and Fixed Signage. For each separate type of sign required, obtain signs from a single manufacturer. Inform the MBTA of single-source supplier prior to submission of artwork.
- D. Accessibility: The ADAAG and the MAAB regulations are pertinent to the design and installation of items covered under the work of this Section. When guidelines conflict, the guideline giving greater access shall be applicable.
- E. Signage and Frame Coordinator Qualifications: The approved signage and frame coordinator for the manufacturing, delivery, and installation of porcelain enamel shall have a minimum of 5 years of successful experience with porcelain enamel signage and frame work, and shall have a reputation for doing satisfactory work on time.
- F. Welding Standards: Comply with applicable provisions of the American Welding Society AWS D1.1 "Structural Welding Code".
 1. Certify that each welder has satisfactorily passed AWS qualification tests for welding processes involved and, if pertinent, has undergone recertification.
- G. Coating Applicator Qualifications: must be experienced in successfully applying specified coatings of the type indicated to specified materials, and equipped with the following:
 1. Application equipment required to apply a uniform coating as recommended by the coatings manufacturer.
- H. Engineering and structural analysis for signs, as well as necessary calculations, shall be prepared under the supervision of, and signed and sealed. These calculations shall include gravity, wind, and seismic loading. The internal structure, dimensions and specifications for all items shall be indicated in the Contract Documents, and shall be indicated in the DB Entity's shop drawings. Signs shall be designed to withstand surrounding environmental conditions.
- I. Coordination: The work in this section shall be completely coordinated with the work of other sections. Verify dimensions and work of other trades that adjoin materials of this section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all work under this contract.
- J. Project Meetings: The signage subcontractor and related subcontractors shall be required to attend project meetings at the project site when required by the DB Entity and MBTA.
- K. Certification: Submit manufacturer's certification that materials furnished comply with requirements specified.

- L. Maintenance Instructions: Submit manufacturer's printed instructions for maintenance of each sign installed to the MBTA, including precautions for use of cleaning materials and solvents for paint removal, which could damage surfaces.
- M. Warranty:
 - 1. Submit a written manufacturer's warranty for MBTA acceptance, signed by the manufacturer, agreeing to repair or replace panels that fail during the specified warranty period. Failures include, but are not limited to, the following:
 - a. Coating degradation.
 - b. Chipping, chalking, fogging or discoloration.
 - c. Fading.
 - d. Structural failure.
 - e. Delamination of applied graphics.
 - f. Delaminating or degradation of applied anti-graffiti coatings.
 - 2. Warranty Period:
 - a. Porcelain Steel Enamel – 10 years
 - b. Aluminum – 7 years
 - 3. The manufacturer's warranty is in addition to, and not a limitation of, other rights the MBTA may have under the contract documents.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver and store work under this section in a manner to prevent the cracking or stress of components, and to prevent mechanical damage or damage from the elements.
 - 1. Porcelain Enamel Signs: Store units at building site, under cover. Place units on minimum 4" high wood blocking. Do not use non-ventilating plastic or canvas shelters that could create humidity chambers. If package becomes wet, remove carton and crating immediately. Provide 1/4" spaces between stacked units to promote air circulation.
- B. Deliver work under this section to site in ample time to avoid delay in job progress and at such times as to permit proper coordination of the various parts.
- C. Installation of this work shall be scheduled to occur near time of Contract Substantial Completion.
- D. Handle signs carefully to prevent breakage, surface abrasion, denting, soiling, and other defects. Comply with the manufacturer's written handling instructions for unloading components subject to damage. Inspect sign components for damage on delivery.
 - 1. Do not install damaged sign components.
 - 2. Repair minor damage to signs, provided the finished repair is equal in all respects to the original work and is accepted by MBTA; otherwise, remove and replace damaged sign components.

1.7 PROJECT CONDITIONS

- A. Inspection of Site: The DB Entity shall visit the site of the proposed work and become fully acquainted with existing conditions, and to become fully informed as to the facilities involved and the difficulties and restrictions attending the performance of the contract, prior to submitting a price quotation.
- B. Substrates: Proceed with work of this section only when substrate construction and penetration work have been completed.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Porcelain Enamel on Steel Signs:
 - 1. Acceptable Porcelain Enamel Sign Manufacturers: Provide products of one of the following manufacturers or approved equal if they meet the requirements of these specifications:
 - a. Winsor Fireform Porcelain, Inc., Tumwater, WA
 - b. Cherokee Porcelain Enamel Corp., Knoxville, TN
 - c. KVO Industries, Inc., Santa Rosa, CA
 - 2. Metal Preparation/Cleaning:
 - a. All panels shall be degreased by immersion in an approved degreasing fluid. The panels shall then be rinsed in a heated water bath.
 - b. After the first rinse, panels shall be immersed in a caustic solution sufficient to provide an "etched" surface capable of good porcelain adherence. The panels shall then be rinsed.
 - c. After the third rinse, the chemical action shall be neutralized in a soda ash solution then dried rapidly.
 - 3. Porcelain Enameling:
 - a. A porcelain enamel ground coat shall be applied to all areas of each unit, including backside and flanges, by spraying methods recognized by the Porcelain Enamel Institute. At least one additional separately fired cover-coating shall be applied to the face side and flanges of each unit. For corrosion protection and flatness, one additional coating shall be applied to the backside of each panel.
 - b. Apply digitally supplied sign content graphics by silkscreen process; each color shall be fired separately and shall be uniform and even.
 - 4. Finish and Background Color Control
 - a. Color to match approved samples based on MBTA standard colors.
 - b. Continuity of coating: Visual inspection of each unit shall reveal no visible breaks, gas bubbles, scumming, hairlines, stress lines or surface defects in the cover coat.

- c. Check color at each application of enamel with a Hunter Lab D-25 P.C. color difference meter. Produce colors within the limits established during processing of submittals.
 - d. The color and finish shall match a color sample previously submitted to and accepted by the MBTA.
 - 5. Ground and Overcoat Thickness
 - a. Ground and overcoat thickness shall be applied in accordance with PEI recommendations to a thickness range between 0.004 to 0.020", as required by the manufacturer to suit the intended use.
 - 6. Firing
 - a. Panels shall be fired in a continuous furnace (not a batch-type furnace) at a temperature between 1450 - 1600 degrees Fahrenheit to fuse the porcelain enamel to the metal, expel any volatile matter, and ensure color uniformity.
 - b. After firing, every panel is submitted to a visual inspection for color consistency against the control panel as accepted by the MBTA.
 - 7. Glasses
 - a. Glasses used in the screening process shall be acid resistant and opaque. The glasses shall be corrosion proof, UV proof, wind proof, and vandal resistant. All screen glass must be milled to a 400 mesh particle size or smaller.
 - 8. Mural Panels
 - a. When one image spans several panels either a larger sized porcelain panel will be required or margins shall be minimized to reduce white seams.
- B. Aluminum Signs
- 1. Acceptable Aluminum Sign Manufacturers: Provide products from manufacturers if they meet the requirements of the specifications following.
 - 2. Aluminum Grade: Alloy 6063-T5 aluminum sheet. Thicknesses as indicated on the sign schedule
 - a. Surfaces constructed to remain flat under installed conditions within a tolerance of plus or minus 1/16" (1.5 mm) measured diagonally from corner to corner. Increase metal thickness or reinforce with concealed stiffeners or backing materials as required to produce surfaces without distortion, buckles, warp, or other surface deformations.
 - b. Unframed Single Sheet Panels: Provide unframed single sheet sign panels with edges mechanically and smoothly finished. The thickness of the aluminum sheeting shall be as shown on the plans or in these specifications.
 - c. Aluminum panels shall be free of buckles, warps, dents, cockles, burrs, and any other defects resulting from fabrication processes.
 - d. All possible fabrication including shearing, cutting and punching of holes shall be completed prior to pretreatment of the sheeting.

3. Coordinate dimensions and attachment methods to produce message panels with closely fitting joints. Align edges and surfaces with one another in the relationship indicated.
4. Continuously weld joints and seams unless other methods are indicated; grind, fill, and dress welds to produce smooth, flush, exposed surfaces with welds invisible after final finishing.
5. Provide concealed sealing of joints to exclude water and provide corrosion protection, exclude sealing of joints where drainage of moisture will be inhibited - do not seal weep holes. Seal joints with specified sealers. For exposed sealers, provide color to match finish. Provide joint sealers tested for adhesion and compatibility with specified materials and finishes.
6. Mounting Method: Provide members with pins of length shown; for installation, weld to base plates or mechanically fasten where shown unless otherwise indicated. Provide turned pins and other anchorage provisions to resist vandalism and theft.
7. Silk screening imaging: Screen-printed graphics shall be produced directly from full-sized digital vector files, provided to the DB Entity as final approved graphics. Graphic files shall utilize digitally-prepared screens and shall be printed in accordance with accepted industry standards. No hand-cut screens will be accepted. All screen-printing shall be executed in such a manner that all edges and corners of letterforms are true and clean. Letterforms, color areas, or lines with rounded positive or negative corners, built-up edges, bleeding, spattering, etc. will not be accepted. All inks shall be applied evenly without pinholes, scratches, orange peeling, etc. All silk screening processes shall be accepted by the MBTA prior to fabrication.
8. Finishes:
 - a. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations relative to applying and designating finishes.
 - b. The front and back surfaces of all aluminum panels shall be cleaned, deoxidized, and coated with a light, tightly adherent chromate conversion coating free of any powdery residue.
 - c. Shop finish individual components prior to mechanical assembly.
 - d. Color to match approved samples based on MBTA standard colors.
 - e. Shop Painting of Panel Faces:
 - 1) Abrasive brush blasting preparation (SSPC-SP7) to a 100-mesh sandpaper texture.
 - 2) Finish Coats: Provide intermediate and finish coats of "Imron Elite" polyurethane enamel or approved equal to achieve the colors and matte finish selected by the MBTA.
9. Anti-graffiti coating
 - a. For signs scheduled to receive anti-graffiti coating, provide a high-durability, "permanent type" quality, matte finish, non-yellowing, and suitable for painted aluminum surfaces, as manufactured by one of the following companies, or approved equal:
 - 1) Monopole, Monochem Permashield Premium
 - 2) Dumond CPU 647 Graffiti Barrier Coat
 - 3) Adsil Microguard AD00

- b. Apply anti-graffiti coatings in strict accordance with manufacturer's instructions
- c. Warranty: 10 years

C. Hardware and Frames

1. Supply sign frames and hardware as indicated on the drawings.
2. Structural steel materials, details and workmanship shall conform to the specifications of the latest edition of the A.I.S.C. Specifications for the Design, Fabrication, and Erection of Structural Steel Buildings. ASTM standards:
 - a. Extruded Bars and Shapes: ASTM B 221 (ASTM B 221M), 6063-T6.
 - b. Plate and Sheet: ASTM B 209 (ASTM B 209M), 6061-T6.
 - c. Die and Hand Forging: ASTM B 247 (ASTM B 247M), 6061-T6.
 - d. Castings: ASTM B 26/B 26M, A356-T6.
3. Anchors and Inserts: Use non-ferrous metal or hot-dipped galvanized anchors and inserts for exterior installations and elsewhere as required for corrosion resistance. High strength bolts other than anchor bolts, nuts and washers shall conform to ASTM-A325. Use toothed steel or lead expansion bolt devices for drilled-in-place anchors. Furnish inserts, as required, to be set into concrete or masonry work.
4. Tamper resistant fasteners to be stainless steel, 3/8" dia. button head Phillips socket pinhead.
5. Threaded studs shall be low carbon mild steel with a minimum yield strength of 50,000 PSI.
6. All hardware shall be as indicated on Design Documents: 316 stainless steel, or galvanized per ASTM-A153 requirements.
7. Where mechanical fasteners and hardware are required, they shall be of adequate thickness, length and construction to properly secure the sign unit. Any visible portion of any mounting device shall be finished to match adjacent sign surface, unless otherwise specified.
8. Non-metallic Washers: Provide rigid neoprene separators between fasteners and non-compatible materials being joined.
9. Welding Electrodes and Filler Metal: Type and alloy of filler metal and electrodes as recommended by producer of metal to be welded, complying with applicable AS specifications, and as required for color match, strength, and compatibility in the fabricated items.
10. Galvanizing Repair Paint: High zinc dust content paint for re-galvanizing welds in galvanized steel, with dry film containing not less than 94 percent zinc dust by weight, complying with DOD- P-21035 or SSPC-Paint 20.
11. Backing Materials: 1/2" cement board backing, for locations requiring non-combustible assemblies - Hardibacker 500 Board or equal. Where combustible materials are allowed, backing may be 1/2" APA Graded, Exterior Grade A-C Plywood and Marine Grade Plywood, as indicated on the drawings.

D. Adhesives:

1. Where adhesive mounting techniques are specified, the DB Entity shall use adhesives specifically designed for compatibility with the base materials and the desired adhesive strength. All adhesives shall be tested on site. All adhesives shall be indicated in the shop drawings.
2. Surfaces on which signage is to be installed using adhesive shall be free of grease, oil, or any other residue.
3. Foam tape shall be 1/32" thick, high-density open cell double coated polyurethane foam tape for applications indicated as manufactured by the 3M Co. or approved equal.
4. Very high bond (VHB) tape shall be double coated acrylic foam tape.

E. Sealant:

1. For joints indicated in the drawings, provide silicone sealant that meets or exceeds the industry specifications TT-S-230C Class A, ASTM C 920, Class 50, Type S, Grade NS as manufactured by one of the following companies, or approved equal:
 - a. Tremco, Spectrem 1
 - b. Pecora, 864NST
2. Install in strict accordance with manufacturer's instructions.
3. Surface Preparation: prepare joints in accordance with ASTM C 1193 and manufacturer's instructions. For good adhesion, the joint interface must be sound, clean and dry. Clean joint surfaces to remove dirt, dust, oils, wax, paints, and other contamination capable of affecting primer and sealant bond.
4. Joint-Sealant Backing:
 - a. General: provide sealant backings of material and type that are non-staining; are compatible with joint substrates, sealants, primers, and other joint fillers; and are approved for applications indicated by sealant manufacturer based on field experience and laboratory testing.
 - b. Elastomeric Tubing Sealant Backings: neoprene, butyl, EPDM, or silicone tubing complying with ASTM D 1056, nonabsorbent to water and gas, and capable of remaining resilient at temperatures down to minus 26 degrees F. Provide products with low compression set and of size and shape to provide a secondary seal, to control sealant depth, and to otherwise contribute to optimum sealant performance.
 - c. Bond-Breaker Tape: polyethylene tape or other plastic tape recommended by sealant manufacturer for preventing sealant from adhering to rigid, inflexible joint-filler materials or joint surface at back of joint where such adhesion would result in sealant failure. Provide self-adhesive tape where applicable.
5. Color: match to frame color as closely as possible – use dark sealant with dark-colored frames and light sealant with light-colored (or galvanized) frames.

2.2 FABRICATION

A. Porcelain Enamel Signs:

1. ASTM A424. Porcelain sign panels shall be #16 gauge prime vitreous enameling steel finished with non-fading class A or AA acid resisting Architectural porcelain enamel in color specified, fused to the metal at temperatures between 1450 F to 1600 F. Porcelain enamel sign panels shall be of the best commercial quality and their forms shall be flat, straight, and true. Finish shall be non-reflective matte. Base metal shall receive a ground coat on all surfaces and successive face coats as required on the front and on all flanges. Silkscreened color shall be applied to face surface only. Exercise extreme care in all handling and stacking of porcelain work to avoid chipping. Graphics shall be of high resolution as per specifications.
2. Fabricate from pan-formed porcelain enameled steel plate with flat-flanged edges. All forming shall be mechanical and done in advance of welding.
3. Precisely form work to sizes, shapes, and profiles indicated on accepted shop drawings. Fabricate work with uniform joints that are not visible. Work to be truly straight, plumb, level and square with smooth flat surfaces and sharp corners
4. All welds shall be clean, sound and solid, free from defects and gas bubbles, and ground and sanded smooth to 3/16" to match the 3/16" radii of the mechanical break. They shall be done using a hand oxyacetylene fusion technique with no additions of foreign metals.
5. All necessary holes and cutouts shall be drilled or punched and welded in advance of enameling, with edges sufficiently ground to hold a porcelain coating.
6. Fabricate laminated sandwich construction, consisting of front sheet of porcelain enameled steel plate, on a 1/2 in. thick Marine Grade plywood core, with a layer of galvanized steel backing.

B. Aluminum Signs

1. Coordinate dimensions and attachment methods to produce message panels with closely fitting joints. Align edges and surfaces with one another in the relationship indicated.
2. Continuously weld joints and seams, unless other methods are indicated; grind, fill, and dress welds to produce smooth, flush, exposed surfaces with welds invisible after final finishing.
3. Provide concealed sealing of joints to exclude water and provide corrosion protection, exclude sealing of joints where drainage of moisture will be inhibited, and do not seal weep holes. Seal joints with specified sealers, and for exposed sealers, provide color to match finish. Provide joint sealers tested for adhesion and compatibility with specified materials and finishes.
4. Mounting Method: Provide members with pins of length shown for installation weld to base plates or mechanically fasten where shown unless otherwise indicated. Provide turned pins and other anchorage provisions to resist vandalism and theft.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The DB Entity shall examine substrates, supports, and conditions under which this work is to be performed, and notify the MBTA, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means DB Entity accepts substrates and conditions.
- B. Notification Point: The MBTA will be given notice to perform field inspection at the start of installation of signage. If work does not meet project requirements, the DB Entity must remove and replace deficient work.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. Strictly comply with accepted shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.
- B. Install work plumb, level, and in true plane and alignment. Provide signs and graphics where shown or scheduled using mounting methods indicated.
- C. Protect adjacent or adjoining surfaces and work from damage during installation in this section.
- D. Work shall be designed and anchored so that work will not be distorted nor the fasteners overstressed from expansion and contraction of metal or other materials as applicable.

3.3 TOLERANCES

- A. The following installed tolerances are allowable variations from locations and dimensions indicated by the contract document and shall not be added to allowable tolerances indicated for other work:
 - 1. Allowable Variation from True Plumb, Level and Line: Plus or minus 1/32" from true position for signage smaller than 24" by 24" in size; plus or minus 1/16" from true position for signage 24" by 24" in size and larger.
 - 2. Allowable Variation from True Plane of Adjacent Surfaces: Plus or minus 1/16".

3.4 CLEANING AND PROTECTION

- A. Adjust work to present the best possible appearance. Touch-up damaged finishes and eliminate any evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned.
- B. Provide temporary protection to ensure work is delivered without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

- C. Manufacturer shall provide MBTA with information on cleaning and maintenance recommendations for all signs.
- D. Names, stamps and decals of manufacturers, installers or maintainers of signs shall not be visible in the finished work.

END OF SECTION

SECTION 10401

METAL SIGN FRAMES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Station Identification and Wayfinding signs as indicated – porcelain enamel on steel
 - 2. Maps – Line, RTL, Neighborhood, Bus Neighborhood maps – porcelain enamel on steel
 - 3. Historic Interpretive Murals – porcelain enamel on steel
 - 4. Sign frames and mounting accessories as indicated and required
- B. Related Work:
 - 1. Section 09900 – PAINTING.
 - 2. Section 10100 – DISPLAY CASES.
 - 3. Section 10400 – FIXED SIGNAGE.
 - 4. Section 10426 – TACTILE /BRAILLE SIGNAGE.
 - 5. Section 10428 – MBTA LOGO LOLLIPOP SIGN.
 - 6. Division 16 of Exhibit 2A.1 – ELECTRICAL - “Exit” signs; and “Variable Message Signs”.
- C. Transportation: Deliver all sign frames and mounting hardware, to the job site.
- D. Temporary: Provide fabrication, erection, and removal of any and all temporary safety barricades, temporary holding, retaining or storage structures necessary as described herein
- E. Permits: Obtain permits required by Authority Having Jurisdiction for installation of signs and frames.

1.2 PERFORMANCE REQUIREMENTS

- A. Performance Requirements for Fixed Signage Metal Frame Work.
 - 1. Design Criteria: Design, fabricate, and install sign frame items to withstand normal exposure to weather, temperature variation, wind loads and building movement; provide units resistant to vandalism and theft.
 - 2. Field Measurements: Check actual locations of construction - to which metal fabrications must fit - by accurate field measurements before fabrication; show recorded measurements on final shop drawings.

3. The drawings indicate minimum dimensions and thicknesses for components. Where performance requirements necessitate thickness of material to be increased or additional reinforcing to be added such revisions shall be made without changing the visible profiles of inlay elements. Where changes cannot be made without changing visible profiles they shall be made only with acceptance by the MBTA.
4. Thermal Movements: Allow for thermal movement resulting from the following maximum change (range) in ambient temperature in engineering, fabricating, and installing signs to prevent buckling, opening of joints, over-stressing of components and connections, and other detrimental effects. Base engineering calculation on actual surface temperatures of materials due to both solar heat gain and nighttime sky heat loss.
 - a. Temperature Change (Range): 0 - 180 deg F ambient, material surfaces.
5. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials. Insulating materials shall not be visible to public view in final configuration.

1.3 SUBMITTALS

- A. All submittals shall be provided to the MBTA for review; disposition and documentation management.
- B. Product Data: Manufacturer's product data, any limitations and recommendations for each material used, installation instructions, and manufacturer's certification (stating that materials comply with requirements) shall be submitted to the MBTA for review and acceptance.
- C. Engineering and structural analysis for metal sign and frame work, as well as necessary calculations, shall be prepared under the supervision of, and signed and sealed by, the Engineer of Record. These calculations shall include gravity, wind, and seismic loading. The internal structure, dimensions and specifications for all items shall be indicated in the Design Documents, and shall be indicated in the subcontractor's shop drawings. Signs shall be designed to a proper level to withstand abuses of their environment.
- D. Shop Drawings: Submit shop drawings for fabrication and installation of each sign assembly, including, but not limited to: sign frames and associated sign panels drawings, plans and elevations; sign content elevation (from SIGNmaker™ 1/2"=1'-0" elevation export file); and large-scale details of each sign frame and sign panel showing all required mounting holes, slots, clips, flanges, and other integral fastener components and accessory items. Shop drawings must be provided within 30 days of receiving signage plan and 1/2"=1'-0" elevation export file from MBTA. After action, provide copies of shop drawings on which action has been taken to the MBTA.
- E. Frame Field Measurements: Provide measurements of frame openings to MBTA. Final graphics export will be based on field verified sizes.
- F. Mock-ups: Provide mock-ups in place of each frame type including; suspending, spanning, surface mounted, and freestanding for locations as determined by the MBTA, to verify selections made under sample submittals and to demonstrate aesthetic effects and quality of materials and execution. Build mock-ups to comply with the specified requirements, using materials indicated for final unit of Work. If required, mock up shall include both welded and mechanical connections. Welded connections shall

be done in the shop, and not visible in final configuration as accepted by Engineer of Record, MBTA Capital Delivery Department, and MBTA Sign Shop. Mechanically attach signage in field.

1. If the MBTA determine mockups do not comply with requirements, provide new corrected frames until mockups are accepted.
 2. Accepted mock-ups may become part of the completed Work if undisturbed at time of Substantial Completion.
- G. Installer: Installer shall be trained or certified by the manufacturer to perform work. Manufacturer shall certify installer as acceptable for terms of warranty.
- H. Certificates: Welder and weld procedure qualifications.
- I. Weld inspection reports.

1.4 QUALITY ASSURANCE

- A. MBTA Reference Standards: Comply with the MBTA Signage Guidelines V 03.2015.
- B. Reference Standards: The work shall conform to the codes and standards of the following regulatory Agencies and Authorities as further cited herein:
1. ADAAG: Americans with Disabilities Act Accessibility Guidelines
 2. ANSI: American National Standards Institute.
 3. ASTM: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 as published in "Compilation of ASTM Standards in Building Codes".
 4. MAAB: Massachusetts Architectural Access Board.
 5. AWS D1.1, Structural Welding Code – Steel
 6. AWS D1.2, Structural Welding Code – Aluminum
 7. AWS D1.1, Structural Welding Code – Sheet Steel
 8. AWS D1.1, Structural Welding Code – Stainless Steel
- C. Source: For each type of material required for the work of this section, provide Single-Source Responsibility. This local Single-Source supplier will control coordination and installation of Frames and Fixed Signage.
- D. Installer Qualifications: Installation of sign frames specified in this section shall be performed by the fabricator. Fabricator Qualifications: The approved fabricator shall have a minimum of 5 years of successful experience with metal frame work, and shall have a reputation for doing satisfactory work on time and shall have recently successfully completed similar work.
- E. Galvanizer Qualifications: Engage the services of a qualified galvanizer who has demonstrated a minimum of five years experience in the successful application of galvanized coatings.

- F. Welding Standards: Comply with applicable provisions of the American Welding Society AWS D1.1 "Structural Welding Code".
 - 1. Certify that each welder has satisfactorily passed AWS qualification tests for welding processes involved and, if pertinent, has undergone recertification.
- G. Coordination: The work in this section shall be completely coordinated with the work of other sections. Verify dimensions and work of other trades that adjoin materials of this section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all Work under this Project.
- H. Project Meetings: The signage subcontractor and related subcontractors shall be required to attend project meetings at the Project site when required by the DB Entity and MBTA Capital Delivery Department.
- I. Certification: Submit manufacturer's certification that materials furnished comply with requirements specified.
- J. Inspection: Except as otherwise specified, only visual inspection of welds, materials, workmanship, finished products, and installation.
- K. Maintenance Instructions: Submit manufacturer's printed instructions for maintenance of each frame installed to the MBTA, including precautions for use of cleaning materials and solvents for paint removal, which could damage surfaces.
- L. Warranty:
 - 1. Submit a written Manufacturer's warranty for MBTA acceptance, signed by the manufacturer, agreeing to repair or replace panels that fail during the specified warranty period. Warranty begins at substantial completion. Failures include, but are not limited to, the following: Coating degradation or structural failure.
 - 2. Warranty Period: Steel Frames – 30 years; Aluminum – 10 years.
 - 3. The Manufacturer's warranty is in addition to, and not a limitation of, other rights the MBTA may have under the Project.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Deliver and store work under this Section in a manner to prevent the cracking or stress of components, and to prevent mechanical damage or damage from the elements.
- B. Deliver and store frames in wooded crates surrounded by sufficient packing material to ensure products will not be damaged.
- C. Deliver work under this Section to Site in ample time to avoid delay in job progress and at such times as to permit proper coordination of the various parts, but minimize on-site storage.

1.6 PROJECT CONDITIONS

- A. Inspection of Site: The DB Entity shall visit the site of the proposed work and become fully acquainted with existing conditions, and to become fully informed as to the facilities involved and the difficulties and restrictions attending the performance of the Project, prior to submitting a price quotation.
- B. Substrates: Proceed with work of this Section only when substrate construction and penetration work have been completed.

1.7 SEQUENCING AND SCHEDULING

- A. General approach: signs will not be fabricated until sign frames have been fabricated to the satisfaction of the DB Entity and the Engineer of Record; sign frames and frameless signs housed within architectural and/or structural spaces will not be fabricated until those spaces have been created, and shop drawings reflect their actual dimensions.
- B. Pre-Construction Conference: the DB Entity shall attend a pre-construction conference with MBTA, sign frame fabricator, and sign fabricator. The agenda will include: signage scope of work, schedule, including expected lead times, submittal process and the critical path to completion. Discuss minimum clearances of signs, based on the anticipated thickness of finish galvanization, paint, and construction tolerances. Included in this discussion is the workflow below, which includes related work in Fixed Signage Mandatory Specification Section 10400:
 - 1. MBTA shall provide 1/2" scale png sign files for use by the sign installer, and a field measurement schedule in Excel format, requiring field measurements of all locations where the signage frame is housed within architectural and/or structural elements upon request from the DB Entity.
 - 2. MBTA will determine which signs and frames will be mocked up.
 - 3. The DB Entity shall provide Porcelain Enamel color samples (See Fixed Signage Specification 10400), a completed field measurement schedule in Excel format (1.3.F), and frame shop drawings, stamped by the Engineer of Record (1.3.C, 1.3.D)

Mockups (may run concurrently with 4-7)

- a. MBTA shall provide: Full scale digital .eps files with revised measurements to the DB Entity (See Fixed Signage Specification Mandatory 10400) at the request of the DB Entity at the request of the DB Entity.
- b. The DB Entity issues: Full sized digital and paper proofs of sign elevations using .eps files (See Fixed Signage Specification 10400).
- c. Upon acceptance, the DB Entity shall issue a notice to proceed on fabrication of sign and sign frame mock-ups.
- d. Upon satisfaction with mock-ups, the DB Entity shall issue a notice to proceed with fabrication of sign frames for locations not dependent upon construction of structural and architectural elements.

4. Upon construction of the structural and architectural elements that will house sign frames and frameless signs, the subcontractor shall revise the shop drawings and field measurement schedule if indicated, and submit to DB Entity for acceptance.
5. Upon satisfaction, MBTA shall provide: Full scale digital .eps files with revised measurements to the DB Entity (See Fixed Signage Mandatory Specification 10400) at the request of the DB Entity.
6. The DB Entity issues: Full sized digital proofs and paper proofs of sign elevations using .eps files (See Fixed Signage Specification Mandatory 10400)
7. Upon acceptance of digital and paper proofs, and assuming satisfaction with mock-ups, MBTA shall issue a notice to proceed with fabrication of sign frames and all associated mounting elements, and with those signs not requiring sign frames.
8. Fabrication of signs requiring sign frames (See Fixed Signage Mandatory Specification 10400) shall not proceed until the sign frames have been fabricated, and have been accepted by MBTA for conformance with shop drawings, including size, fit, and quality of fabrication and finish. At no time is the DB Entity to alter digital artwork provided by MBTA to fit frames. Delivery of approved frames shall occur a minimum of 180 days prior to anticipated date of Contract Substantial Completion, to allow adequate time for fabrication and delivery of porcelain enamel sign panels.

PART 2 - PRODUCTS

2.1 MATERIALS AND PRODUCTS

- A. Structural steel materials, details and workmanship shall conform to the specifications of the latest edition of the A.I.S.C. Specifications for the Design, Fabrication, and Erection of Structural Steel Buildings. ASTM standards:
 1. Extruded Bars and Shapes: ASTM B 221 (ASTM B 221M), 6063-T6.
 2. Plate and Sheet: ASTM B 209 (ASTM B 209M), 6061-T6.
 3. Die and Hand Forging: ASTM B 247 (ASTM B 247M), 6061-T6.
 4. Castings: ASTM B 26/B 26M, A356-T6.
- B. Anchors and Inserts: Use non-ferrous metal or hot-dipped galvanized anchors and inserts for exterior installations and elsewhere as required for corrosion resistance. High strength bolts other than anchor bolts, nuts and washers shall conform to ASTM-A325. Use toothed steel or lead expansion bolt devices for drilled-in-place anchors. Furnish inserts, as required, to be set into concrete or masonry work.
- C. Tamper Resistant Fasteners: shall be stainless steel, 3/8" dia. button head Phillips socket pinhead.
- D. Threaded Studs: shall be low carbon mild steel with minimum yield strength of 50,000 PSI.

- E. All hardware shall be as indicated on drawings: 316 stainless steel, or galvanized per ASTM-A153 requirements.
- F. Where mechanical fasteners and hardware are required, they shall be of adequate thickness, length, and constructed to properly secure the sign unit. Any visible portion of any mounting device shall be finished to match adjacent sign frame surface, unless otherwise specified.
- G. Non-metallic Washers: Provide rigid neoprene separators between fasteners and non-compatible materials being joined.
- H. Welding Electrodes and Filler Metal: Type and alloy of filler metal and electrodes as recommended by producer of metal to be welded, complying with applicable AS specifications, and as required for color match, strength, and compatibility in the fabricated items.
- I. Galvanizing Repair Paint: High zinc dust content paint for re-galvanizing welds in galvanized steel, with dry film containing not less than 94 percent zinc dust by weight, complying with DOD- P-21035 or SSPC-Paint 20.
- J. Separate dissimilar metals.

2.2 FABRICATION

- A. Assemble items in the shop to greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limits. Clearly mark units for reassembly and coordinated installation. Use connections that maintain structural value of joined pieces.
- B. Fabricate work to be truly straight, plumb, level, and square.
- C. Work Exposed to View: Take special care in choosing materials that are smooth and free of blemishes such as pits, roller marks, trade names, scale and roughness. Fabricate work with uniform, hairline tight joints. Form welded joints and seams continuously and grind flush and smooth to be invisible after painting. For exposed fasteners, use hex head bolts or Phillips head machine screws, or acorn head screws and bolts as indicated.
- D. Welded Connections: Perform welding to comply with AWS for recommended practices, using method appropriate for metal and finish indicated. Grind exposed welds flush and smooth to blend with adjoining finish metal surfaces. Maintain open joint clearances as indicated in drawings.
- E. Cut, drill, and tap as indicated to receive finish hardware, screws, and similar items metals cleanly and accurately. Remove burrs and ease edges to a radius of approximately 1/32 inch (1mm), unless otherwise indicated. Remove sharp or rough areas on exposed surfaces.
- F. Fabricate seams and other connections that will be exposed to weather in a manner to exclude water. Provide weep holes where water accumulates.
- G. Provide frames complying with A-F to hot-dip galvanizer, notify MBTA for inspection prior to hot-dip galvanizing.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The DB Entity shall examine substrates, supports, and conditions under which this work is to be performed, and notify the MBTA in writing of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.
- B. Notification Point: The MBTA shall be given 72 hour notice to perform field inspection at the start of installation of signage. If work does not meet project requirements, the DB Entity must remove and replace deficient work.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. Strictly comply with accepted shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.
- B. Install work plumb, level, and in true plane and alignment using mounting methods indicated.
- C. Protect adjacent or adjoining surfaces and work from damage during installation in this section.
- D. Work shall be designed and anchored so that work will not be distorted nor the fasteners overstressed from expansion and contraction of metal or other materials as applicable.
- E. No field welding of sign frames. Field welding of attachments shall be allowed as required and accepted by MBTA. Welds shall not be visible in final configuration.

3.3 TOLERANCES

- A. The following installed tolerances are allowable variations from locations and dimensions indicated by the DB Entity and shall not be added to allowable tolerances indicated for other work:
 - 1. Allowable Variation from True Plumb, Level and Line: Plus or minus 1/32 inch from true position for signage smaller than 24 by 24 inches in size; plus or minus 1/16 inch from true position for signage 24 by 24 inches in size and larger.
 - 2. Allowable Variation from True Plane of Adjacent Surfaces: Plus or minus 1/16 inch.

3.4 CLEANING AND PROTECTION

- A. Adjust work to present the best possible appearance. Touch-up damaged finishes and eliminate any evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned. MBTA shall be final authority on acceptance of repaired work.

- B. Provide temporary protection to ensure work is delivered without damage or deterioration at time of final acceptance. Remove protections and re-clean as necessary immediately before final acceptance.
- C. Touch-up Painting: Immediately after erecting, clean bolted connections and abraded areas.
- D. The DB Entity shall provide Authority with information on cleaning and maintenance recommendations for all signs from the manufacturer.
- E. Names, stamps and decals of manufacturers, installers or maintainers of signs shall not be visible in the finished work. All assembly markings shall not be visible in the finished work.

END OF SECTION

SECTION 10424

SPECIALTY SIGNAGE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This section specifies specialty signage.
- B. Related Work:
 - 1. Section 10400 – FIXED SIGNAGE.
 - 2. Section 10401, METAL SIGN FRAMES.
 - 3. Section 10426, TACTILE/BRAILLE SIGNAGE.
 - 4. Section 10428 – MBTA LOGO LOLLIPOP SIGN.
- C. Provide all signs and graphics required by authorities having jurisdiction even if not otherwise indicated in the Contract Documents. Fire sprinkler room identification shall comply with Fire Department requirements.
- D. Permits: Obtain permits required by Authority Having Jurisdiction for installation of signs.

1.2 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material used. Provide manufacturer's certification stating that materials comply with requirements.
- B. Shop Drawings: Provide large scale shop drawings for fabrication and installation of each sign type including mounting. Provide large scale layouts of sign wording, spacing, type size and style. Provide plans, elevations, and details of anchorage, connections and accessory items. Provide installation templates for work installed by others.
- C. Templates: Submit full size templates or film positives for all messages and graphics for all Sign Types. Outline drawings of letterforms will not be accepted as templates.
- D. Sign Schedules: Submit complete sign schedule for each sign. Use same designation as on the Shop Drawings.
- E. Samples for Approval: Sample submittals are in addition to quantities shown in sign schedule. Record project samples to be kept on file.
 - 1. For each typestyle specified submit full samples of all alphabets, including numbers and punctuation, on 11 inch by 17 inch photostats and samples of standard letter spacing and word spacing (at min. of 3/4 inch cap height) for approval prior to fabrication.
 - 2. Submit artwork of all symbols and logos to be used on 11 inch by 17 inch photostats for approval prior to fabrication.
 - 3. Submit samples of colors on all substrates specified for each sign type.

1.3 QUALITY ASSURANCE

- A. MBTA Reference Standard: Comply with the MBTA, Guidelines and Standards, Part V, Graphics, Revised Fall 1990 with 1995 Supplement. A copy can be viewed or supplied on request to the MBTA Design Department, 12th Floor, 100 Summer Street, Boston, MA 617-222-5044.
- B. Reference Standards: The Work shall conform to the codes and standards of the following agencies as further cited herein:
 - 1. ADAAG: Americans with Disabilities Act Accessibility Guidelines
 - 2. ANSI: American National Standards Institute.
 - 3. ASTM: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 as published in "Compilation of ASTM Standards in Building Codes".
 - 4. MAAB: Massachusetts Architectural Access Board.
- C. Source: For each type of material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.
- D. Accessibility: The ADAAG and the MAAB regulations are pertinent to the design and installation of items covered under the work of this Section. When guidelines conflict, the guideline giving greater access shall be applicable.
- E. Qualifications: The approved manufacturer shall have a minimum of 5 years of successful experience with work of similar and complexity, and within schedule.
- F. Engineering Delegated Design: Engineering and structural analysis, as well as any necessary calculations shall be prepared under the supervision of, and signed and sealed by, a qualified Professional Engineer licensed in the Commonwealth of Massachusetts. Professional Engineer shall have minimum 5 years experience performing work of similar scope and complexity. These calculations shall include gravity, wind and seismic loading. The internal structure, dimensions and specifications for all items shall be indicated in the subcontractor's shop drawings. Sign subcontractor to engineer signs to proper level to withstand abuses of their environment.
- G. Coordination: The Work in this section shall be completely coordinated with the work of other sections. Verify dimensions and work of other trades that adjoin materials of this section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all Work under this Project.
- H. Hold Points - Mockups: Provide one full size mock-up in place of each type of signage.
 - 1. If mockups do not comply with requirements, provide new identification device until mockups are accepted.
 - 2. Accepted mockups may become part of the completed Work if undisturbed at time of Contract Substantial Completion.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Deliver and store work under this section in a manner to prevent cracking or stress of components and to prevent mechanical damage or damage by the elements.

- B. Deliver work under this section to Site in ample time to avoid delay in job progress and at such times as to permit proper coordination of the various parts.
- C. Delay installation of this work until near time of opening for revenue service.

1.5 PROJECT CONDITIONS

- A. Substrates: Proceed with work of this Section only when substrate construction and penetration work have been completed.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Specialty Sign Manufacturers: Provide products of one of the following manufacturers if they meet or exceed the requirements of these specifications:
 - 1. Andco Industries Corp.
 - 2. A.R.K. Ramos Manufacturing Company, Inc.
 - 3. Best Manufacturing Co.
 - 4. Gemini, Inc.
 - 5. Lake Shore Markers.
 - 6. Metal Arts, Division of L & H Manufacturing Co.
 - 7. OMC Industries, Inc.
 - 8. The Southwell Company.

2.2 MATERIALS

- A. Steel
 - 1. Structural steel materials, details and workmanship shall conform to the specifications of the latest edition of the A.I.S.C. Specifications for the Design, Fabrication, and Erection of Structural Steel Buildings.
 - 2. Steel posts shall be Schedule 40 pipe, 2 inch internal diameter, ASTM A120 Standard Weight. The bottom of each post shall be deformed to provide for anti-rotation.
- B. Aluminum: Alloy 6063-T5, urethane finish.
- C. Plywood: APA Graded, Exterior Grade A-C Plywood and Marine Grade Plywood, as required.
- D. Bronze
 - 1. Cast bronze buttons shall be solid silicon bronze, sand cast from pre-alloyed ingots with no scrap permitted, with an applied wax finish. Original of buttons shall be sculpted from reproductions of the artifacts as indicated in the drawings. Bronze shall be cast in sizes

and thicknesses as shown on drawings. Sand sides to a smooth finish.

2. Original buttons shall be sculpted in clay from reproductions of the artifacts as indicated in the drawings.
 3. Sculptor shall be pre-qualified for the work indicated through submission of one complete, full scale, BT-5 sculpted clay button. If approved, the button may be used for casting production.
 4. Sculpting work to be provided by qualified sculpture studio.
- E. Plastic Laminate: Provide high pressure laminate engraving stock, with face and core plies in contrasting colors, in finishes and color combinations from manufacturer's full range.
- F. Cast Acrylic Sheet: Provide cast (not extruded or continuous cast) methyl methacrylate monomer plastic sheet, in sizes and thicknesses indicated, with a minimum flexural strength of 16,000 psi when tested according to ASTM D 790, with a minimum allowable continuous service temperature of 176 deg F, and of the following general types:
1. Transparent Sheet: Where sheet material is indicated as "clear," provide colorless sheet in matte finish, with light Transmittance of 92 percent, when tested according to the requirements of ASTM D 1003.
 2. White Translucent Sheet: Where sheet material is indicated as "white," provide white translucent sheet of density required to produce uniform brightness and minimum halation effects.
 3. Opaque Sheet: Where sheet material is indicated as "opaque," provide colored opaque acrylic sheet in colors and finishes.
- G. Hardware
1. Tamper resistant fasteners to be stainless steel, 3/8" dia. button head Phillips socket pinhead.
 2. High strength bolts other than anchor bolts, nuts and washers shall conform to ASTM A325.
 3. Threaded studs shall be low carbon mild steel with a minimum yield strength of 50,000 PSI.
 4. All hardware shall be galvanized per ASTM-A153 requirements.
 5. Where mechanical fasteners and hardware are required, shall be of adequate thickness, length and construction to properly secure the sign unit. Any visible portion of any mounting device shall be finished to match adjacent sign surface, unless otherwise specified.
 6. Metal fasteners and hardware in contact with dissimilar metals shall have a protective coating or neoprene shields to prevent electrolytic action.
- H. Adhesives
1. Where adhesive mounting techniques are specified, the subcontractor shall use adhesives specifically designed for compatibility with the base materials and the desired adhesive strength. All adhesives shall be tested on site. All adhesives shall be indicated in the shop drawings.

2. Surfaces on which signage is to be installed using adhesive shall be free of grease, oil, or any other residue.
3. Foam tape shall be 1/32" thick, high density open cell double coated polyurethane foam tape.
4. Very high bond (VHB) tape shall be double coated acrylic foam tape.
5. Provide necessary amounts of clear silicone sealant or grout for use in pin mounting.

I. Silk Screening

1. Screen printed text and symbols shall utilize photographically prepared screens and shall be printed in accordance with accepted industry standards. No hand-cut screens will be accepted. All screen printing shall be executed in such a manner that all edges and corners of letterforms are true and clean. Letterforms, color areas, or lines with rounded positive or negative corners, built-up edges, bleeding, spattering, etc. will not be accepted. All photoscreens shall be prepared from typesetter's reproduction of the text specified, or camera ready artwork. All artwork and typesetting shall be no less than 50% of actual specified size. All inks shall be applied evenly without pinholes, scratches, orange peeling, etc.

J. Typesetting

1. All typeset messages shall be prepared on a computer. Letterforms shall match the samples shown in the drawings. Output for photographic reproduction shall be 2400 dots per inch. No typesetter's proofs shall be enlarged more than three times for use as graphics.
2. Typical type and symbol layout for each sign type is indicated on the Drawings. All type shall be placed according to the dimensions shown on the drawings.

2.3 FABRICATION

A. Acrylic or Plastic Laminate Panel Signs: Fabricate as follows:

1. Construction: Backplate, 1/8 in. acrylic or plastic laminate.
2. Raised Letter Construction: 1/32 in. routed letters permanently mounted to surface of plate.
3. Border Style: None (straight).
4. Background Texture: Smooth.
5. Edges: Eased.
6. Fasteners: Flexible self-adhesive.
7. Corners: Square.
8. Braille: Provide raised Grade 2 Braille on each sign, as required.

B. Acrylic Letterform Signs: Fabricate as follows:

1. Construction: 6 in. high, 1/2 in. deep acrylic.
2. Projection: 1 in.
3. Color: Integral black letters.

- C. Fabricate work to be truly straight, plumb, level and square with smooth flat surfaces and sharp corners, except where indicated otherwise.
- D. Precisely form work to sizes, shapes, and profiles indicated on accepted shop drawings.
- E. Fabricate work with uniform joints that are not visible.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The DB Entity shall examine substrates, supports, and conditions under which this work is to be performed and notify the MBTA, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means DB Entity accepts substrates and conditions.
- B. Notification Point - Work shall be subject to inspection and acceptance by the MBTA in the shop or field at any reasonable time. Provide at least 72 hours notice for inspection of complete fabricated signs before delivery.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. All locations where signs are to be installed new must be field measured. This must be documented and sent to the MBTA prior to final digital artwork submittal and fabrication of signage.
- B. Strictly comply with accepted shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
- C. Install work plumb, level, in true plane and alignment. Provide signs and graphics where shown or scheduled using mounting methods indicated.
- D. Protect adjacent or adjoining surfaces and work from damage during installation in this Section.
- E. Work shall be designed and anchored so that work will not be distorted nor the fasteners overstressed from expansion and contraction of metal or other materials as applicable.
- F. Acrylic Letterform Sign Installation: Install cut letterform type signage mounted on canopy fascia in accordance with accepted shop drawings.
- G. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials. Insulating materials shall not be visible to public view in final configuration.

3.3 TOLERANCES

- A. The following allowable installed tolerances are allowable variations from locations and dimensions indicated by the Volume 2 and shall not be added to allowable tolerances indicated for

other Work:

1. Allowable Variation from True Plumb, Level and Line: Plus or minus 1/16 inch from true position for signage smaller than 24 by 24 inches in size; plus or minus 1/8 inch from true position for signage 24 by 24 inches in size and larger.
2. Allowable Variation from True Plane of Adjacent Surfaces: Plus or minus 1/16 inch.

3.4 CLEANING AND PROTECTION

- A. Adjust work to present the best possible appearance. Touch-up damaged finishes and repair damage to eliminate evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned. MBTA shall be final authority on acceptance of repaired work.
- B. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.
- C. The DB Entity shall provide Authority with information on cleaning and maintenance recommendations for all signs from the manufacturer.
- D. Names, stamps and decals of manufacturers, installers or maintainers of signs shall not be visible in the finished work. All assembly markings shall not be visible in the finished work.

END OF SECTION

SECTION 10426

TACTILE-BRAILLE SIGNAGE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies all ADA-required tactile/Braille signage as indicated on the Drawings and specified herein.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 10100 – DISPLAY CASES
 - 2. Section 10400 – FIXED SIGNAGE
 - 3. Section 10401 – METAL SIGN FRAMES
 - 4. Division 16 – ELECTRICAL - “Exit” signs; and “Variable Message Signs”.
- C. Permits: Obtain permits as required by Local Authorities for installation of signs.

1.2 SUBMITTALS

- A. Product Data: Manufacturer's product data, any limitations and recommendations for each material used, installation instructions, and manufacturer’s certification (stating that materials comply with requirements) for the Engineer of Record’s and MBTA’s review and acceptance.
- B. acceptance Drawings: Provide dimensioned shop drawings of each individual sign, based on .eps files supplied by the MBTA, along with a complete sign schedule utilizing the same designations as indicated on the MBTA’s drawings. The shop drawings must represent exactly what will be etched on each sign. No fabrication shall take place without acceptance of the shop drawings by the Engineer of Record and MBTA.
- C. Provide four copies of shop drawings for action by the Engineer of Record and MBTA.
- D. Samples for Approval:
 - 1. Provide one full-size, complete sample of a representative sign, etched, painted and finished, for acceptance by the Engineer of Record and MBTA.
 - 2. ADA compliance: the DB Entity shall complete the attached “ADA Tactile/Braille Metrics Check list” to assure that all metrics of sample sign are in compliance with ADA defined metrics.
 - 3. Approval of sample sign is required from the MBTA prior to final signage production.
 - 4. Sample will be resubmitted, if necessary, until it meets quality standards.

5. Once approved, the sample sign will be forwarded to the project site for installation (completed sample sign to be provided to the Designer of Record and MBTA at no extra charge).

1.3 QUALITY ASSURANCE

- A. Reference Standards: The Work shall conform to the codes and standards of the following regulatory Agencies and Authorities as further cited herein:
 1. ADA: Americans with Disabilities Act 2010 Standards
 2. ANSI: American National Standards Institute.
 3. ASTM: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 as published in "Compilation of ASTM Standards in Building Codes".
 4. MAAB: Massachusetts Architectural Access Board.
- B. Performance Requirements
 1. Painted Sign Finish shall comply with the following performance requirements:
 - a. Weatherability: When tested in accordance with ASTM G 53, after 500 hours in Weatherometer (equivalent to approximately 3 years exterior exposure):
 - b. Gloss retention not less than 88.0 determined in accordance with ASTM D 523 at a 60 degree angle.
 - c. Color shall not change more than 1.68 units determined in accordance with STM D 2244 and measured with a Hunter Colorimeter, Model D25.
 2. Durability: Sign finish shall not effect after repeated use of cleaners such as Graffiti Remover #1120 manufactured by Organics Corp., Lodi, NJ.
- C. Source: For each type of material required for the work of this section, provide Single-Source Responsibility.
- D. Accessibility: The ADA 2010 Standards and the MAAB regulations are pertinent to the design and installation of items covered under the work of this Section. When guidelines conflict, the guideline giving greater access shall be applicable.
- E. Qualifications: The approved manufacturer shall have a minimum of 5 years of successful experience with similar work, and shall have a reputation for doing satisfactory work on time.
- F. Coordination: The work in this Section shall be completely coordinated with the Work of other Sections. Verify dimensions and work of other trades that adjoin materials of this Section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all Work under this Project.
- G. Certification: Submit manufacturer's certification that materials furnished comply with requirements specified.
- H. Maintenance Instructions: Submit manufacturer's instructions for maintenance of tactile/Braille sign to the MBTA, including precautions for use of cleaning materials and solvents.

I. Warranty:

1. Submit a written Manufacturer's warranty for MBTA acceptance, signed by the manufacturer, agreeing to repair or replace panels that fail during the specified warranty period. Failures include, but are not limited to, the following:
 - a. Coating degradation.
 - b. Chipping, chalking, fogging or discoloration.
 - c. Fading.
2. Warranty Period: 1 year from product ship date.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Deliver and store work under this Section in a manner to prevent the cracking or stress of components, and to prevent mechanical damage or damage from the elements.
- B. Deliver work under this Section to Site in ample time to avoid delay in job progress and at such times as to permit proper coordination of the various parts.
- C. Installation of this work shall be scheduled to occur near time of Substantial Completion.
- D. Inspect sign components for damage on delivery.
 1. Do not install damaged signs. Replace any damaged signs with new signs.

1.5 PROJECT CONDITIONS

- A. Substrates: Proceed with Work of this Section only when substrate construction and penetration work have been completed.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Zinc Signs
 1. 0.125" one-piece zinc plate, utilizing chemical etch process to produce raised characters in compliance with ADA and supplied graphics. Chamfer or ease all sides and corners to remove sharp edges.
 2. Acceptable Manufacturers: the following is a partial list of zinc signage manufacturers:
 - a. Vivid Manufacturing
 - b. Dixie Graphics
 - c. Kroy Sign Systems

- d. Etchcraft Incorporated
- e. Advance Corporation
- f. ADA Signs
- g. ASI
- h. ASE Manufacturing

B. Attachments

1. Mechanical:

- a. Threaded inserts appropriate to substrate material – 4 per sign
- b. Tamper resistant, ¼” diameter stainless steel Flat Head Phillips Pin-Head screws. Screws shall seat into countersunk holes such that when fully tightened the screw head is flush with sign background surface. Paint screws to match background paint color of sign
- c. Non-metallic Washers: Provide rigid neoprene separators between fasteners and non-compatible materials being joined.

2. Adhesive:

- a. Where adhesive mounting techniques are specified, very high bond (VHB) tape specifically designed for compatibility with the base materials and the desired adhesive strength shall be used. All adhesives shall be tested on site. All adhesives shall be indicated in the shop drawings.
- b. Very high bond (VHB) tape shall be double coated acrylic foam tape as manufactured by the 3M Co., or approved equal.
- c. Surfaces on which signage is to be installed using adhesive shall be free of grease, oil, or any other residue.

2.2 Fabrication

A. Zinc Signs:

- 1. Etching: Signs reverse-etched to create all tactile text, lines, arrows, and braille glyphs raised 1/32” high. Braille glyphs shall be standard rounded grade 2 Braille as rendered in the EPS files. Cross section angle of raised characters shall not exceed 45 degrees. Text and Braille shall be finished to provide smooth, non-pointed edges. Background surface shall be smooth texture.
- 2. Finishes:
 - a. Background - Mathews baked-on acrylic polyurethane enamel paint with eggshell/matte finish. Custom color shall be: Black.
 - b. Foreground - (tactile lettering only) brushed natural zinc with U.V. resistant clear urethane topcoat.
 - c. Predrilled holes: Provide four ¼” counter sunk mounting holes, centered 3/8” from edges, only in corners of signs scheduled to be screw attached. All other signs to be provided without mounting holes.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Prior to installation, the DB Entity shall examine substrates, supports, and conditions under which this work is to be performed, and notify the MBTA in writing of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means DB Entity accepts substrates and conditions.
- B. Notification Point: MBTA will be given 72 hour notice to perform field inspection prior to the start of signage installation. The MBTA shall conduct a detailed inspection of all tactile/Braille signs to be installed prior to installation to assure compliance with the supplied drawings. A formal signoff by the MBTA must be executed prior to commencement of any installation. If work does not meet project requirements, the DB Entity must replace deficient work.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. All locations where signs are to be installed new or retrofitted to existing frames must be field measured by the DB Entity. This must be documented and sent to the Engineer of Record and MBTA prior to final digital artwork submittal and fabrication of signage.
- B. Strictly comply with accepted shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
- C. Install work plumb, level, and in true plane and alignment. Provide signs and graphics where shown or scheduled using mounting methods indicated.
- D. Protect adjacent or adjoining surfaces and work from damage during installation in this Section.
- E. Work shall be designed and anchored so that work will not be distorted nor the fasteners overstressed from expansion and contraction of metal or other materials as applicable.
- F. The tactile/Braille signs are small in size and shall be installed plumb and square. In the event that an adjacent material, such as a doorframe, is slightly out of plumb, the DB Entity shall install the tactile/Braille sign parallel so as to minimize the visual conflict.

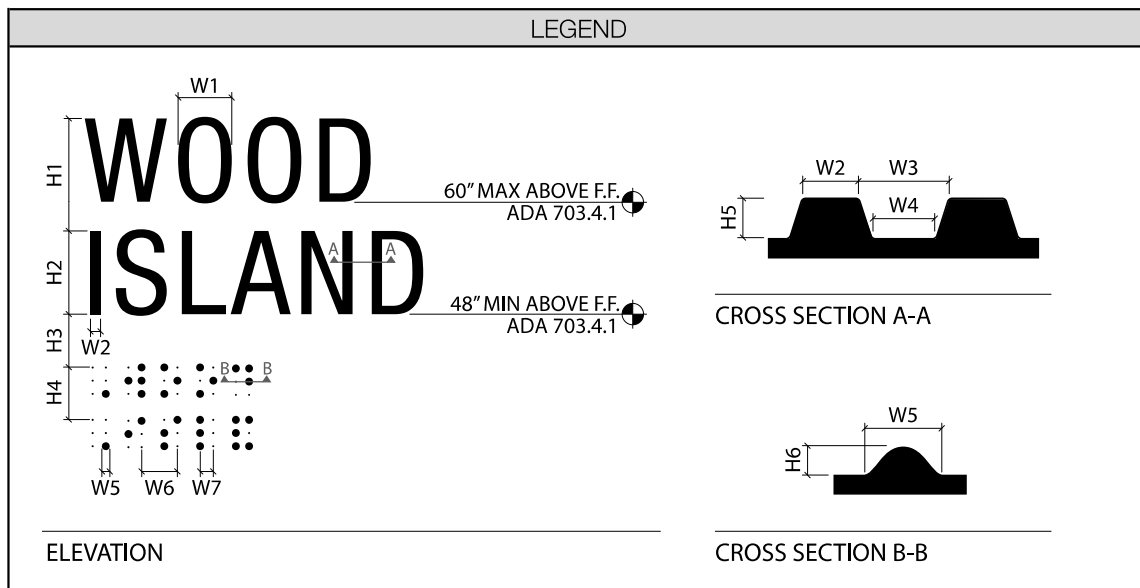
3.3 CLEANING AND PROTECTION

- A. Adjust work to present the best possible appearance. Touch-up damaged finishes and eliminate any evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned.
- B. Provide temporary protection to ensure work is delivered without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.
- C. The DB Entity shall provide the Authority with information on cleaning and maintenance recommendations for all signs from the Manufacturer.

- D. Names, stamps and decals of manufacturers, installers or maintainers of signs shall not be visible in the finished work.

3.4 ADA Compliance Checklist

- A. Tactile/Braille signs must comply with the dimensional requirements of ADA 703.3 (2010). The following legend graphically illustrates each ADA 703.3 metric.
- B. Once a mockup has been fabricated, and prior to submission for acceptance, the fabricator must complete the following check list to assure that the sample product is in complete compliance with ADA metrics. Completed checklist must be submitted with sample sign for approval. Samples submitted without a completed checklist will be rejected.
- C. Tactile metrics legend



D. ADA 703.2 and 703.3 Compliance Checklist

ADA 703.2 – Raised Characters						
Legend Symbol	ADA Reference	Description	ADA Values	ADA Values for 5/8" Text	Check by Contractor	Check by Designer
H5	703.2.1 Depth	Depth of character above background	$\geq 1/32"$ (0.8 mm)	-		
-	703.2.2 Case	All Uppercase	Y/N	-		
-	703.2.3 Style	Sans serif, not italic, oblique, script, highly decorative, or of unusual forms	Y/N	-		
W1	703.2.4 Character Proportions	Width of uppercase "O" relative to height of uppercase "I" (H2)	$0.55 \leq W1/H2 \leq 1.1$	Min: 0.344" Max: 0.743"		
H2	703.2.5 Character Height	Height of uppercase "I"	$0.625" \leq H2 \leq 2"$ $16 \text{ mm} \leq H2 \leq 51 \text{ mm}$	0.625"		
W2	703.2.6 Stroke Thickness	Width of uppercase "I" relative to height of uppercase "I" (H2)	$W2/H2 \leq 0.15$	$\leq 0.094"$		
W3	703.2.7 Character Spacing	Rectangular cross section or top of beveled cross section	$0.125" \leq W3 \leq 4(W2)$ $3.2 \text{ mm} \leq W3 \leq 4(W2)$	Min: 0.125" Max: 0.376"		
W4	703.2.7 Character Spacing	Base of beveled cross section	$0.0625" \leq W4 \leq 4(W2)$ $1.6 \text{ mm} \leq W4 \leq 4(W2)$	Min: 0.063" Max: 0.376"		
H1	703.2.8 Line Spacing	Distance between baselines of raised characters relative to height of uppercase "I" (H2)	$1.35 \leq H1/H2 \leq 1.7$	Min: 0.844" Max: 1.063"		

ADA 703.3 – Braille						
Legend Symbol	ADA Reference	Description	ADA Values	-	Check by Contractor	Check by Designer
-	703.3.1 Dimensions & Capitalization	Domed or rounded shape	Y/N			
-	703.3.1 Dimensions & Capitalization	Uppercase letters only before first word of sentences, proper nouns and names, individual letters of the alphabet, initials, acronyms	Y/N			
W5	703.3.1 Braille Dimensions	Dot base diameter	Min: 0.059" (1.5 mm) Max: 0.063" (1.6 mm)			
W7	703.3.1 Braille Dimensions	Distance between two dots in the same cell	Min: 0.090" (2.3 mm) Max: 0.100" (2.5 mm)			
W6	703.3.1 Braille Dimensions	Distance between corresponding dots in adjacent cells	Min: 0.241" (6.1 mm) Max: 0.300" (7.6 mm)			
H6	703.3.1 Braille Dimensions	Dot Height	Min: 0.025" (0.6 mm) Max: 0.037" (0.9 mm)			
H4	703.3.1 Braille Dimensions	Distance between corresponding dots from one cell directly below	Min: 0.395" (10 mm) Max: 0.400" (10.2 mm)			
-	703.3.2 Position	Braille below corresponding text. If multi-lined, below entire text.	Y/N			
H3	703.3.2 Position	Distance from Braille to tactile characters, raised borders, and decorative elements.	$\geq 0.375"$ (9.5 mm)			

END OF SECTION

SECTION 10428

MBTA LOGO “LOLLIPOP” SIGN

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the MBTA logo sign as indicated on the DB Entity’s accepted shop drawings and specified herein. All modes of transport requiring a logo sign will use this specification to maintain consistency of appearance.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 09900 – PAINTING
 - 2. Section 10401 – METAL SIGN FRAMES
 - 3. Division 16 - ELECTRICAL; Signs.
- C. Permits: Obtain permits required by Authority Having Jurisdiction for installation of signs.

1.2 GRAPHICS

- A. MBTA logo dimensions can be found in MBTA 2013 Logo Sign Guidelines and must be followed to ensure consistency. MBTA logo graphics can also be provided by MBTA upon request.

1.3 PERFORMANCE REQUIREMENTS

- 1. Design Criteria: Design, fabricate, and install sign items to withstand normal exposure to weather, temperature variation, wind loads and building movement; provide units resistant to vandalism and theft.
- 2. Field Measurements: Check actual locations of construction - to which metal fabrications must fit - by accurate field measurements before fabrication; show recorded measurements on final DB Entity’s accepted shop drawings prior to fabrication
- 3. Thermal Movements: Allow for thermal movement resulting from the following maximum change (range) in ambient temperature in engineering, fabricating, and installing signs to prevent buckling, opening of joints, over stressing of components and connections, and other detrimental effects. Base engineering calculation on actual surface temperatures of materials due to both solar heat gain and nighttime sky heat loss.
 - a. Temperature Change (Range): 0 - 180 deg F ambient, material surfaces.
- 4. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials.

1.4 SUBMITTALS

- A. All submittals shall be provided to the MBTA.
- B. Product Data: Manufacturer's product data, any limitations and recommendations for each material used, installation instructions, and manufacturer's certification (stating that materials comply with requirements) for the MBTA's review and acceptance.
- C. DB Entity's accepted shop drawings: Provide shop drawings for fabrication and installation of logo sign including mounting. Provide plans, elevations, and details of anchorage, connections and accessory items. Provide installation templates for work installed by others. Provide four copies of shop drawings for action by the MBTA. After action, provide two copies of shop drawings on which action has been taken for MBTA's records.
- D. Sign Schedules: Submit complete Sign Schedule for logo sign. Use same designation as on the DB Entity's accepted shop drawings.
- E. Samples for Approval: Sample Submittals are in addition to quantities shown in sign schedule. They are record project samples to be kept on file.
 - 1. Paper Proofs: Provide proofs for logo sign including half-size elevation sample of the entire logo sign.
 - 2. Submit 3" x 4" samples of polycarbonate lens material in white and black colors.
 - 3. Acceptance of all proofs is required from the MBTA prior to final sign production.
 - 4. Color samples and paper proofs will be resubmitted until they meet quality standards outlined in the next section.
 - 5. Provide samples and proofs to the MBTA at no extra charge.

1.5 QUALITY ASSURANCE

- A. MBTA Reference Standard: Comply with the MBTA Logo Sign Guidelines.
- B. Reference Standards: The work shall conform to the codes and standards of the following agencies as further cited herein:
 - 1. ADAAG: Americans with Disabilities Act Accessibility Guidelines
 - 2. ANSI: American National Standards Institute
 - 3. ASTM: American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 as published in "Compilation of ASTM Standards in Building Codes"
 - 4. MAAB: Massachusetts Architectural Access Board
 - 5. Structural Code:
 - a. Latest edition of the Massachusetts State Building Code
 - b. AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals

- c. Latest edition of NFPA 70 National Electrical code
- C. The Lollipop Sign shall be certified as UL listed and have affixed to the sign the UL Certification Listing Mark and all required markings.
- D. Accessibility: The ADAAG and the MAAB regulations are pertinent to the design and installation of items covered under the work of this Section. When guidelines conflict, the guideline giving greater access shall be applicable, however written acceptance must be obtained by the MBTA Capital.
- E. Qualifications: The approved manufacturer shall have minimum of 5 years of successful experience with similar work, shall have a reputation for doing satisfactory work on time.
- F. Welding Standards: Comply with applicable provisions of the American Welding Society AWS D1.1 "Structural Welding Code."
 - 1. Certify that welder has satisfactorily passed AWS qualification tests for welding processes involved and, if pertinent, has undergone recertification.
- G. Coating Applicator Qualifications: must be experienced in successfully applying specified coatings of the type indicated to specified materials, and equipped with the following:
 - 1. Application equipment required to apply a uniform coating as recommended by the coatings manufacturer.
- H. Engineering: Design, engineering and structural analysis for the Lollipop Sign and supports, as well as necessary calculations, shall be prepared under the supervision of, and signed and sealed by, the Engineer of Record. These calculations shall include gravity, wind, and seismic loading. The internal structure, dimensions and specifications for all items shall be indicated in the DB Entity's accepted shop drawings, and shall be indicated in the drawings. The Engineer of Record shall engineer signs to a proper level to withstand abuses of their environment.
- I. Coordination: The work in this Section shall be completely coordinated with the work of other Sections. Verify dimensions and work of other trades that adjoin materials of this Section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all work under this Contract.
- J. Hold Points: Completed logo sign shall be available for inspection for two weeks prior to installation, with notification given to the MBTA. If MBTA determines sign does not comply with requirements, provide new logo sign until it is accepted.
- K. Project Meetings: The signage subcontractor and related subcontractors shall be required to attend project meetings at the Project site when required by the MBTA.
- L. Certification: Submit manufacturer's certification that materials furnished comply with requirements specified.
- M. Maintenance Instructions: Submit manufacturer's printed instructions for maintenance of each sign installed to the MBTA, including precautions for use of cleaning materials and solvents for paint removal, which could damage surfaces.
- N. Warranty:

1. Submit a written Manufacturer's warranty for the MBTA acceptance, signed by the manufacturer, agreeing to repair or replace lenses that fail during specified warranty period. Failures include, but not limited to, the following:
 - a. Coating degradation
 - b. Chipping, chalking, fogging or discoloration.
 - c. Fading.
 - d. Structural failure.
 - e. Delamination of applied graphics.
 - f. Delaminating or degradation of applied anti-graffiti coatings.
2. The manufacturer's warranty is in addition to, and not a limitation of, other rights the MBTA may have under the Contract Documents.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver and store work under this Section in a manner to prevent cracking or stress of components and to prevent mechanical damage or damage by the elements.
- B. Deliver work under this Section to Site in ample time to avoid delay in job progress and at such times as to permit proper coordination of the various parts.
- C. Installation of this work shall wait until near time of revenue service.
- D. Handle signs carefully to prevent breakage, surface abrasion, denting, soiling, and other defects. Comply with the manufacturer's written handling instructions for unloading components subject to damage. Inspect sign components for damage on delivery.
 1. Do not install damaged sign components.
 2. Repair minor damage to signs, provided the finished repair is equal in all respects to the original work and is accepted by MBTA in writing; otherwise, remove and replace damaged sign components as directed and without exception.

1.7 PROJECT CONDITIONS

- A. Inspection of Site: The DB Entity shall visit the site of the proposed work and become fully acquainted with existing conditions, and to become fully informed as to the facilities involved and the difficulties and restrictions attending the performance of the Project, prior to submitting a price quotation.
- B. Substrates: Proceed with work of this Section only when substrate construction and penetration work have been completed.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Logo “Lollipop” Sign: Each sign will be shop fabricated by the DB Entity off-site and delivered and installed at the locations as shown on the DB Entity’s accepted shop drawings.
- B. Lens: The lens shall be Solar Grade, vacuum-formed, UV resistant, high-impact polycarbonate convex sheets with 2 ½” bow. The polycarbonate shall be ¼” in thickness. The lens shall be white with a black “T” on the surface on both exterior sides. The black “T” logo shall be embossed such that it protrudes .375” out from the white background.
- C. Structural Steel:
1. The sign’s post shall be a schedule 80 steel pipe, with an outer diameter of 3.5” and an inner diameter of 2.90”. The pipe will be welded to steel gusset plate and steel base plate.
 2. The frame shall be a C4 x 5.4 steel rolled channels with ¼” weep holes, and opening wide enough for the pipe. The channel will be bent and welded to form a circle with the flange on the outside.
 3. The sign frame and support shall be shop painted steel.
- D. Sign Connections:
1. Logo sign attached and or supported as shown on the MBTA’s Green Line Extension Station Signage Components, including supports and connections.
 2. Continuously weld joints and seams unless other methods are indicated; grind, fill, and dress welds to produce smooth, flush, exposed surfaces with welds invisible after final finishing.
 3. Logo sign pipe will be secured in Portland cement concrete or bituminous concrete sidewalks or other rigid surfaces and shall be in accordance with the DB Entity’s accepted shop drawings. Any leveling of the sign baseplate to the concrete sub-base should be filled with a pourable cementitious, non-shrink grout.
 4. The polycarbonate lens will be mechanically fastened to the frame with two half-circle angle long leg in aluminum ring frame, for each sign face.
 5. Neoprene sponge between channel ring frame and lens shall conform to ASTM D1056, Type 2, Class C, Grade 2.
 6. The steel pipe will connect to the circular channel ring frame by sliding the pipe through hole cut at base of the channel ring. Two steel angle clips welded to the interior of the channel ring at the top and two at the bottom will be mechanically fastened to the pipe.
 7. All hardware shall be as indicated on DB Entity’s accepted shop drawings.
- D. Hardware:
1. Anchors and Inserts: Use non-ferrous metal or hot-dipped galvanized anchors and inserts for exterior installations and elsewhere as required for corrosion resistance. High strength bolts other than anchor bolts, nuts and washers shall conform to ASTM A325.
 2. Tamper resistant fasteners to be stainless steel, 3/8" dia. button head Phillips socket pinhead.

3. Threaded studs shall be low carbon mild steel with a minimum yield strength of 50,000 PSI.
 4. All hardware shall be as indicated on DB Entity's accepted shop drawings: 316 stainless steel, or galvanized per ASTM-A153 requirements.
 5. Where mechanical fasteners and hardware are required, they shall be of adequate thickness, length and construction to properly secure the sign.
 6. Welding Electrodes and Filler Metal: Type and alloy of filler metal and electrodes as recommended by producer of metal to be welded, complying with applicable AS specifications, and as required for color match, strength, and compatibility in the fabricated items.
 7. Galvanizing Repair Paint: High zinc dust content paint for re-galvanizing welds in galvanized steel, with dry film containing not less than 94 percent zinc dust by weight, complying with DOD- P-21035 or SSPC-Paint 20.
- E. Coatings: The logo sign frame, post, and anchors shall all receive the Exterior Ferrous Metal, Urethane system as specified in section 09900. Finish will be color semi-gloss black.
- F. Electrical:
1. Electrical wire shall be #10 and be a 3 wire system.
 2. Conduit shall be rigid galvanized steel.
 3. Twelve Light-Emitting Diode (LED) shall be 5000K. Power supply shall be 277volt or 120volt, depending on site conditions, damp rated. The LEDs will be tacked to two 3" wide steel sheet metal channels placed in the inside of the steel channel ring to either side of the pipe. These two channels will be bent with flanges out (opposite of channel ring frame bend), so that the wiring will fit between the steel sheet metal channel and the channel ring frame. See DB Entity's accepted shop drawings for clarification.

2.2 FABRICATION

- A. Precisely form work to sizes, shapes, and profiles indicated on DB Entity's accepted shop drawings.
- B. Any material defects or damage due to shipment will be repaired or replaced by the supplier.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The DB Entity shall examine substrates, supports, and conditions under which this work is to be performed and notify the MBTA, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means DB Entity accepts substrates and conditions.

- B. Notification Point: The MBTA will be given 72 hour notice to perform field inspection at the start of installation of signage. If work does not meet project requirements, the DB Entity must remove and replace deficient work.

3.2 INSTALLATION/APPLICATION/ERECTION

- A. Strictly comply with DB Entity's accepted shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
- B. Install LED lighting in accordance with manufacturer's instructions.
- C. Install sign plumb, level, in true plane and alignment. Provide logo sign where shown or scheduled using mounting methods indicated.
- D. Protect adjacent or adjoining surfaces and work from damage during installation in this Section.
- E. Work shall be designed and anchored so that work will not be distorted nor the fasteners overstressed from expansion and contraction of metal or other materials as applicable.
- F. Verify all electrical wiring and connections are secure and protected.

3.3 TOLERANCES

- A. The following allowable installed tolerances are allowable variations from locations and dimensions indicated by the Contract Documents and shall not be added to allowable tolerances indicated for other work:
 - 1. Allowable Variation from True Plumb, Level and Line: Plus or minus 1/16 inch from true position for signage smaller than 24 by 24 inches in size; plus or minus 1/8 inch from true position for signage 24 by 24 inches in size and larger.
 - 2. Allowable Variation from True Plane of Adjacent Surfaces: Plus or minus 1/16 inch.

3.4 CLEANING AND PROTECTION

- A. Adjust work to present the best possible appearance. Touch-up damaged finishes and eliminate any evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned.
- B. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.
- C. The DB Entity shall provide Authority with information on cleaning and maintenance recommendations for logo sign from the manufacturer.
- D. Names, stamps and decals of manufacturers, installers or maintainers of signs shall not be visible in the finished work.

END OF SECTION

SECTION 10440

SITE SIGNAGE

PART 1 - GENERAL

1.1 GENERAL PROVISIONS

- A. This Section specifies furnishing and installing aluminum signs on galvanized steel posts and furnishing and installing other types of site signage indicated herein.

1.2 DESCRIPTION OF WORK

- A. Work Included: Provide labor, materials and equipment necessary to complete the Work of this Section, including the following:
 - 1. Trailblazer signs, handicapped parking signs, parking space assignment signs, directional signs, safety signs, and other types of site signage.
- B. Related Work: The following items are not included in this Section and are specified under the designated Sections:
 - 1. Section 03300 – CAST-IN-PLACE CONCRETE
 - 2. Section 10400 – FIXED SIGNAGE
 - 3. Section 10424 – SPECIALTY SIGNAGE
 - 4. Section 10426 – TACTILE/BRAILLE SIGNAGE
 - 5. Section 10428 – MBTA LOGO “LOLLIPOP” SIGN
 - 6. Section 16742 – VARIABLE MESSAGE SIGN SYSTEM

1.3 SUBMITTALS

- A. Product Data: Include construction details, material descriptions, and dimensions of individual signs.
- B. Shop Drawings: Include plans, elevations, and large-scale sections of typical members and other components. Show mounting methods, grounds, mounting heights, layout, spacing, reinforcement, accessories, and installation details.
 - 1. Take measurements in the field and verify all dimensions before submitting shop drawings or samples.
 - 2. Provide message list for each sign, including large-scale details of wording, lettering, and artwork.
 - 3. Where provisions must be made for attaching other materials to work included under this Section or where provisions must be made for assembly and installation in the field, the required cut outs and attachments shall be provided in the shop. All such items shall be indicated on the shop drawings.

- C. Samples for Verification: For each type of sign, include the following Samples to verify color selected:
 - 1. Panel Signs: Full-size Samples of each type of sign required.
 - 2. Approved samples will not be returned for installation into Project.
 - 3. The MBTA may inspect all material and workmanship at any time during the progress of the work and shall have the right to reject all material and workmanship that does not conform to the Specifications or that is not considered of adequate quality in terms of accuracy of registration, color, or coverage.
 - 4. List manufacturer and name for each type and color of paint used.
- D. Maintenance Data: For all signage, cleaning and maintenance requirements to be included in maintenance manuals.

1.4 COLOR SAMPLES

- A. Colors shall be pure, non-fading pigments, mildew-proof, sun proof, finely ground in approved medium. Colors used shall be submitted on the respective material surfaces. The "Commuter Rail" purple paint color shall match Dupont Imron 1976.

1.5 QUALITY ASSURANCE

- A. Source Limitations: Obtain each sign type through one source from a single manufacturer.
- B. Regulatory Requirements: Comply with the Massachusetts Architectural Access Board, Americans with Disabilities Act (ADA), and with code provisions as adopted by authorities having jurisdiction.
- C. Deliver and store work in a manner to prevent cracking, chipping, or stress of components and to prevent mechanical damage or damage by the elements. Damaged items shall be removed and replaced as directed.

1.6 PROJECT CONDITIONS

- A. Field Measurements: Where sizes of signs are determined by dimensions of surfaces on which they are installed, verify dimensions by field measurement before fabrication and indicate measurements on shop drawings.

1.7 COORDINATION

- A. For signs supported by or anchored to permanent construction, advise installers of anchorage devices about specific requirements for placement of anchorage devices and similar items to be used for attaching signs.

PART 2 - PRODUCTS

2.1 COORDINATION

- A. General: Provide signs that comply with requirements indicated for materials, thicknesses,

finishes, colors, designs, shapes, sizes, and details of construction as indicated. Produce smooth panel sign surfaces constructed to remain flat under installed conditions within tolerance of plus or minus 1/16 inch measured diagonally. Provide the following:

1. Code-Required Signs for Certificate of Occupancy:
 - a. Type: Photopolymer on acrylic or printed acrylic / aluminum as applicable.
 - b. Color: Selected from manufacturer's standard colors including dark blue.
 - c. Edge: Square cut.
 - d. Corner: Square cut.
 - e. Type Size - Room #: 1-1/4 in. high.
 - f. Type Size - Room Name: 5/8 in. high.
 - g. Typeface: Gill Sans.
2. Exterior Signs:
 - a. Type – Entrance: Fabricated monolithic aluminum sign with stencil cut graphics and non- illuminated.
 - b. Type – Directional: Fabricated aluminum sign, 3 inches deep, double post and panel.
 - c. Raised-Copy Thickness: Not less than 1/32 inch.
 - d. Changeable Message Inserts: Where indicated, fabricate signs to allow insertion of changeable messages in form of transparent covers with paper inserts printed by MBTA.

2.2 ACCESSORIES

- A. Glass Mounting: Blank panel same size as sign mounted to reverse side of glass.
- B. Anchors and Inserts: Provide nonferrous-metal or hot-dip galvanized anchors and inserts for exterior installations and elsewhere as required for corrosion resistance. Use toothed steel or lead expansion-bolt devices for drilled-in-place anchors. Furnish inserts, as required, to be set into concrete or masonry work.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Examine substrates, areas, and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of work.
- B. Verify that items provided under other sections of Work are sized and located to accommodate signs.
- C. Examine supporting members to ensure that surfaces are at elevations indicated or required to comply with authorities having jurisdiction and are free from dirt and other deleterious matter.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. General: Locate signs and accessories where indicated, using mounting methods of types described and in compliance with manufacturer's written instructions.
 - 1. Install signs level, plumb, and at heights indicated, with sign surfaces free from distortion and other defects in appearance.
 - 2. Interior Wall Signs: Install signs on walls adjacent to latch side of door where applicable. Where not indicated or possible, such as double doors, install signs on nearest adjacent walls. Locate to allow approach within 3 inches of sign without encountering protruding objects or standing within swing of door.

3.3 CLEANING AND PROTECTION

- A. After installation, clean soiled sign surfaces according to manufacturer's written instructions. Protect signs from damage until acceptance by MBTA.

END OF SECTION

SECTION 10606

BICYCLE STORAGE RACKS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies bicycle storage racks.
 - 1. Storage and handling requirements and recommendations.
- B. Shop Drawings: Manufacturing details for each bicycle rack.

1.2 SUBMITTALS

- A. Product Data: Manufacturer's data sheets on each product to be used, including preparation instructions and recommendations.
- B. Samples for Verification: For each finish product specified, two samples, minimum size 6 inches (150 mm) square representing actual product, color, and patterns.

1.3 QUALITY ASSURANCE

- A. Manufacturer Qualifications: A firm experienced in manufacturing bicycle racks similar to those required for this project and with a record of successful in-service performance.
- B. Installers Qualifications: An experienced installer who has completed installation of bicycle racks similar in material, design, and extent to that indicated for this project and whose work has resulted in construction with a record of successful in-service performance.
- C. Source Limitations: Obtain each color, finish, shape and type of bicycle rack from a single source with resources to provide components of consistent quality in appearance and physical properties.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Store products in manufacturer's unopened packaging until ready for installation.
- B. Store and dispose of solvent-based materials, and materials used with solvent-based materials, in accordance with requirements of local authorities having jurisdiction.

1.5 PROJECT CONDITIONS

- A. Maintain environmental conditions (temperature, humidity, and ventilation) within limits recommended by manufacturer for optimum results. Do not install products under environmental conditions outside manufacturer's absolute limits.

PART 2 - PRODUCTS

2.1 BICYCLE STORAGE RACKS

- A. Basis-of-Design Product: Dero Bike Racks; Dero Decker, Modular 2-Tiered or an approved equal.

1. Construction: 11 gauge (0.06 inch) (1.52 mm) steel for corner pieces and cross braces.
2. Capacity: DD-SS-8; 8 bike capacity, 17 inch (432 mm) spacing.
3. Upper Bike Stalls: 3/8 inch (9.5 mm) mounting hardware.
4. Lower Bike Stalls: 1/4 inch (6.4 mm) mounting hardware.
5. Square Beams: 6 inch (152 mm) and 2 inch (51 mm), 0.1875 inch (4.763 mm) thick.
6. Mounting Brackets: 0.1793 inches (7 gauge) (4.554 mm) thick.
7. Base Plates and Locking Flange: 0.25 inches (6.35 mm) thick.
8. Roller Cart Sides: 0.1196 inches (11 gauge) (3.038 mm) thick.
9. Tubes: 1.25 inches (31.7 mm) diameter, 0.625 inches (15.9 mm) diameter, 0.0598 inches (16 gauge) (1.519 mm) thick.
10. Wheel Tray: 0.0598 inches (16 gauge) (1.519 mm) thick.
11. Second Level Bike Positions: Assisted lift.
12. Finish: Hot dipped galvanized coating.

2.2 MATERIALS

- A. Steel Tube: ASTM A 513, electric welded steel tubing.
- B. Steel Pipe: ASTM A 500B, steel pipe.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Do not begin installation until substrates have been properly prepared.

3.2 INSTALLATION

- A. Install bike storage racks in accordance with manufacturer's instructions.
- B. Install level, plumb, and true.

3.3 PROTECTION

- A. Protect installed bike racks until completion of Project.
- B. Touch-up, repair or replace damaged products before Contract Substantial Completion.

END OF SECTION

SECTION 11140

VEHICLE SERVICE EQUIPMENT

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- B. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- C. Furnish and install the equipment items listed below by their identifier:
 - 1. Pallet, Spill Containment (EQ ID: 1234)
 - 2. Pump, air piston, 3:1 ratio (Waste Oil) (EQ ID: 7530)
 - 3. Receiver, used oil, 25 gallons (EQ ID: 7706)
 - 4. Hoist, truck repair, 15,000 lbs, above-slab (EQ ID 9443)
- D. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in Article 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The DB Entity shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 3 - Concrete
 - 2. Division 15 - Mechanical
 - 3. Division 16 – Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.

- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Volume 2 Technical Provisions.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the DB Entity.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Volume 2 Technical Provisions. Acceptance will be based on the technical requirements herein as determined by the MBTA.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Volume 1 Contract Terms and Conditions.

PART 2 – PRODUCTS

2.1 PALLET, SPILL CONTAINMENT (EQ ID: 1234)

A. Manufacturer's Reference

1. Prime Manufacturer: Specifications are based on products identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Eagle Manufacturing, Wellsburg, West Virginia, (304) 737-3171
 - 1) Model: 1640
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions.

B. General Description

1. Spill containment pallet for up to 4 drums.

C. Capacities/Capabilities

1. Capacity: 132 gal.
2. Provide a drain connection.
3. Provide forklift able design to allow use of a forklift or pallet jack to move the pallet.
4. Provide load capacity of 8,000 lbs.
5. Dimensions: 52.5" wide x 51" length x 13 ¾" height.
6. Meet EPA requirements for secondary spill containment of hazardous materials (40 CFR 264.175)

2.2 PUMP, AIR-POWERED, OILS, MEDIUM PRESSURE (EQ ID: 7530)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on furniture identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Graco, Minneapolis, MN, (612) 623-6000
 - 1) Model: LD Series 3:1 #24G579

2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions, furniture produced by other manufacturers, including the following, may be considered as equal:

- a. Flowserve, Irving, TX, (800) 728-6989
- b. Parker Autoclave Engineers, Erie, PA, (814) 860-5700

B. Capacities/Dimensions:

1. Ratio: 3:1
2. Mounting: Bung Mount
3. Output per cycle: 142 cc
4. Output at 75 CPM: 2.5 gpm (25.3 lpm)
5. Motor size: 4.25" effective diameter
6. Maximum fluid pressure: 450 psi
7. Air Input Pressure Range: 20-150 psi
8. Air Inlet size: ¼" inch
9. Pump Inlet size: 1" inch npt(f)
10. Pump outlet size: ½" inch npt(f)

C. Features/Performance/Construction:

1. Provide electronic controls for pump diagnostics, material usage tracking, and pump runaway protection.

2.3 RECEIVER, WASTE OIL, 25 GALLONS (EQ ID: 7706)

A. Manufacturer's Reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer's name and model to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Graco, Incorporated, Minneapolis, MN (612) 623-6000
 - 1) Model: 248866
2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:
 - a. The Aro Corporation, Bryan, OH (419) 636-4242
 - b. Lincoln, A Pentair Company, St. Louis, MO (314) 679-4200

B. Capacities/Dimensions:

1. Capacity: 25 gallons
2. Dimensions:
3. Length: 24 inches
4. Width: 24 inches
5. Height: 45 to 72 inches
6. Dry weight: 54 pounds
7. Fluid inlet/inspection port size: 3 inch (76 millimeter) buttress
8. Fluid outlet fitting size: 3/4 inch NPT
9. Collection funnel size: 22 x 24 inches

C. Features/Performance/Construction:

1. Unit shall be constructed of heavy duty, durable UV-stabilized polymer.
2. The unit shall include a gravity feed drain valve and a quick disconnect method of suction-evacuation from the top of the unit.
3. The unit shall be mounted on semi-pneumatic, synthetic rubber wheels and polyurethane front casters.
4. The unit shall contain a funnel assembly capable of extending to 72 inches.
5. The unit shall be dent, rust, and corrosion resistant.

D. Finish: UV-stabilized polymer complete with necessary markings to readily identify contents.

2.4 HOIST, TRUCK REPAIR, 15,000 LBS, ABOVE-SLAB

A. Manufacturer's Reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer's name and model to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. American Solving Inc., Brook Park, OH (440-234-7373)
 - 1) Model: Heavy Capacity Mobile Scissor Lift Table
2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:
 - a. Duff-Norton, Charlotte, NC (704) 588-4610

B. Capacities/Dimensions:

1. Capacity: 15,000 lbs

2. Dimensions: Capable of securely holding all types of trucks to be used on the Type 7, 8, and 9 light rail vehicles.

C. Features/Performance/Construction:

1. Provide two rails onto which to lower a light rail vehicle truck.
2. Provide continuously variable height adjustment. The lowest setting shall allow the rails to rest on the floor. The highest height shall place the top of rail at least six (6) feet above finished floor.
3. Provide pushbutton controls for raising and lowering of the table.
4. The table shall not lower in the event of power failure.
5. Provide end stops on the support rails to prevent rolling of the truck. End stop positions shall be adjustable if needed to secure trucks of different dimensions.
6. The truck repair hoist is to remain completely stationary while loaded with a truck.

D. Finish:

1. Provide yellow safety markings.
2. Paint equipment in manufacturer's standard color.

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. Anchorage: Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- B. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.

END OF SECTION

SECTION 11161

MISCELLANEOUS STATION EQUIPMENT

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies mobile wheelchair lifts, Stryker Evacuation Chairs and dock bumpers.

1.2 QUALITY ASSURANCE

- A. Provide where indicated on the DB Entity's accepted Shop Drawings such equipment as specified hereinafter complete and ready for operation. Provide necessary accessories, items of equipment, plumbing, mechanical, electrical, and structural items, whether specified or not in order to provide properly installed and functional equipment.
- B. Equipment as selected by the MBTA is suitable for installation in the space allocated on the DB Entity's accepted Shop Drawings and operation on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity must be provided by the DB Entity at no additional cost to the MBTA and shall require the MBTA's prior acceptance.
- C. In all cases where a device or part of the equipment is referred to in the singular number, it is intended that such reference shall apply to as many such devices as are required to complete the installation.
- D. When two or more similar items of equipment are required, they shall be products of a single manufacturer.
- E. Permits and Tests: Obtain necessary permits from local authorities having jurisdiction, make application and file drawings if required for such permits, and pay for such permits. Obtain acceptance by governing authorities and by the MBTA and pay all costs connected therewith. Obtain MBTA's acceptance prior to contacting or submitting documents to governing authorities. Obtain and file with the MBTA written evidence that above requirements have been met.
- F. Applicable Codes:
 - 1. Unless otherwise directed by the MBTA, work shall conform to Federal, State, and Local governing rules, regulations, and ordinances, including OSHA and NFPA requirements, as applicable, and shall pass inspection by the authorities having jurisdiction.
 - 2. Provide materials and labor above and beyond those required by these Specifications in order to meet these requirements and to obtain approvals of inspections and tests.
- G. Certification:
 - 1. Furnish certificates stating that materials and workmanship comply with the applicable code requirements.
 - 2. Before final acceptance, furnish certificates of the authorities having jurisdiction.

H. Quality Control Program:

1. Submit to the MBTA for acceptance a quality control program that meets the requirements of ANSI ZI.8 specifications of general requirements for quality control program explaining the quality control procedures to be utilized for the manufacture, fabrication, and installation of equipment. Include details of the methods and procedures to be used to regulate the production of the equipment to assure compliance with the specified standards of quality. In addition, include complete information on the proposed methods of testing and inspection and identify the authorized representatives performing this work and their duties.
2. During the course of the work, the MBTA will monitor the Quality Control Program to verify compliance. Work undertaken, including the ordering and purchase of materials and supplies for the work, prior to acceptance of the Quality Control Program shall be at the DB Entity's risk.

I. Warranty:

1. Lift Warranty: 2 year warrantee from date of invoice.
2. Provide the manufacturer's standard warranty or a minimum of one year warranty whichever is greater which starts on the date of formal final acceptance of the facility or the separate equipment.

1.3 SUBMITTALS

- A. Submit the following in accordance Project requirements and as specified in by Equipment Specifications.
1. Shop Drawings.
 2. Product data.
 3. Installation instructions.
- B. Sequence of Review for Alternate Equipment Selection: When a proposed piece of equipment is of different manufacture than that specified, comply with the following procedures:
1. Tentative Review of Alternate Equipment: Before submittal of shop drawings, submit to the MBTA for review, drawings, specifications, and lists of alternate equipment to be incorporated in the work. This list shall include catalog numbers, cuts, and such other descriptive data as may be required to assure compliance with these Specifications. No consideration will be given to partial lists submitted from time to time. Approval of alternate equipment will be tentative subject to submission of complete shop drawings indicating compliance with the Contract Documents.
 2. Final Review of Alternate Equipment: After receiving tentative approval of alternate equipment lists submit shop drawings, product data and installation instructions for final approval.
- C. Shop Drawings: Shop drawings shall consist of the following as applicable:
1. Layout drawings showing equipment layout, elevations, conduit runs, utility layout and hook-ups, and all required dimensions.
 2. Fabrication drawings, including bill of materials.
 3. Detail drawings.

4. Foundation structural support drawings including anchor bolt plan and elevation.
 5. Utility connection plan.
 6. Electrical control diagram.
 7. Electrical wiring diagram.
 8. Electrical equipment layout, with all motors, limit switches, solenoid valves, disconnect switches, control panels, etc. located and labeled.
 9. Pumping systems including routing, sizing, valves, lubricators, regulators, pumps, nozzles, etc. fully noted and scheduled.
- D. Product Data: Manufacturer's literature including catalog cuts, pamphlets, descriptive literature, equipment specifications, performance and test data, and brochures which adequately describe the piece of equipment or product.
- E. Installation Instructions: Manufacturer's recommended installation instructions and manufacturer's installation drawings.
- F. Operations and Maintenance Manuals: Submit manuals for each equipment item.
- G. Provide the MBTA with specialized test equipment and tools necessary to maintain equipment components and sub-assemblies. Provide one set of maintenance equipment and tools with the final O&M Manuals for each piece of equipment.
- H. Guarantee spare parts availability for a period of ten years. Include guarantee in O&M Manual.

1.4 OPERATIONS AND MAINTENANCE MANUALS

- A. Submit operations and maintenance manuals for each machinery and equipment item as follows:
1. One copy of sample format and outline of contents in draft form with the equipment shop drawings.
 2. One copy of complete manual in final form on equipment delivery date.
 3. Five copies of approved manual after the equipment is installed and ready to test.
- B. Prepare manuals using the following materials:
1. Loose leaf, on 60-pound, three hole punched paper.
 2. Holes reinforced with plastic cloth.
 3. Page size, 8-1/2 inches by 11 inches.
 4. Foldout diagrams and illustrations.
 5. Reproducible by dry-copy xerography method.
 6. Oil-, moisture- and wear-resistant plastic covers.

C. General Requirements for Manuals:

1. Manuals furnished may be manufacturer's standard publications in regard to size and binding provided they comply with specified requirements relative to quantity and quality of information and data.
2. Bind manuals within hard or flexible covers. Make illustrations clear, and printed matter, including dimensions and lettering on drawings, easily legible. If reduced drawings are incorporated into manuals, heavy-up original lines and letter as necessary to retain their legibility after reduction. Larger drawings may be folded into manuals to page size.
3. Clearly identify each manual through the front cover with at least the following information:
(*description of manual)
(description of equipment or systems)
MBTA
GLX
(Name of the DB Entity)
accepted by: (MBTA Signature) Date

D. Format Manuals as Follows:

1. Title page: Include the name and function of the equipment, manufacturer's identification number, and the Project Specifications number and title.
2. Table of contents, in numerical order listing all sections and subsection titles of the O&M Manual with reference to the page on which each starts-and a list of included diagrams and drawings.
3. Index, in alphabetical order.
4. Frontispiece: Recognition illustration of the equipment described in the O&M Manual.
5. Manufacturer's literature describing each piece of equipment, including major assemblies and subassemblies, and giving manufacturer's model number and drawing number.
6. Operation instructions including step-by-step preparation for starting, operation, shutdown and draining and emergency requirements.
7. Control diagrams, as-installed by the manufacturer.
8. Sequence of operation by the control manufacturer.
9. Wiring diagrams, as-installed and color codes, of electrical motor controllers, connections and interlock connections.
10. Diagrammatic location, function and tag numbers of each valve.
11. Maintenance instructions: Include step-by-step procedures for inspection, operation checks, cleaning, lubrication, adjustments, repair, overhaul, disassembly, and reassembly of the equipment for proper operation of the equipment. Include list of special tools which are required for maintenance with the maintenance information.
12. Possible breakdowns and repairs.
13. Manufacturer's parts list of all functional components, control diagrams and wiring diagrams, giving manufacturer's model number and manufacturer's part number.

14. "Long-Lead-Time' spare parts list for all spare parts not readily available on the open market or for which it is anticipated ordering and delivery time will exceed 10 days.
15. List of nearest local suppliers of all equipment parts.
16. Lubrication schedule indicating type and frequency of lubrication.
17. Manufacturer's warranty and guarantee data.
18. Spare parts data as follows:
 - a. Complete list of parts and supplies, with current unit prices and sources of supply.
 - b. List of parts and supplies that are either normally furnished at no extra cost with purchase of equipment, or specified herein to be furnished as part of Contract.
 - c. List of additional items recommended by manufacturer to assure efficient operation for period of 120 days.
19. Appendix: Include safety precautions, a glossary, and, if available at time of submittal, copies of test reports, and other relevant material not specified to be submitted.
20. Delete information on material or equipment not used in the work from the O&M Manual.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Equipment and components shall be suitably packed or crated to prevent damaged in transit or during handling. Items shall be carefully stored at the site as required in a manner to avoid misalignment or distortion, and shall be adequately protected against damage by weather or other cause.
- B. Special precautions shall be taken to prevent damage to electrical components such as motors, controls and conductors.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Material and equipment particulars and requirements as specified in manufacturer's standard installation procedures.
- B. Mobile Wheelchair Lift:
 1. Basis of Design: The Mobile Lift TX from Adaptive Engineering Inc. or approved equal.
 2. Lift must be ADA compliant and can quickly be stored in a designated storage location.
 3. Lift Criteria:
 - a. Typical lifting time: 20 seconds to max. lifting height
 - b. Max. lifting height: 60" (1.52m)
 - c. Crank force: 5 lbs. to lift 150 lbs.; 11 lbs to lift 300 lbs.
 - d. Capacity: 600 lbs. (275 kg)
 - e. Lift weight: 289 lbs. (135 kg)
 - f. Lift height: 66" (1.76m)
 - g. Lift width: 37.5" (.95m)

- h. Length: 72" (1.83m)
- i. Platform size: 34" x 56" (.86m x 1.42m)
- j. Bridge Ramp: 20"L x 28"W (.51m x .71m)

C. Shop Paint:

- 1. Shop prime paint: Rust inhibitor paint containing at least 50 percent rust inhibitor pigments.
- 2. Shop finish paint: Manufacturer's standard finish coat system.

D. Motors:

- 1. Provide motors of sufficient capacity to operate the given equipment under all conditions of operation without loading beyond the nameplate current or power.
- 2. In no case are motors offered to be less than the horsepower specified except when it can be demonstrated that because the efficiency of the driven equipment is greater than that specified and lesser horsepower will suffice.
- 3. Motors for periodic usage designed as standard efficiency, all other motors designed as high efficiency, each bearing the UL label and constructed to standards of NEMA, IEEE, ANSI, and AFBMA.
- 4. Provide motors designed for operation on the electrical service characteristics indicated on the DB Entity's accepted Shop Drawings.
- 5. Design motors to operate in an ambient temperature of 40 degrees C in continuous operation (unless otherwise specified) with a service factor of 1.15.
- 6. Motors designed for outdoor service or corrosive atmosphere service shall have the motor windings protected by U.S. Motors Everseal Solid-Cast Encapsulation, Westinghouse Life-Guard Encapsulation, or approved equal.
- 7. Motors rate on horsepower or greater shall have a full-load power factor of 85 percent or higher. Motors rated 20 horsepower and over shall be designed for reduced voltage starting.
- 8. Provide motors of totally enclosed type unless otherwise specified.
- 9. Provide vertical motors with thrust bearings adequate for axial loading to which they can be subjected in operation.
- 10. Bearings for motors one-half horsepower and larger shall be rated for 20-year life under AFBMA Standards.

E. Equipment Anchors: Provide anchors for equipment requiring such. Size anchors for embedding in concrete and expansion anchors as recommended by equipment manufacturers. When recommendations are not provided, size anchors in the largest diameter that will pass through the bolt heads in equipment bases. Anchor lengths as indicated on the DB Entity's accepted Shop Drawings or as recommended by equipment manufacturer.

- 1. Expansion Anchors: Conforming to Federal Specification FF-S-325, Group II, Type 4, Class I Stainless Steel; such as Hilti Kwik-Bolt, Phillips Red Head Wedge-Anchor and Molly Parabolt, or approved equal.
- 2. Steel Anchor Bolts: Shapes as indicated or as recommended by equipment manufacturer, ASTM A 307 with galvanized finish.

- F. Dock Bumpers: provide heavy duty dock bumpers for loading dock areas.
 - 1. Dock Bumper basis of design: Grainger Dock Bumper Model 5W823 or approved equal
 - 2. Bumper Shape: Rectangular
 - 3. Overall Dimensions: 10 ¾"W x 10"H x 4 ½"D
 - 4. Bumper Material: Rubber

2.2 MATERIALS

- A. Stairway Evacuation Chairs: Provide manufacturer's standard completely assembled units, minimum 300 pound capacity, wall mounted on brackets. Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, the following:
 - 1. Evacu-Trac CD7 by Garaventa.
 - 2. Evac+Chair by Evac+Chair Corp.
 - 3. Model 49 Sirocco Stair Chair by Ferno.
 - 4. Evacuation Chair Model 6253 by Stryker.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. General: Installation particulars and requirements are as specified in manufacturer's standard installation procedures.
- B. Shop Painting: Paint equipment with one coat of approved shop primer and manufacturer's standard finish coat system. Indicate brand and type of paint on shop drawings. Colors shall be accepted by the MBTA.
- C. Electrical Requirements:
 - 1. Power supply for equipment is designed as 480V, 3-phase, 60Hz unless otherwise specified.
 - 2. Provide transformers for equipment as required to step down the specified supply voltage to provide lower voltage for controls and accessories and to provide voltage compatible with equipment as required.
 - 3. Provide wiring and conduit for a complete installation and proper operation of all equipment and accessories. Provide electrical service devices (disconnect switches) complying with the requirements of Division 16; Electrical. As work of this Section, install these electrical service devices, perform wiring (including conduit installation) and make connections between these electrical service devices and equipment specified in the various Sections referenced in Related Work Specified Elsewhere. Size wiring and conduits for the loads and voltages indicated on the DB Entity's accepted Shop Drawings. Wiring and conduit type shall be in accordance with the requirements of the National Electrical Code for the individual equipment location except where more stringent requirements are specified in Division 16. In no case shall maximum current carried exceed that specified by the National Electrical Code for type of conductor used.
 - 4. Provide disconnect switches (fused and non-fused as required), motor starters and start-stop control stations for all equipment subject to the following conditions:

- a. Provide above stated electrical devices consistent with NEC and equipment design requirements, as well as the electrical power circuit design for each piece of equipment.
 - b. Provide the type of electrical device based on the requirements of the proceeding paragraph and the electrical characteristics of the Project electrical design.
 - c. Sizing of the above state electrical devices is the responsibility of the DB Entity based on the information supplied by equipment manufacturers and is subject to the MBTA's review.
5. Provide control devices necessary for proper operation and locate to permit efficient operation of the equipment, and where possible group in a factory fabricated NEMA approved control panel complying with the requirements of Division 16; Electrical.
 6. Identify switches, lights and control functions with legend plates. Construct the plates of polyvinyl chloride materials of laminated multiple construction, and rout engraved with appropriate legends. Submit the size of letters, colors and legend for review. Mount legend plates on the equipment in an approved manner. No decals will be accepted.

D. Mechanical Requirements:

1. Piped services for equipment are specified as work of Division 15; Mechanical and are terminated near the piece of equipment in a shut-off means. As part of the work off this Section, extend these piped services to the equipment and make the associated connections.
2. Provide piping, fittings, valves connections, etc. of a type and size as recommended by the equipment manufacturer that will properly interface with the piped services provided under Division 15; Mechanical.
3. Provide gas piping and connections in accordance with the requirements of the American Gas Association for Stationary and vibration producing equipment.

E. General Installation Requirements:

1. Furnish common and skilled labor, tools, rigging equipment, scaffolding, shims, dowels, and other materials necessary to make complete installation of equipment specified and indicated in the Contract Documents.
2. Conduct loading, transportation, unloading, and storage of products such that they are kept clean and free from -damage. Bear transportation costs. Mark and tag equipment with equipment item numbers.
3. Perform work in an acceptable manner and install materials and equipment as recommended by the manufacturers and in accordance with specified codes and standards.
4. Repair or replace materials and equipment marred or damaged in any way, shape, or form to the satisfaction of the MBTA at no additional cost to the MBTA.
5. Be responsible for safety and protection from loss or damage of equipment received until work is complete. Provide secured areas for equipment that will not be installed as soon as it arrives on Site.
6. Reassemble equipment items which were dismantled for shipment or moving. Assemble items which are delivered knocked down, or disassembled.
7. Provide grout, shim material and miscellaneous steel necessary for brackets, anchors or supports required in installation of equipment.
8. Perform field machining that might be required to fit equipment together or to install equipment.

9. Lubricate apparatus before start-up.
 10. Field check for clearance and interferences before fabrication or installation and relocate material and equipment furnished as required to eliminate interferences.
 11. Details listed in these Specifications are given for a better understanding of the Work and do not place limitation on the amount of work to be done nor do they relieve the DB Entity of additional work that may be required for a complete installation.
- F. Setting and Alignment of Equipment:
1. Set and align equipment in accordance with manufacturer's recommendation, conformed shop drawings and applicable standards of trade practice.
 2. Set equipment plumb and level. Demonstrate adequate leveling of installed equipment.
 3. Retighten bolted connections after installation.
- G. Equipment Foundations:
1. Provide anchor bolts where required to mount equipment. Coordinate with other trades to insure the proper installation of the anchor bolts.
 2. Provide concrete pads and grout pads as required to stabilize equipment base to concrete slab and foundations where indicated and where recommended by the manufacturer. Grouting requirements and grout material shall be in accordance with the recommendations of the manufacturer.
 3. Grout under base plates after they have been set, aligned and leveled.
 4. Provide hard rubber shimming and dampening pads as recommended by the manufacturer for leveling of equipment and dampening of equipment vibration transmission.
- H. Cleaning and Protection:
1. Clean fabrication assemblies and equipment items thoroughly before and after operating and testing.
 2. Protect equipment from damage, deterioration, paint or coating spills or spots, corrosion, or harm from any source.
- I. Motors and Drives:
1. Check motors and drives for correct rotation and alignment before placing equipment into operation.
 2. Disconnect couplings and realign before placing into service or testing.
 3. Adjust belt drives and replace worn belts.
- J. Field Painting:
1. Field painting equipment, including touch-up painting is included as work under this Section. Normally, equipment shall be factory finished as previously specified.
 2. Touch-up or repaint to match original finishes, factory finished or painted equipment and materials which are scratched or marred during shipment or installation.

3.2 TRAINING PROGRAM

- A. At least 30 days prior to schedule delivery of equipment, submit to the MBTA, a detailed outline of the proposed training program for the MBTA's personnel. Include such information as the duration of the program, material and literature to be utilized, topics covered, and any material and equipment required to be provided by the MBTA. The MBTA will provide transit vehicles and transit vehicle components required for the training program.
- B. Include familiarization with equipment operation and performance and detailed instruction in operation and maintenance of the equipment including "hands-on" training.
- C. The program shall be provided for the following as a minimum: MBTA - 8 hours; Operating personnel - 40 hours; Maintenance Personnel - 48 hours.
- D. Include each piece of equipment's operation and maintenance manual as a basic text for instruction. Organize the program to permit the MBTA to develop, within its own organization, the capability to continue the education of its personnel in the proper operation, maintenance, and repair of the equipment. Assume no prior knowledge, on the part of the MBTA personnel, of the equipment.
- E. Conduct the training program prior to final equipment testing and acceptance. Notify the MBTA of the proposed training period at least 14 days prior to commencement of the training program. The MBTA will provide the exact number of MBTA personnel who will attend 7 days prior to the start of the program.
- F. Conduct the training program on Site, on the pieces of equipment supplied as part of this Contract.

3.3 EQUIPMENT TESTING AND CHECK-OUT

- A. Submit acceptance testing program for work performed under this Section to the MBTA for review and approval 45 days prior to the start of testing. Design the program to show that the work performed, or equipment installed, under this Section will perform as intended. Perform all tests to written test procedures that have been reviewed and accepted by the MBTA. The test procedures will include the following:
 - 1. Item tested and date of test.
 - 2. Acceptance criteria.
 - 3. Measuring and test equipment used and calibration data.
 - 4. Result of the test.
 - 5. Signature of person performing the test.
- B. Provide a qualified manufacturer's representative to supervise testing by the DB Entity, including those personnel of the contract operator required in providing vehicles and components, in the presence of the MBTA, to ensure proper operation of equipment.
- C. Before Final Acceptance, test the equipment in the presence of the MBTA to his satisfaction and to demonstrate that it is correctly connected, installed and operating properly.
- D. The MBTA will provide transit vehicles and transit vehicle components required for the testing procedures.
- E. The equipment testing shall not only demonstrate that each piece of equipment has been properly installed and connected and operates properly but shall also demonstrate that the equipment performs

the work for which it is intended. Design the equipment test so that all assemblies, subassemblies, components, auxiliary functions, and safety devices are utilized in the testing procedure at least once.

- F. Tested equipment found to be defective or inoperable to any extent shall be reported to the MBTA immediately.
- G. Repair or replace, at no additional expense to the MBTA, any operating difficulty or defective item and restore the equipment to proper operation before testing is continued.
- H. Protect equipment and surrounding areas from damage resulting from testing operations. Clean-up spills or leakage resulting from testing.
- I. Bear all expenses of all tests, including the furnishing of all necessary instruments, test weights, lubricants, hydraulic fluids, supplies, data recorders, and operating personnel.

END OF SECTION

SECTION 11500

INDUSTRIAL AND PROCESS EQUIPMENT

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of DB Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity shall be provided at no additional cost to the MBTA and shall be as accepted by the MBTA.
- D. Furnish and install the equipment items listed below by their identifier
 - 1. Eye wash, Primary, Portable Station Kit (EQ ID: 2296)
 - 2. Vise, Combination, Swivel Base, 5" (EQ ID: 2629)
 - 3. Tank, parts cleaning (EQ ID: 3025)
 - 4. Washer, hi pressure/hot water, NG (EQ ID: 3050)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, those listed in Article 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The DB Entity shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 3 - Concrete
 - 2. Division 15 - Mechanical
 - 3. Division 16 - Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements".
- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Volume 1 Contract Terms and Conditions.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the DB Entity.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Volume 1 Contract Terms and Conditions. Acceptance will be based on the technical requirements herein as determined by the MBTA.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Volume 1 Contract Terms and Conditions.

PART 2 – PRODUCTS

2.1 EYE WASH, PRIMARY, PORTABLE STATION KIT (EQ ID: 2296)

A. Manufacturer's Reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer's name and model to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Uline, Pleasant Prairie, WI, (800) 295-5510
 - 1) Model: H-1142
2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Speakman Company, New Castle, DE, (800) 537-2107
 - b. Haws Corporation, Sparks, NV, (775) 359-4712

B. Capacities/Dimensions:

1. Size: 26" x 19 ½" x 19 ½" (LxWxH)
2. Capacity: 16 gallon
3. Flow rate: 0.4 gpm over 15 minutes

C. Features/Performance/Construction

1. Featuring a FDA approved high-density green polyethylene tank easily activated by pulling the yellow activation arm down to the open position.
2. A wide-fill opening with threaded cap permits easy inspection, cleaning and filling.
3. Relocation is simple due to the easily mounted (bracket included) and light design of this 16 gallon (60.6 L) portable.

2.2 VISE, COMBINATION, SWIVEL BASE, 5" (EQ ID: 2629)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Yost Visers, Holland, MI - (616) 396-2063
 - 1) Model: 33C
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2

Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:

- a. Ridgid Tool Co., Elyria, OH - (216) 323-5581
- b. Milwaukee Tool and Equipment Co., Milwaukee, WI - (414) 645-0200

B. Capacities/Dimensions:

1. Jaw width (nominal inches): 5"
2. Jaw opening (nominal inches): 7 ½"
3. Throat depth (nominal inches): 6"
4. Min. pipe capacity (nominal inches): 1/8"
5. Max. pipe capacity (nominal inches): 4 ½"
6. Base: Swivel

C. Features/Performance/Construction:

1. 65,000 PSI tensile ductile iron body parts.
2. Interlocking swivel base with 360 degree motion.
3. Two (2) lockdowns.
4. Hardened, replaceable steel pipe jaws.
5. Pipe jaws set back to allow for machinist's vise use.
6. Pipe jaws designed to grip pipe securely.
7. Design helps prevent pipe marring, crushing or bending.
8. Conforms to Fed. Spec. GGG-V-410B Type IV.
9. No pinch main screw handle.
10. Replaceable hardened steel flat serrated jaws.
11. Continuous rolled thread on main screw.
12. Material: Ductile Iron

2.3 TANK, PARTS CLEANING, 16-42 GALLON (EQ ID: 3025)

- A. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
1. Graymills, Inc. (877) 465-7867
Model: Clean-O-Matic Solvent Parts Washer 500-A
 2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2

Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:

- a. Safety-Kleen Systems, Inc. (800) 323-5040
- b. Ultimate Washer, Inc. (866) 858-4982

B. Capacities/Dimensions:

1. Operating Fluid Capacity: 16-42 Gallons
2. Dimensions: 44" L x 21" W x 23 ¾" H

C. Features/Performance/Construction:

1. Unit is to be made of 16 gauge, powder-coated steel.
2. Provide the capability for three cleaning methods:
 - a. Pump for in-tank agitation.
 - b. Pistol-grip nozzle, with capability for both light spray and solid stream.
 - c. Flush hose with hand-held brush.
3. Provide capability to switch between or use all of the above cleaning methods at once.
4. Provide washable 40 mesh screen solvent filter.
5. Provide drain plug.
6. Maximum Flow Rate: 2400 GPH
7. Unit is to be mounted on casters to provide mobility.

D. Utility Requirements:

1. Motor Horsepower: 1/3 HP
2. Electrical Supply: 115V, 60 Hz, 1 Phase AC
3. Provide nearby domestic water hose bib for filling tank.

2.4 WASHER, HI PRESSURE/HOT WATER, NG (EQ ID: 3050)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. The Hotsy Corporation, Camas, WA - (360) 833-1600
 - 1) Model: 995SS
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:

- a. Landa, Inc., Camas, WA (360) 833-9100
- b. Alkota Cleaning Systems, Inc., Alcester, SD - (605) 934-2222

B. Capacities/Dimensions:

1. Pump motor: 460V AC, 3 phase, 5 HP
2. Operating pressure: 2,000 PSI
3. Maximum discharge capacity: 4 GPM
4. Overall dimensions:
 - a. Length: 45"
 - b. Width: 18"
 - c. Height: 48"
5. Net weight: 525 lbs.

C. Features/Performance Construction:

1. Burner: NG fired, 365,000 BTU/hr., AGA-listed gas controls, ring type with aspirating spuds, natural draft.
2. All open flames and fire rings shall be mounted at a minimum of 18" above the finished floor.
3. Heating coil: Vertically-fired; 7/8" OD, hydrostatic-pressure tested; 14,900 PSI burst-rated.
4. Water pump: Triplex water pump with positive displacement, ceramic plungers, brass manifold, and oil bath crankcase.
5. Fabrication: Welded angle iron frame shall have heavy gauge tank and cabinet.
6. Piping: Supplier shall provide piping (schedule 80) from high-pressure wash unit to each trigger gun wand for a complete and operable system.
7. The manufacturer shall supply all necessary soap system equipment including piping, fittings, distribution hose, and connections for a complete and operable soap distribution system.
8. Controls: Adjustable temperature controller, safety pressure relief valve, pressure switch, ON/OFF electric motor switch with overload protection, unloader, water heater switch, detergent valve, and automatic non-contaminating float valve.

D. Accessories:

1. Trigger gun and hose assembly (50' long hose).
2. The DB Entity supplied scabbard for trigger gun: Wall mounted; one (1) at each trigger gun location.
3. Hose reel: Hotsy No. 860204, or equivalent. One (1) at each trigger gun location.
4. Draft diverter: Hotsy No. 835526, or equivalent.
5. Remote starter: Smart box with soap solenoid and remote.
6. Replacement nozzle: 2.5 mm with quick disconnect.
7. The DB Entity supplied replacement nozzle holder: Wall mounted.

8. Powershine Plus© detergent: 55 gallon drum.
 9. Breakthrough© detergent: 55 gallon drum.
 10. Time delayed shutdown: 1 minute delay.
- E. Utility Requirements:
1. Electrical: 460V AC, 3 phase, 5 H.P.
 2. Plumbing:
 3. Water: ¾” to supply, 40 to 60 PSI, 4 GPM minimum (regulate water supply if greater than 60 PSI).
 4. Natural gas: 1 to 1 ½” NPT to supply 525,000 BTU at equipment.
 5. Stack size: 8” with draft diverter.
- F. Finish:
1. Durable enamel using the MBTA’s choice from the manufacturer’s standard colors

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Install equipment in accordance with the plans, shop drawings, and manufacturer’s instructions:
 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. Anchorage: Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- B. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.

- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the MBTA or designated representative for acceptance inspection.

END OF SECTION

SECTION 11520

MISCELLANEOUS SHOP EQUIPMENT

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity shall be provided at no additional cost to the MBTA and shall be as accepted by the MBTA.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Cart, deionized water, portable (EQ ID: 5041)
 - 2. Platform, work, portable (EQ ID: 8002)
 - 3. Platform, work, roof (EQ ID: 8005)
 - 4. Pallet Jack, 5500 lbs (EQ ID: 9815)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, those listed in Article 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The DB Entity shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 - Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements".
- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the DB Entity.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions. Acceptance will be based on the technical requirements herein as determined by MBTA.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.

PART 2 – PRODUCTS

2.1 CART, DEIONIZED WATER, PORTABLE (EQ ID: 5041)

- A. Manufacturer's Reference:
 - 1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Flow-Rite Controls, Ltd., Byron Center, MI - (616) 583-1700
 - 1) Model: BA-MS-105

2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:
 - a. Philadelphia Scientific, Montgomeryville, PA - (215) 616-0390
 - b. Battery Watering Technologies, Clemmons, NC - (336) 714-0448

B. Capacities/Dimensions:

1. Tank capacity: 22 gallons
2. Overall dimensions (nominal):
 - a. Width: 20"
 - b. Length: 27"
 - c. Height: 35"
3. Power supply:
 - a. A 12V sealed battery with its own on-board charger.
 - b. 110V AC Charger; 12V DC Volt Meter.

C. Features/Performance/Construction:

1. Cart shall have an onboard battery charger with voltmeter with cord to plug into a 120 VAC outlet.
2. Cart shall have a suction pump with an in-line pressure regulator to limit maximum pressure.
3. Cart shall be mounted on wheels.
4. Cart shall have a minimum 6 feet of dispensing hose with a sensor to shut off water flow when a battery cell is full.

D. Accessories:

1. Requires Flow-Rite Deionized Water Filter w/ Regulated Hose (Model No. BA-MS-341), or equivalent.
2. Removes ions and heavy metals that are present in tap water.
3. The separate bed deionizer uses an ion exchange cartridge to filter the water before it enters the battery.
4. Low pressure bypass for maintaining pressure in the event that a cartridge is not changed and becomes clogged.
5. 20' supply hose with inline strainer.
6. 110-115V AC Light (water quality indicator)

2.2 PLATFORM, WORK, PORTABLE (EQ ID: 8002)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.

a. Ladder Man, Wooster, OH - (800) 783-8887

1) Model: 40218

2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal.

a. Cotterman Co., Crosswell, MI - (810) 673-4400

b. Gillis, Prospect Heights, IL - (877) 445-5471

B. Capacities/Dimensions:

1. Maximum capacity: 500 lbs.

2. Overall dimensions (nominal):

a. Width: 36"

b. Length: 58"

c. Platform height: 20"

3. Platform dimensions:

a. Width: 36"

b. Length: 48"

c. Weight: 102 lbs.

C. Features/Performance/Construction:

1. Extra wide work platform with ½" sure-grip rubber pad.

2. Platform shall have two (2) rear 4" rigid casters.

3. Platform shall be of heavy-duty welded steel construction.

4. Platform shall be constructed with two (2) steps with grip strut treads.

D. Accessories:

1. Each unit shall be wrapped in non-conductive material, 3M black rollstock.

E. Finish:

1. Durable enamel using the MBTA's choice from the manufacturer's standard colors

2.3 PLATFORM, WORK, ROOF (EQ ID: 8005)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Service Scaffold Co, Inc., South Fallsburg, NY - (845) 434-8888
 - 1) Model: SSC Series
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions, equipment produced by other manufacturers, including the following, may be considered as equal:
 - a. Universal Manufacturing Corp., Zelienople, PA - (800) 836-8780
 - b. Mdm Scaffolding Services, Inc., Grapevine, TX - (800) 339-2390

B. Capacities/Dimensions:

1. Maximum capacity: 500 lbs.
2. Platform dimensions:
 - a. Width: 30"
 - b. Length: 14'-0"
 - c. Height: Height of LRV + 30"
3. Stairs to platform:
 - a. Width: 2'

C. Features/Performance/Construction:

1. Equipment shall be designed to access rooftops without the use of a fall protection system.
2. Guardrails shall be included on three (3) sides of each platform.
3. Platforms shall be designed to connect together across the rooftop with gates creating a safety approved area.
4. Each platform shall include toe plates on three (3) sides.
5. Each unit shall include a stairway with handrails on both sides.
6. Treads shall include traction gripping.
7. Each platform shall have continuous rubber protective bumpers.

D. Finish:

1. Durable enamel using the MBTA's choice from the manufacturer's standard colors

2.4 PALLET JACK, 5500 LBS (EQ ID: 9815)

A. Manufacturer's Reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer's name and model to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Wesco Industrial Products, Inc., Lansdale, PA, (215) 699-7031
 - 1) Model: 272148
 2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Dayton, Vandalia, OH, (937) 454-7545
 - b. Lift-Rite Inc., Ontario, Canada, (905) 456-2603
- B. Capacities/Dimensions:
1. Capacity: 5,500 lbs.
 2. Overall dimensions
 - a. Fork Width: 21 inches
 - b. Fork Length: 48 inches
 - c. Weight: 157 lbs.
 3. 8 inch raised height
 4. 3 inch lowered height
 5. 6 inch wide forks
- C. Features/Performance/Construction:
1. 8" moldon polyurethane steering wheels
 2. 3" moldon polyurethane load wheels
- D. Finish: Durable enamel in manufacturer's standard color

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.

2. **Fitting:** Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. **Anchorage:** Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- B. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the MBTA or designated representative for acceptance inspection.

END OF SECTION

SECTION 11550 WHEEL TRUING MACHINE

PART 1 - GENERAL

1.1 PURPOSE

- A. This document covers the procurement of a new under floor, single axle full profile wheel truing milling machine for all Light Rail Vehicles (LRV) of the Massachusetts Bay Transportation Authority (MBTA) Green Line.
- B. This Specification outlines and provides criteria to be used in procuring a new under floor wheel truing re-profiling machine, enabling the DB Entity to furnish an end item in compliance with the requirements of this specification. The work performed by the DB Entity shall comply with all applicable standards, codes and regulations, wheel specifications, and MBTA documents, drawings, and requirements.

1.2 VARIATIONS

- A. This specification identifies the acceptable equipment configuration and functions of the wheel truing machine. Alternate manufacturer models may be proposed. In all cases the DB Entity must provide in writing sufficient technical description of the alternate unit(s) and proves it meets specification. The MBTA must have ample time and supporting documentation to review the proposed equipment meets the specification.
- B. Conflicts and recommendations shall be referred to the MBTA.

1.3 QUALITY CONTROL PROGRAM

- A. Submit to the MBTA for approval a detailed narrative explaining the quality control procedures to be utilized for the fabrication and installation of equipment. The narrative shall include details of the methods and procedures to be used to regulate the production of the equipment to assure compliance with the specified standards of quality. The narrative shall also include full information on the DB Entity's methods of testing and inspection and shall identify the DB Entity's representatives and their duties.
- B. Any work undertaken, including the ordering and purchase of materials and supplies for the Work, by the DB Entity prior to approval of the Quality Control Program shall be at the DB Entity's risk.
- C. Upon delivery of the equipment, submit certificates of compliance. Each certificate shall be signed by an authorized representative of the manufacturer stating that the equipment complies in all respects with the Contract Documents.
- D. DB Entity shall verify foundations, structures and other construction is adequate for the wheel truing machine in operation with any MBTA Green Line vehicle.

- E. Verify that the wheel truing machine will function in both, the CNC and manual controlled mode, properly with every vehicle in the MBTA Green Line rail fleet.
- F. Verify that all dimensions, foundations and utility supplies are adequate for the wheel truing machine. Verify dimensions of all vehicles that relate to fabrication of the wheel truing machine and notify the Engineer of Record of any discrepancy before fabrication and delivery of the equipment to the site.

1.4 QUALIFICATIONS

- A. The DB Entity must include a firm with a minimum of 10 years successful experience in the manufacturing and installation of under floor wheel truing milling machines for Light or Heavy Rail Vehicles. DB Entity shall provide documentation that they regularly engaged in successful design, manufacturing, and installation of wheel truing machines for low floor and centerless vehicles including those with independently rotating wheels.
- B. The manufacturer of the wheel truing machine shall provide written instructions on how their centerless wheel truing machine will true the power and unpowered bogies of the No. 7 SRC, No. 8 low floor car, and the No. 9 low floor car.
- C. The DB Entity shall provide a list of comparative installations currently in operation for a period of at least the past five years, including names and phone numbers for engineers and or technicians at other Transit Authorities using the system.
- D. The DB Entity's product support and repair department shall be capable of responding and providing on-site assistance if necessary within 48 hours of notification.
- E. Manufacturer must maintain an adequate supply of spare parts for the expected life of the equipment supplied under this contract. The manufacturer shall be able to ship parts within 24 hours of notification if the parts are not commercially available.
- F. The DB Entity's installer of the wheel truing machine shall have previous experience in the installation of wheel truing machine equipment.
- G. The equipment manufacturer shall employ of specialists who are trained and experienced in the methods and requirements necessary for the proper execution of the Work in this specification.

1.5 SUBMITTALS

- A. The DB Entity shall submit a list of a minimum of five transit properties where similar under floor wheel truing machines were installed and are currently operating successfully. A reference contact person, address and telephone number at these properties with English speaking capabilities shall be furnished. In addition, commercial literature or drawings of these models shall be furnished for illustration.

- B. The DB Entity shall submit all sub-contractor contact information and qualifications in the particular subcontracted scope of work.
- C. Preliminary installation drawings sufficiently detailed indicating required concrete foundation dimensions, equipment attachment details, required electrical and mechanical services, as well as drawings and catalog cuts indicating operation, dimensions, and all features for all equipment to be supplied, shall be submitted.
- D. Three hard copies and one electronic copy on a USB 3 drive of the following manuals and drawings shall be submitted by the DB Entity to the MBTA with all revisions to the manuals throughout the warranty period:
 - 1. Detailed Operating Instruction Manuals for the wheel truing machine system and all auxiliary equipment.
 - 2. Detailed Maintenance Instruction Manuals for the wheel truing machine system and all auxiliary equipment.
 - 3. Parts Manuals with OEM part numbers for the wheel truing machine and all auxiliary equipment.
 - 4. Site dimensions, foundation requirements and drawings for wheel truing machine system. Above and below grade electrical schematics and installation instructions. Electric power requirements with wiring diagrams and conduit runs.
 - 5. General equipment arrangement drawing(s), including outline dimensions and equipment component layout.
 - 6. Electrical control schematics.
 - 7. Hydraulic-pneumatic schematics.
 - 8. Operating and Maintenance Manuals shall be submitted for each equipment item as follows:
 - a. One electronic copy on a USB 3 drive and one hard copy of sample formats and outline of contents in draft form 30 days prior to the earliest scheduled equipment delivery to be submitted to the MBTA for approval.
 - b. Tolerances, clearances, and dimensions shall follow the system of ounces, pounds, gallons, inches, and feet, as used in the United States (metric conversions may be provided parenthetically).
 - c. One hard copy and electronic copy on a USB 3 drive of complete manual in final form on equipment delivery date.
 - d. Three copies of approved manual after the equipment is installed and ready to test.
 - e. One additional set of manuals suitable for shop environment shall be

prepared from the following materials:

- 1) Loose leaf, on 60-pound, punched paper.
 - 2) Holes reinforced with plastic cloth.
 - 3) Page size, 8-1/2 inches by 11 inches.
 - 4) Foldout diagrams and illustrations. (11 x 17 inches)
 - 5) Reproducible by dry-copy xerography method.
 - 6) Oil-, moisture and wear-resistant plastic covers.
- f. One set of as-built drawings inclusive of equipment arrangement and as-built installation. Drawing size shall be 22 X 34 inches
- g. Manuals shall include at minimum the following:
- 1) Title page: Include the name and function of the equipment, manufacturer's identification number, and the Project number, title and date.
 - 2) Table of contents, in numerical order listing each section and subsection title with reference to the page on which each starts and a list of included appendices, diagrams and drawings.
 - 3) Index, in alphabetical order.
 - 4) Manufacturer's literature describing each piece of equipment, including major assemblies and subassemblies, and giving manufacturer's model number, specifications and drawing number.
 - 5) Operation instructions including step-by-step preparation for starting, operation, shutdown, maintenance, and emergency operating requirements.
 - 6) Control Schematics and detailed diagrams as installed by the manufacturer.
 - 7) Sequence of operation by the control manufacturer.
 - 8) As-built wiring diagrams with wire color codes and numbers of all electrical wiring including motor controllers, terminal strips and interlock connections.
 - 9) Diagrammatic location, function and tag number of each hydraulic valve and control components.
 - 10) Maintenance instructions shall include step-by-step procedures for inspection, operation checks, cleaning, lubrication, adjustments,

repair, overhaul, disassembly, and reassembly of the equipment for proper operation of the equipment. Include a list of special tools that are required for maintenance with the maintenance information.

- 12) Troubleshooting flow charts shall be included for diagnosis of any major system or control, such as computer controls, hydraulic system, cutter operation, etc.
- 13) Manufacturer's parts list of all components, control diagrams and wiring diagrams, giving manufacturer's model number and manufacturer's part number.
- 14) Recommended preventive maintenance schedule for major system components including lubrication schedule indicating type and frequency of lubrication based on machine hours.
- 15) Manufacturer's warranty for a minimum of two years beyond the final acceptance and guarantee data.
- 16) "Long-Lead-Time" spare parts list for spare parts not readily available on the open market or for which it is anticipated ordering and delivery time will exceed 10 days.
- 17) List of suppliers of all commercially available equipment parts.
- 18) Spare parts data as follows: Complete list of parts and supplies, with current unit prices and sources of supply. List of additional items recommended by manufacturer to assure efficient operation for a period of two (2) years.
- 19) Appendix: Include safety precautions, a glossary, and, if available at time of submittal, copies of test reports, and other relevant material not specified to be submitted.

9. Operating Diagrams:

- a. Piping systems, electrical wiring diagrams, lubricating oil, and other diagrams necessary for operation of the equipment shall be furnished.
- b. No single diagram shall show more than one system or parts thereof.
- c. Diagrams shall be reproduced by photographic process to a size not to exceed 11 inches by 17 inches and shall be complete and legible in all respects. They shall be made on white paper and vacuum-sealed in transparent plastic material impervious to moisture and oil, and resistant to abrasion. Other formats which are equal in clarity, sharpness, durability and permanence will be considered.

10. All drawings shall be prepared in both AutoCAD and PDF format and furnished on USB 3 drive. All manuals shall be furnished on USB3 drive in a PDF format.

11. No equipment shall be delivered until manuals, schematics, and drawings have been reviewed and approved by MBTA.
12. Parts Catalog
 - a. Submit for approval three complete copies and electronic version on USB 3 drive.
 - b. Enumerate and describe every component and its related parts, including identifying numbers and commercial equivalents where applicable.
 - c. Include cut-away, exploded view or assembly drawings that clearly identify all parts of the machine.
13. Spare Parts List
 - a. Submit for approval three complete copies and electronic version on USB 3 drive.
 - b. Submit recommendations for spare parts inventory including types and quantities considered normal for routine maintenance of the equipment for three years.
 - c. Provide two sets of any specialty tools for the wheel profiling machine, required for maintenance or adjustment, packed in an appropriate steel tool box, if required.
 - d. Provide notification of any major parts or components that may become obsolete without an acceptable equivalent replacement throughout the warranty period.
 - e. Include a list of all consumables including OEM serial numbers and specifications for fluids, filters, greases, lights, cutting inserts, and other required consumables and maintenance items.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

The machine to be furnished under the contract shall be a new under floor wheel truing and re-profiling milling machine. The machine shall be designed to recondition the full profile of railroad wheels for transit vehicles; including an integrated wheel measuring system; chip collector system; chip hopper; dust collection system; calibration equipment; vehicle winching system or approved equal; hold down and adapter system for each bogie specified; and any incidental equipment, materials and special tools needed for the complete and proper installation, testing, use and maintenance of this wheel truing equipment.

- A. The machine may be designed and built in either the English or metric systems of units. Indicators, vernier scales and digital readouts shall indicate units in both English and metric. The machine shall comply with prevailing USDOT guidelines as

applicable.

- B. Equipment shall be designed, fabricated, installed and adjusted to secure the best commercially available results with respect to smooth, quiet, convenient and efficient operation, durability, economy of maintenance and operation, and the highest standards of safety.
- C. It is not the intent of the Contract Documents to detail the design and fabrication of the several parts of the equipment, but it is expected that the type, material, design, workmanship and fabrication of each and every part shall be fully adequate for the service required. The components of all electric circuits shall be of ample and proper size, design and material to avoid injurious heating and arcing, and all other objectionable effects which may reduce the efficiency of operation and economy of maintenance and upkeep.
- D. The DB Entity must provide, deliver, install and successfully test the wheel truing machine.
- E. DB Entity is required to obtain and coordinate all necessary vehicle engineering information for the No. 7 SRC, No. 8 low floor car, and the No. 9 low floor car to complete work and meet the performance characteristics herein.
- F. The machine shall be equipped with hydraulic hold-down equipment to assure the required axle load for the correct tool force. Hold-down design shall allow re-profiling wheels on the transit cars, fully assembled truck, or any single axle wheelset. The design shall include hold-down provisions appropriate for the No. 7 SRC, No. 8 low floor car, and the No. 9 low floor car.
- G. The wheel truing machine shall allow re-profiling of a train mounted truck, fully assembled truck or multiple types of single axle wheel sets for the No. 7 SRC, No. 8 low floor car, and the No. 9 low floor car.
- H. The wheel truing machine shall be capable of truing low floor bogies as a single axle wheel set that may have a rotating full length solid or hollow axle, a non-rotating stub axle, rotating stub axle, or similar design on all MBTA Green Line Vehicles.
- I. Re-profiling shall be accomplished without requiring the removal of equipment such as brake disc, actuators, HPCU's, track brake, track brake supports, or any other vehicle mounted equipment.
- J. Re-profiling must meet all Green line wheel specifications, wheel profiles, and MBTA minimum requirements for full wheel profile latest revision of MBTA drawing #51200.
- K. Wheel truing machine must be able to re-profile new wheel diameters to a condemning wheel diameters of all Green Line vehicles as listed below:

Type 7	26"-24" all trucks
Type 8	28"-26" powered truck, 26"-24" trailing truck
Type 9	25.984"-22.835" all trucks

(All diameters are measured at the wheel tape line)

- L. The machine shall be designed for truing wheel-axle sets having a back-to-back wheel gage of 54 3/16" (+1/16") and a standard track gauge of 56.5".
- M. Wheel tread hardness, when new, may range from 320 to 365BHN. Tread hardness of wheels in service may exhibit harder characteristics, especially in the area of flats spots.
- N. During the wheel truing process, the temperatures generated by machining must not exceed 230°F on all surfaces contacting the wheels' resilient rubber materials.
- O. The Wheel Truing Machine, exclusive of the consumable tooling, shall have a design life of 30 years.
- P. The system shall be designed for installation and proper operation in an indoor, transit shop environment.
- Q. The DB Entity shall provide the interface and interlocking device between the operation of wheel truing machine, winching or shunting system, and OCS (Overhead Catenary System) operation.
- R. All articles, materials, fittings, equipment and machinery incorporated in the Work shall be new, of recent manufacture, and free from defects and imperfections; shall be manufacturer's standard make; and shall be of first grade commercial/industrial quality, subject to approval of the MBTA.
 - 1. When two or more similar items of equipment are required, they shall be of the same model and type from a single manufacturer.
 - 2. All materials and equipment shall be installed as recommended by the manufacturers and in accordance with all required codes and standards.
 - 3. All factory finishes or painted equipment and materials which are scratched or marred during shipment or installation shall be repainted or touched up to match original finish.
- S. Subcontractors
 - 1. The work to be performed by any and all subcontractors as part of this contract will have sufficient documentation on their qualifications to skillfully perform the required work.
 - 2. Any subcontractor who the Authority deems to be incapable of performing their required scope of work will be dismissed and replaced by joint approval of both the Authority and supplier.

2.2 MACHINE DESIGN REQUIREMENTS

General Requirements

- A. The wheel truing machine must be of the under-floor type utilizing proven full profile milling technology, capable of simultaneously profiling both wheels of an axle set. The truing machine must be capable of re-profiling badly worn out of round and damaged wheels.
- B. The wheel truing machine will use the latest Siemens automation control software and hardware technology available to complete the wheel truing operation or MBTA approved equivalent. The automation control software and hardware must be fully supported for at least 10 years after the final acceptance date.
- C. Re-profiling operations shall be CNC/PLC controlled. Data is to be transmitted to the CNC/PLC control and be displayed on the Control Screen.
- D. The wheel truing machine must have centerless clamping and cutting capabilities along with provisions for inboard and outboard hold down devices. In board and outboard hold down devices must be of the hydraulic type or MBTA approved equal.
- E. The machine concept shall be such that the centering, driving, hold-down, and cutting forces have no negative effect on the overall accuracies. The design of the machine shall be such as to avert axle deformations during cutting operations. Axial thrusts developed during the machining processes shall be absorbed through axial wheel guides. The machine shall be designed and constructed and supported to reduce sources of vibration.
- F. The machine shall be capable of re-profiling wheel diameters from 20 inches 32 inches. No special provisions, tools or manual settings shall be required to accommodate any of these wheel sizes.
- G. Both wheels of a wheelset will be finished automatically to the diameter that is required to clean up, while removing the minimum amount of material possible.
- H. All controls for machine operation shall be at a control panel beside, yet comfortable away from, the machining area. The operator shall be able to observe the machine's cutting cycle without being exposed to any chip flow or any components underneath the vehicle.
- I. When not in use, the wheel truing machine's "Home" position (rails closed, machine down, etc.) shall ensure adequate clearance between all vehicles in the MBTA's fleet and any use of a railcar mover over the truing pit area.
- J. The wheel truing machine design shall have capabilities to true wheels with inboard and outboard wheel bearing designs.
- K. The wheel truing machine must have automated control system and fully automatic cutting and measuring programs developed for each axle wheel set in the No. 7 SRC, No. 8 low floor car, and the No. 9 low floor car MBTA Green Line Fleet.

- L. A fully integrated and automatic wheel measuring system at each axle wheel set must be included in the wheel truing system. The wheel measuring system must provide pertinent data pre and post cutting including diameter, flange width, axial run-out (back face), radial run-out, back to back, gauge, and profile conformity.
- M. A data collection system with dedicated Ethernet port or equivalent connection to MBTA network will be integrated into the wheel truing machine.
- N. Wheel truing machine will have the capabilities to true all MBTA Green Line axle wheel sets that may have a rotating full length solid or hollow axle, a non-rotating stub axle, rotating stub axle, or similar designs.
- O. The machine shall have a maximum axle load capacity of 20 tons or greater.
- P. Axle deflection during machining operations when restrained by hold-down forces not to exceed 0.020 inches.
- Q. Machine Noise level shall not exceed 80dBA at the operator's station during normal operation, except while cutting and shall be in compliance with NEMA MG 1 Section 9.6 Sound Power Level and OSHA §1910.95 when measured in accordance with OSHA §1910.95 or IEEE 85.
- R. DB Entity will provide one complete set of mechanical hold-down devices and adapters for all No. 7 SRC, No. 8 LFC, and No. 9 LFC trucks along with installation and mounting procedures. The adapters shall enable wheel truing referenced to the axial center of the wheel set. Detailed drawings for the hold down adapters will be provided along with the specifications and finite element analysis proving each hold down adaptor assembly will withstand cutting loads for the equipment's design life.
- S. A totalizing counter for recording the total number of hours of machine operation shall be provided on each machine.
- T. The minimum production rate shall provide an output of eight 28 or 26-inch diameter wheelsets per eight hour shift.
- U. The typical machining cycle, for a wheelset with 28 or 26 inch diameter wheels, being machined shall occur in no more than three passes, including the mounting of any hold down adapters, spotting of the vehicle over the machine, machine set up for cutting, and all measuring processes.
- V. Design the machine with an automatic lubricating system, or provide sealed lubrication, as applicable. For self-lubricating systems, gear oils, hydraulic fluids, greases, and any other required lubricants a one year supply of each lubrication type shall be supplied with the machine. Lubrication change schedule based on hour usage along with acceptable approved equivalent lubrication types will be provided for each applicable area.
- W. A low lubrication warning message shall show on the operators control station display when the reservoirs require filling.

X. Finished wheel set accuracy:

The DB Entity shall guarantee the following accuracies of machined wheel sets on all MBTA Green Line Vehicles:

1. Diameter parity of wheels on same axle not to exceed 0.012 inches and not to exceed 0.024 inches between axles on a single bogie.
2. The eccentricity or radial run-out on each wheel shall be 0.005 inches or less at any point on the wheel profile circumference.
3. Wheel profile machined surface finish not to exceed 200 micro-inches, RMS.
4. Limits of conformity to profiles not to exceed 0.008 inches.
5. Fully re-profiled wheels must meet all measurements and geometric tolerances associated with the latest revisions of Penn Machine drawings PM-9571, PM9572, MBTA drawings 51200, 47639, CAF M.J1.01.003, and CAF M.J2.01.003. Any conflicting measurements and or geometric tolerances must meet the stricter requirement.
6. The finished accuracies must be met when cutting all axle types listed in this specification including independently rotating stub axle, nonrotating stub axle, or similar design.
7. The machine design shall guarantee the above accuracies on all wheel axle sets without involving additional operator intervention.

Y. Drive system:

1. The wheel drive roller system will be able to support, drive, and guide each wheel during the truing operation. Drive roller system of the wheel truing machine must be of the flange driven type. Other means or contact areas for driving the wheels are not acceptable.
2. The wheel drive system shall be a roller friction type arrangement directly contacting the wheel flange. The drive motor shall transmit rotational power through a gear reduction unit. The drive rollers shall not be repositioned to complete the cutting operation.
3. Drive roller system shall be designed for compensation of inaccuracy on worn and flat wheel profiles. Provide a procedure for measuring and replacing process inclusive of pass fail criteria for measuring drive roller wear.
4. Drive rollers shall be machine-able within permissible tolerances. DB Entity shall provide drive roller drawings suitable for re-machining of the rollers.
5. The entire wheel drive system shall hydraulically swivel around a fulcrum point, resulting in lifting the vehicle wheel set off the sliding rail and move into proper cutting position.

6. Wheel truing machining operations shall be performed without lateral re-positioning of drive rollers for machining taper, tread, throat and face of flanges of wheels. The milling head shall only be positioned once per wheel set.

Z. Automatic Wheel Measurement System (Probing System):

1. Wheel truing machine electronic measuring system shall be capable but not limited to measuring wheel diameter, flange width, axial runout (back face), radial run-out, back to back, gauge, and profile conformity.
2. The wheel measuring system must have the ability to locate the wheelset and position the cutter heads to properly re-profile the wheelset during the truing process.
3. The wheel measuring system must be capable of meeting and measuring all of the accuracy requirements listed in this specification.
4. The wheel truing machine measuring system must have the measuring capabilities to deal with high back of flange wear commonly seen throughout the Green Line system.
5. The depth of cut on worn wheel profiles shall be determined by automatic measuring and positioning devices which indicate the required depth of cut to restore the wheel full profile for minimum removal of material.

AA. Milling Cutter Assembly:

1. The milling cutter assemblies shall consist of two full profile high speed milling heads, each housing multiple blades which control the wheel tread and flange contour and contain the round cutting inserts. The cutter blades shall be replaceable and the round carbide cutting inserts shall be easily indexed and/or replaced. The cutting inserts shall be of a low cost throwaway type.
2. Each milling cutter head must be of a quick change design with removable blades. The round carbide cutting inserts are to be indexable on the cutter heads without removing from the machine. A list of recommended and acceptable cutting inserts will be provided along with a six month supply.
3. The cutter blades shall be designed with a set of cutting inserts on the end of the cutter to allow for a chamfer cut at the end of the wheel tread.
4. Each cutter spindle will be independently driven by an adequately powered gear motor to complete the re-profiling process.
5. Cutting capabilities must be robust enough to removing excessive flat spot(s) that are typically seen on the Green Line system without the need to undercut by 1/16th of an inch.
6. Acceptable design depth of a single cut shall be 0.125 inch regardless of wheel condition. Sufficient axle load is required to achieve higher depths of cut.

7. Proposed wheel truing machine shall automatically stop and retract the cutter head in the event of power failure, machine malfunction, loss of power, or emergency stop application.
8. Chip guards shall be provided fitted to the cutters except in that area which it is required for the cutter to contact the wheel. The chip guards shall direct the chips to chutes that will properly convey to a disposal system. The milling process shall produce small, easily removable chips without clogging the disposal system.

BB. Sliding Rail System

3. Provide a sliding rail system over the pit and machine area. Provide the necessary rail supports in the pit area and connecting rails to the existing rails in the shop. The sliding rail system shall be hydraulic, automatically operable with a manual override and safety circuit.
4. The approach rails shall connect the machine to the rail system in the shop providing access on and off the machine. The approach rails will also aid in the alignment of the vehicle to the wheel truing machine.
5. Sliding (retractable) rails shall be hydraulically operated and bridge the opening in the machine through which the cutters contact the wheels for re-profiling. They shall be designed with an appropriate safety factor to withstand the weight of the heaviest MBTA Green Line vehicle.
6. In addition to a rail interlock system, provide at both sides of the pit warning lights which shall show red when the sliding rail is retracted (open) and green when it is extended (closed).
7. The control system safety interlocks shall not have a means of mechanical override.

CC. Mechanical Chip Collector And Conveyor System

1. Provide a chip collection system and conveyor to remove metal debris generated from the cutting process. The chip conveyor shall convey the chips to a suitable, self-dumping 1.5 cu/yd metal hopper/container, provided by the manufacturer. The chip conveyor shall convey the chips to a MBTA approved location without clogging.
2. The mechanical chip collection and conveyor system shall be integrated into the chip guard channel system to properly remove debris during the truing process without clogging or jamming.
3. The system capacity and belt speed shall be equal to, or greater than, the maximum metal removal or cut of the milling operation and be sufficient to carry the volume of chips generated by the wheel truing machine from the bottom of the pit and discharge the chips above rail level into the metal hopper provided by the manufacturer.

4. A single motor shall operate the conveyor system.
5. The controls for the chip disposal system shall be integrated into the wheel truing machine operator's control panel.
6. The conveyor machinery shall be concealed in an enclosure with removable access plates furnished at each turn in conveyor direction and at intermediate points along the conveyor as necessary for maintenance. Belt shall be hinged steel with interlocking side wings and cleats on the pans.
7. Conveyor length shall be based on chip removal from under the machine to a container location that is easily accessible by fork lift for removal. The location of the discharge end of the conveyor and the hopper are subject to the approval of MBTA. If possible and necessary, discharge end of the conveyor shall be stow-able when not in use to maximize clearance adjacent to the conveyor.
8. A chip breaker is not necessary with milling. Metal debris generated from cutting are of a size that can be discharged directly to the chip conveyor system without clogging.
9. Electrically interlock conveyor system to automatically start and stop with the machine operation. A manual on/off control for conveyor system will also be installed along with motor overload protection upon jamming.

DD. Master Machine Control Panel (MMCP)

1. The panel shall house motor starters, disconnect switches, the control circuit transformer, fuse blocks, contact blocks, and interlock necessary for the proper function and operation of the wheel truing machine equipment. Each motor shall be protected by its own circuit breaker and each magnetic motor starter must have overload ground fault protection in all three phases. The machine shall be supplied power from a single 480 Volt, 3 phase, 60 hertz source and shall provide for circuit protection from that point.
2. Control voltage shall be 120 V, 60 Hz or 24 VDC obtained from control transformer(s) furnished within the MMCP. No controls accessible to the operator shall have wiring carrying a voltage potential exceeding 120 Vac to ground.
3. Machine drive shall be by motors of sufficient capacity, provided with infinitely variable speed control. Variable speed controllers shall be mounted in the MMCP.
4. The machine shall be fully wired by the DB Entity requiring a single point of electrical connection from the building to be identified in the shop drawings.
5. The MMCP will meet the proper NEMA enclosure standards listed in this specification and be designed with an integrated climate control system.

EE. CNC Controller

1. Machine operations shall be based on Computer Numerical Control (CNC) operations and be integrated with the Programmable Logic Control (PLC)

functions. The operator control station shall be a centralized CNC operation, incorporating a screen display on which operations and sequencing of operation inclusive of help screens and operating prompts shall be shown.

2. CNC programs will have all safety interlocks listed in section 6.35 of this specification and any other required interlocks integrated into its operating system.
3. The machine operator shall confirm the wheel set data obtained by the measuring system and give a command for the next question or menu direction.
4. The CNC screen shall display images relating to machine operator communications of pre-measuring, determination of depth of cut(s), machining proposal, operational data, final wheel set parameter, post measuring, auxiliary system(s) operations, end of cutting cycle, general wheel set data, and other images determined to be necessary for proper automatic machine operation. All screen and keyboard operations shall be displayed in English.
5. Data input by the machine operator shall be checked for validity. Error input or input outside established and acceptable limits shall be rejected requiring new input via system entry.
6. Image display shall also state each wheel's flange thickness, wheel diameter, back to back, gauge, axial run-out (back face), radial run-out, profile conformity, and other features or dimension relating to operation.
7. The CNC controls shall communicate with the machine Programmable Logic Controller to provide and display diagnostic data of machine fault condition(s) leading to trouble identification.
8. Wheel tread profile(s) shall be permanently stored in the programmable memory. Loss of memory is to be protected during power failure. All backup operating and programming software will be provided to the MBTA along with procedures for re-commissioning if necessary.

FF. Automated Cutting Program

1. The control system provided shall allow the machine to determine the number of cutting passes required to true the wheelset and at what depth each pass should be taken to minimize the amount of material removal.
2. The system shall automatically feed the cutters for each pass and does so at the proper time. The wheelset pre-measure data shall be transferred automatically to the control system from the integrated automatic measuring system.
3. If possible the machine shall incorporate anti-slip controls for counteracting wheel slip when operating near the ultimate limit of high cutting forces and resulting torque.
4. When cutting is complete the cutters shall be automatically withdrawn and traversed to their set-up position. The spindle drives and drive rollers shall automatically shut-off and the machine shall remain in a safe, "idle" condition until

the operator is ready to proceed with machining the next wheelset.

5. In addition, an "Emergency Tool Retract" feature shall be provided, when actuated, shall stop both of the cutters and drive rollers and automatically lower the cutters, in case of an emergency or overload situation.

GG. PLC Controller

1. The Programmable Logic Controller (PLC) shall control the machine functions and operations.
2. PLC functions shall be connected to the CNC control operations and provide a high degree of automation and minimize operator guidance. Operator guidance features shall be included for sequence of machining steps, permissible limit values and fault indication.
3. The PLC control shall also give the proper commands for all auxiliary systems such as the chip conveyors, sliding rail assembly and approach indicators (both sides of machine).
4. PLC shall control the sequence of operation for lifting and initial positioning of wheel sets inclusive of supporting functions for hydraulic and electrical operations.

HH. Data Acquisition System (DAS)

1. The system shall include computer, user-friendly software, storage media, internal modem, wireless network connection, printer, and a work kiosk suitable for a shop environment.
2. The machine shall provide a Data Acquisition system (DAS) to record and store operator identification, vehicle, truck and wheel set identification as appropriate. Display and print out shall include but is not limited to: operator name and employee number, vehicle number, truck serial number, truck position on vehicle (A, B, or C), current vehicle mileage, axle position (1-6), reason for truing (flat spots, regular truing interval, etc.), date and time of start and completion of truing, initial diameter, flange wear, flange height, back to back wheel dimensions, final diameter, and post measuring data of finished wheel set.
3. Permanently stored data shall be transferable to the customer computer network via a category 5 network connection or approved equal.
4. The data acquisition system shall be configured for levels of management and operator password access to various levels of information.

II. Safety Interlocking

1. Design and provide an electrical interlock system to disable control power in the control panel from being applied to the machine unless the Overhead Catenary System (OCS) is de-energized.

2. Provide an interlock to prevent energizing the OCS until the machine is in the green state, and sliding rails are closed, permitting movement of a vehicle over the machine.
3. Provide emergency stops as designed by the manufacturer. Whenever an emergency stop is activated the PLC shall display a visual notification. A minimum of four mushroom style emergency stops shall strategically be placed at various work locations in the pit. The emergency stop buttons shall illuminate when the machine is activated and require pulling out to reset the machine once pushed.
4. Provide an interlock to prevent energizing the railcar mover, cable winching system, or OCS until the wheel truing machine is in the shut-down mode, and sliding rails are closed, permitting movement of a vehicle over the machine.

JJ. Electrical:

1. A single electrical service operating at 480 V/3 PH/60 HZ to be provided by the installer to the equipment. The manufacturer shall provide all other voltages required for operation of the system by transformers.
2. The machine shall be equipped with a grounding system to protect the equipment and operating personnel. Equipment grounding, structural steel grounding, and rail grounding shall be accomplished by individually connecting each item with properly sized copper conductor and a common ground bus bar in the pit area. The grounding system shall be properly wired to the ground at the MBTA power distribution panel. A similar but separate grounding system shall be provided for the control circuits. DB Entity will provide embedded ground rods if needed and comply to NEC Article 250.
3. Control panels enclosures exposed to wet conditions shall be: NEMA 4X stainless steel. Enclosures within the building: NEMA 12 type or approved equal.
4. Wiring at the machine and control panel cabinets shall comply with NFPA 70 and NFPA 79.
5. Wire chases and conduits shall be easily accessible with appropriate junction boxes for repair and replacement purposes.
6. Wire terminations, to the extent possible, shall be by lugs secured in terminal blocks with numbered terminals and color coded wires with wire markers.
7. Minimum size shall be AWG No. 12 for power circuits and AWG No. 14 for control circuits. Wire shall be copper. Wires in each of the control panels shall be color coded and tagged with a number on each end. The color and number must be marked in the wiring diagram supplied by the DB Entity. Appropriate wire sizes must meet the load required.
8. Provide each individual motor circuit with branch circuit over current protection in all phases using multiple circuit breakers.

9. Equipment shall be totally wired including all non-embedded conduits by the equipment manufacturer up to and including the main disconnect switch.
10. Use liquid tight flexible metal conduit connections to motor terminal boxes, dry type transformers, and equipment subject to movement or vibration.
11. Identify wiring by a wire tag with a number corresponding to the wiring diagram.
12. Provide transformers to step down the 480 V 3 phase supply voltage to lower required voltages and single phase for controls and accessories.
13. The maximum control voltage shall be 120 V.
14. Maximum current: Not to exceed that specified by NEC for the type of conductor.
15. Provide unfused disconnect switches, motor starters and start-stop control stations for all equipment.
16. Provide electrical switches in compliance with NEC, equipment design requirements, and the electrical power circuit design for each piece of equipment.
17. Electrical control cabinet and operator control panels shall meet the specifications for an electrical enclosure with NEMA 12/13 standards. Included in the cabinet shall be a main disconnect switch along with all fuses, motor starters, relays and terminals. All wiring for the controls and motors shall be in accordance with Division 26 requirements for use of type MTW, THWN and THHN stranded wire.
18. All motors shall be TEFC (totally enclosed, fan cooled) to provide the required operational reliability in any operating environment.

KK. Hydraulics:

1. The Hydraulic System shall be comprised of solenoid controlled hydraulic valves, flow controls, hydraulic filters for optimal performances and adequately sized oil reservoir. All valves provided to fulfill the various machine functions shall be compact mounted on a manifold sub plate for easy maintenance.
2. A hydraulic hold down system shall be provided for lightweight equipment, to increase friction force between the wheels and the drive rollers.
3. The hold down unit shall be provided for re-profiling all wheelset configurations of all Green Line Vehicles.
4. The hold down unit shall produce the appropriate forces to properly reprofile Green Line wheelsets to the required accuracies.

LL. Dust Extraction System

1. A dust collection unit shall be provided for the wheel truing machine area in accordance with NFPA 90A or similar.

2. The unit shall be of sufficient size to draw a vacuum through the piping system to the truing area to remove air borne particles generated by wheel truing.
3. Flexible hoses shall be provided as required for movement of the machine only.
4. Collected materials shall be deposited in a 3 CY capacity canister for disposal.
5. Replaceable filter media shall be provided and easily replaced.
6. The dust and fume extraction system shall be a single unit placed adjacent to the wheel truing machine pit and can be operated in automatic and manual modes. The suction pipes shall be positioned close to the working area of the tooling. Provide suction diversion valve to accommodate vacuum hose connection when wheel truing machine is not in use.

MM. Paint

1. Paint all non-stainless steel and galvanized metal component parts of the wheel truing machine, except electrical connections and machined surfaces. Prepare all surfaces to be painted as recommended by the paint manufacturer.
2. Surface Preparation: All painted surfaces shall be free of grit, oil, contaminants or other substances that could prevent proper adhesion.
3. Equipment shall be given one shop prime coat of approved rust-
4. inhibitive paint containing manufacturer's standard finish coat system suitable for a transit maintenance facility environment. All color selections must be approved by MBTA.
5. Field painting equipment, including touch-up painting, if any, is included under this Section. Normally, equipment shall be factory finished as previously specified. Where factory finishes are provided on equipment and no additional field painting is specified, all marred or damaged surfaces shall be touched up or refinished so as to leave a smooth, uniform finish at the time of final acceptance. Touch-ups shall be of the same color and type of paint as the original. Provide one gallon of matching touch up paint.

NN. Signage

1. All equipment, control panels and ancillary devices shall be clearly and distinctly identified by signage to indicate its intended use and purpose for all related operator and maintenance functions. All wording and symbols shall be in English.
2. All control, warning and instructional information shall be engraved on stainless steel metal and be riveted or screwed into conspicuous places, unless otherwise approved by the MBTA. All characters' colors shall be in contrast with the background color. All colors shall be resistant to fading from all sources including, but not be limited to, sunlight, dirt, extreme temperatures, age, ozone, oil and common cleanser.

PART 3 - EXECUTION

3.1 GENERAL TRUING PIT DESIGN AND FABRICATION REQUIREMENTS

- A. Designed truing pit location, its appurtenances, and accessories will provide proper ergonomics and sufficient clearance to accommodate the transit vehicles without damaging vehicle bodies, equipment, trucks, and other components.
- B. The DB Entity shall furnish an affidavit certifying that all materials and workmanship comply with the applicable building code requirements. Before final acceptance, the DB Entity shall furnish certificates of the agencies having jurisdiction.
- C. During the course of the work, inspections and/or audits at the DB Entity's or supplier's facilities may be conducted to ensure quality control. Construction work will be inspected by the MBTA periodically during the course of the work.
- D. The DB Entity shall be responsible for the coordination of all work performed at the site, by his own forces or by subcontractors, as required. The coordination effort shall include at a minimum, workspace allocation, wheel truing equipment layout, foundations and structures, utility connections, electrical equipment layout, piping systems, safety systems, drainage or sump pump needs, and pit exhaust or air filtration systems.
- E. The DB Entity shall provide a qualified representative at the site to supervise work related to equipment installation, subcontracting checkout and startup.
- F. Equipment and or modifications proposed by DB Entity shall be suitable for installation in the space allocated for the new wheel truing machine.
- G. The DB Entity shall visit and prepare the site prior to the installation process. The DB Entity shall perform an as-built field verification and structural analysis of the existing site to ensure that it is compatible with its proposed wheel truing machine. A copy of this report and preliminary shop drawings shall be submitted to the MBTA for review.
- H. Any modification or redesign to the building structure, pit amenities or utilities shall be provided by the DB Entity at no additional cost to the MBTA.
- I. DB Entity generated changes to the wheel truing machine, shall be the responsibility of the DB Entity.
- J. Provide heavy duty pit open grating walking surfaces, non-slip diamond plate steel stairways, handrails and supports as required for operators working in the pit. All walking surfaces shall be covered with non-slip silica grit. Wire mesh grating is not acceptable for walking surfaces.
- K. Provide additional heavy duty grating flush with the top of rail between the approach rails from the face of the pit wall to the machine.
- L. Removable sections of grating shall be provided as required to access equipment below the grating such as heaters, sump pumps and chip conveyor system.

- M. Removal, modification and re-installation of the existing running rail ground bonds and the like. All modified track work shall be straight and tangent in relationship to the original shop rails. MBTA must approve any and all track modification or installation.
- N. Installation of vehicle alignment rails will be provided to properly align vehicle to wheel truing machine cutting position.
- O. Compressed air piping shall be coordinated with building compressed air piping installation as required. DB Entity will supply any required air regulators and air filtration systems needed to properly protect wheel truing equipment and components.
- P. Design and provide all interconnecting piping sized for air flow rates as indicated.
- Q. The operator control stations shall be conveniently located in the equipment pit for one-man operation. Controls shall be within easy reach of the machine operator.
- R. The layout of the pit shall allow sufficient room for worker accessibility all around the machine.
- S. Provide appropriate task lighting. Illumination level for task lighting at work locations shall be light emitting diode (LED). Approved lighting fixtures shall be appropriately rated for the cutting environment.
- T. Supply two universal cutter alignment maintenance stations to check reassembled cutters to identify high or low cutter blades, worn cutter blades, out-of-tolerance carbide insert diameters, burrs and/or chips lodged between cutter blades and cutter body slots, etc. The alignment stations will also identify possible cutter problems upon re-assembly of the cutters. The operator shall be able to continue to operate the wheel truing machine in the automatic mode while performing these maintenance checks on the spare set of cutter assemblies.

3.2 DELIVERY, STORAGE AND HANDLING

- A. The manufacturer shall store the equipment until such time that it is required for installation in the pit within the newly constructed building.
- B. Equipment and components shall be suitably crated to prevent damage in transit or during handling. Items shall be carefully stored at the site as required in a manner to avoid misalignment or distortion, and shall be adequately protected against damage by weather or other cause.
- C. Special precautions shall be taken to prevent damage to electrical components such as motors, controls and conductors.
- D. The DB Entity shall notify the MBTA in writing of the expected delivery date and time. This notification shall be made a minimum of 15 days in advance of delivery.
- E. All materials shall be delivered to the site with their original manufacturer's markings

and identification intact. Reject materials that are damaged, improperly identified or not in conformance with reviewed shop drawings and catalog cuts. The MBTA reserves the right to also reject such materials.

3.3 INSPECTION, TESTING AND STARTUP

A. Inspection and Testing

1. In-factory testing will be performed at the manufacturer's facility. The DB Entity shall designate a representative who shall be an appropriately qualified individual, and who will coordinate the on-site installation and commissioning.
2. The in-factory inspection and test(s) shall include a visual inspection, demonstration of proper operation of all functions and equipment, running tests of electrical controls, AC breaker, transformer, all motors, and computer control.
3. Equipment shall be fully factory tested by the DB Entity prior to delivery. The MBTA will provide one of each bogie type for this purpose. Cost of insuring, loading, transporting and unloading in both directions of transport shall be borne by the DB Entity.
4. Before final acceptance, the DB Entity-furnished equipment shall be tested, in the presence of a designated MBTA engineering representative, and demonstrated to be correctly connected and installed. The DB Entity shall submit a test plan and schedule to the MBTA for approval fourteen (14) days prior to the start of the equipment test and check-out.
5. All performance requirements included in this specification shall be included in the test plan and schedule. Additionally, all recommended testing and check-out procedures of the manufacturer shall be carried out completely.
6. Equipment tests shall not only be performed to demonstrate that the equipment has been properly installed and operates properly, but also to demonstrate that the equipment performs the work as described in the contract documents.
7. Any tested equipment found to be defective or inoperable to any extent shall be reported to the MBTA.
8. Testing shall include verification of proper operation of the DAS, hydraulic system functions including a pressure test for leakage, machine accuracy and machining tolerance, along with measuring system accuracy while machining actual wheel sets. The DB Entity shall provide written documentation to the MBTA of all testing and results.
9. The DB Entity shall bear all expenses of all tests, including the furnishing of all necessary instruments, lubricant, hydraulic fluids, supplies, data recorders, operating personnel for testing.
10. The on-site test shall duplicate those test performed in-plant. Provide an Acceptance Testing Program for approval prior to testing, including:

- a. Demonstration and operation of Mechanical Chip Collector System.
- b. Demonstration of hold-down equipment adequacy for all the No. 7, No. 8, and No. 9 vehicle trucks.
- c. During the tests should the profiling machine, or the chip collection system, or any part thereof, in the determination of the MBTA fail to function properly, the DB Entity shall make modifications, adjustments or replace impaired parts as may be required for safe and proper operation, at no additional cost to the MBTA. Perform additional test deemed necessary to verify equipment is operating properly and safely after any changes.

B. Follow-up Inspection and Testing

1. The DB Entity shall provide complete follow-up inspections of the machine:
 - a. First inspection at two months after date of final acceptance of the machine. At this time a complete re-alignment and/or adjustment of all critical machine elements shall be made. All machine functions will be tested for proper operation and verified. A written report to the MBTA of all findings, maintenance and operating recommendations and any items in need of attention, shall be made.
 - b. Second inspection at six months after date of final acceptance of machine. At this time a complete re-alignment and/or adjustment of all critical machine elements shall be made. All machine functions will be tested for proper operation. A written report to the MBTA of all findings, maintenance and operating recommendations and any items in need of repair or modification shall be made.
 - c. At twelve months after date of Final acceptance of the machine. At this time all machine functions will be tested for proper operation, maintenance and operating recommendations and any items in need of repair or modification shall be made.
 - d. At eighteen months after the date of Final Acceptance of the machine. All machine functions will be tested for proper operation. A written report of all findings, maintenance and operating recommendations and any items in need of repair or modification shall be made.
 - e. A final inspection shall be conducted at twenty-four months after the date of Final Acceptance. All machine functions will be tested for proper operation of findings, maintenance and operating recommendations and any items in need of repair or modification shall be made.
2. Any necessary alterations to the machine required to provide wheel truing operation, as here-in defined, shall be made by authorized factory service personnel, provided by the DB Entity at no additional cost to the MBTA.

3.4 TRAINING

- A. All training shall be provided by a qualified representative of the DB Entity. The training plan and objectives shall be reviewed by and approved by the MBTA prior to the start of such activities.
- B. Prior to delivery, the DB Entity shall submit for review a program, which shall adequately train MBTA personnel to correctly operate, maintain and troubleshoot the equipment. The DB Entity shall be responsible for supplying all materials required for the program.
- C. The DB Entity shall provide three levels of training (operator, maintenance and computer maintenance/programming) which will ensure that MBTA personnel clearly understand the functioning of the system and become capable of taking any actions necessary for routine operation, maintenance, recalibration and repairs.
- D. A complete operators training class of minimum 80 hours duration for up to six operators and four maintenance personnel including test materials and manuals provided to the MBTA in Microsoft Word format electronically. Training shall be comprised of both classroom and hands-on training. During training, all machine functions must include classroom discussion and an opportunity for each of the individuals to perform actual machine set-up and operation.
- E. The operator training shall include but not be limited to:
 - 1. Description of the operating systems of the wheel truing machine.
 - 2. Demonstration of all standard equipment and accessories on the machine.
 - 3. Demonstration of computer system and operation procedure for wheel truing and data analysis. Sufficient hands-on training by each participant to ensure knowledge and performance competency of each operator.
- F. The maintenance training shall include, but not be limited to:
 - 1. Description of the operating systems of the wheel truing machine.
 - 2. Demonstration of all routine maintenance and preventive maintenance procedures including lubrication requirements and replacement of wear parts.
 - 3. Demonstration of all standard equipment and accessories on the machine.
 - 4. Troubleshooting common problems of the equipment and understanding the readings and operation of computer.
- G. Training shall begin after the wheel truing machine is installed and demonstrated to be working properly. The DB Entity will develop a mutually agreeable training schedule.
- H. All training shall be held at the Authorities facilities. All classes will be scheduled for weekday's single shift Monday through Friday.

- I. DB Entity shall submit one copy of the proposed training manual to the MBTA for review and approval 45 days prior to the beginning of training.
- J. The DB Entity shall provide sufficient quantities of bound training manuals at the start of the training classes for each trainee.
- K. Following completion of training, DB Entity shall furnish the following to the MBTA:
 - 1. A letter attesting to the names of persons receiving instruction and the date's instruction took place.
 - 2. Certification of completion and capability of operation for each person receiving instruction.
 - 3. Provide electronically formatted material covering the essential information contained in the training sessions.

END OF SECTION

SECTION 13000

PRE-ENGINEERED BUILDING SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Furnish and install pre-engineered building and components including the following:
 - 1. Structural steel frame
 - 2. Roof covering system including exterior roof panels, panel attachments, insulation, trim, flashings, sealants and mastics.
 - 3. Exterior wall systems including wall panels, panel attachments, insulation, trim, flashings, sealants and mastics. Reinforcing steel, masonry joint reinforcement, ties and anchors
- B. Furnish and install wall accessories including the following:
 - 1. HM doors and frames
 - 2. Windows
 - 3. Louvers
- C. Furnish and install roof accessories including the following:
 - 1. Gutters and downspouts
- D. Other specifications sections which directly relate to the work of this section include, but are not limited to the following:
 - 1. Section 03300 – Cast-in-Place Concrete
 - 2. Section 08331 – for the furnish of overhead doors to be installed under this section
 - 3. Section 09900 - Paints and Coatings: Finish painting of structural members, doors, and factory prime painted miscellaneous items.

1.2 SUBMITTALS

- A. Design data: Provide detailed design criteria in compliance with all project building code requirements and calculations prepared by a licensed Structural Engineer registered in the Commonwealth of Massachusetts. A Civil Engineer's P.E. stamp shall not be accepted as a substitute of the above requirement. Provide all column base reactions and anchor bolt configuration for design of foundations within one week of award of contract. Preliminary foundation design will be indicated on the drawings until final reactions are issued
- B. Test reports: Submit certified reports for tests required. Including providing a statement of average net-area compressive strength of masonry units in accordance with ACI 530.1 for masonry and mortar types specified herein.
- C. Shop drawings shall also include erection sequence drawings detailing all temporary structural support until the structure is stable.

- D. Anchor bolt installation drawings: Provide anchor bolt layouts with minimum bolt diameters, spacing and configuration, including anchor bolt length and details for each column base plate.
- E. Selection samples: For each finish product specified, two complete sets of color chips representing manufacturer's full range of available colors and patterns
- F. Certification: Manufacturer certification that the building conforms to the Contract Documents and manufacturer's standard design procedures. The certification shall be prepared and signed by a licensed Structural Engineer registered in the Commonwealth of Massachusetts verifying compliance with all code requirements, project criteria, standards, etc.

1.3 QUALITY ASSURANCE

- A. Provide metal building frame, metal wall panels, metal roof panels, accessories and miscellaneous materials for a complete enclosure including supports for building components specified in other sections.
 - 1. Manufacturer qualifications: Not less than 5 years of experience in the actual production of specified products. Members of the Metal Building Manufacturer's Associations (MBMA) and primary manufacturer of frames, secondary steel, roof and wall sheeting and trim.
 - 2. Installer qualifications – Firm experienced in application or installation of systems similar in complexity to those required for this project, acceptable or licensed by manufacturer, 3 years of experience with systems and successfully completed not less than 5 comparable scale projects using this system
- B. Design structural systems according to professionally recognized methods and standards and legally adopted building codes and to withstand gravity and lateral loads in compliance with Contract Documents.
 - 1. Allowable deflections: Deflection/drift criteria shall follow recommendations outlined in AISC design guide 3 and MBMA serviceability recommendations and as defined below:
 - a. Maximum deflection of main framing members shall not exceed 1/240 of the span length.
 - b. Maximum deflection due to snow load in roof panels and purlins shall not exceed 1/360 of the span length.
 - c. Maximum deflection due to wind load in wall panels and girts shall not exceed 1/360 of the span length.
 - d. Lateral building deflections, or drift, at the roof level of the structure in relation to the slab on grade, shall not exceed H/240. H is the dimension from the slab on grade to the roof level.
 - 2. Metal wall panels (interior and exterior) shall not to be used as shear elements.
 - 3. Construct assembly to permit movement of components without buckling, failure of joint seals, undue stress on fasteners or other detrimental effects, when subject to temperature range of 100 degrees F (37 degrees C) in a 24-hour period.
 - 4. Design and fabricate wall and roof systems free of distortion or defects detrimental to appearance or performance. Some oil canning in rolled panels especially in the flats of the panel is normal and is not cause for rejection.

- C. Elements required for support of lights and light battens, hanging fixtures, mechanical equipment, piping, ceiling hanger wires, and all other items required to provide a complete building and not specifically indicated on the drawings
- D. Design under supervision of professional engineer licensed in the Commonwealth of Massachusetts.
- E. Roof System tested and certified to meet Factory Mutual FM Global wind classification rating FM 1-120
- F. Envelope shall include semi-rigid blanket insulation and /or rigid board insulation to meet energy code requirements.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Store products in manufacturer's unopened packaging until ready for installation
- B. Deliver to project site stacked on pallets and in undamaged condition and handle materials in strict compliance with manufacturer's instructions and recommendations. Protect from all possible damage.
- C. Cover and protect from weather.
- D. Store and dispose of solvent-based materials, and materials used with solvent-based materials, in accordance with requirements of local authorities having jurisdiction.

1.5 PROJECT CONDITIONS

- A. Maintain environmental conditions (temperature, humidity, and ventilation) within limits recommended by manufacturer for optimum results. Do not install products under environmental conditions outside manufacturer's absolute limits.

PART 2 - PRODUCTS

2.1 STRUCTURAL STEEL FRAMING

- A. Primary framing: Rigid Frame (RF Series) solid web framing consisting of tapered or uniform depth rafters rigidly connected to uniform depth columns. Provide a clear span that supports the loads at bay spacing indicated. Steel Surface Preparation: SSPC-SP 2.
- B. Purlins: Zee-shaped; depth as required; with minimum yield strength of 60,000 psi (410 MPa); simple span or continuous span as required for design. G-30 galvanized standard material with G-90 availability. Welded members are manufacturer's standard primer.
- C. Girts: Zee- or Cee-shaped; depth as required, with minimum yield strength of 60,000 psi (410 MPa); simple span or continuous span as required for design. G-30 galvanized standard material with G-90 availability. Welded members are manufacturer's standard primer.
- D. Transbay members: Bar joist, parallel chord, secondary joists; simple span, utilizing materials, sizes and yield strength as required.

- E. Wind bracing: Portal frames, torsional bracing, diagonal bracing and/or diaphragm elements in accordance with manufacturer's standard design practices; utilizing rods, angles, and other members, with minimum yield strengths as required for design but in most cases, 50 ksi.
- F. Welding: welding procedures, operator qualifications and welding quality standards shall be in accordance with AWS D1.1 – Structural Welding Code and AWS D1.3 Structural Welding Code – Sheet Steel. Welding inspection shall be in accordance with AWS D1.1, paragraph 6.9. Welder certifications shall be supplied upon request.
- G. Finish: Provide compatible primer and top coat from same manufacturer. The DB Entity to coordinate if top coat is shop applied or field applied.

2.2 MISCELLANEOUS FRAMING

- A. Base angles: 2 inch by 3 inch by 0.060 inch (50 mm by 75 mm by 1.5 mm) galvanized steel angles, with minimum yield strength of 55 ksi (380 MPa), anchored to the floor slab or grade beam with power driven fasteners or equivalent at a maximum spacing of 4 feet (1220 mm) on center and not more than 6 inches (150 mm) from the end of any angle member. Anchors are not provided by the metal building manufacturer.
- B. Door headers and jambs: Zee- or Cee-shaped; depth as required; with minimum yield strength of 60 ksi (410 MPa).

2.3 MODIFIED BITUMINOUS ROOFING

- A. Base ply and base flashing ply: Will be one ply of approved ASTM D 6163 Type I, 80 mil SBS (Styrene-Butadiene-Styrene) rubber modified base sheet.
- B. Cold bitumen membrane inner ply adhesive: The standard bitumen will consist of a V.O.C free, non-asbestos containing cold applied adhesive
- C. Modified membrane/top flashing ply: 160 mil SBS (Styrene-Butadiene-Styrene) and SIS (Styrene-Isoprene-Styrene) rubber modified membrane incorporating recycled content and reinforced with a strong fiberglass and polyester composite scrim
- D. Surfacing: Two coats of specified coating, manufacturer approved.
- E. Insulation adhesive performance requirements: Two component, foam adhesive as recommended by insulation manufacturer and approved by FM Global indicated ratings.

2.4 METAL-FACED INSULATED WALL PANELS

- A. Wall Panels: Panel rib; 36 inch (915 mm) wide net coverage, with 1-3/16 inch (30 mm) high major ribs at 12 inches (305 mm) on center with minor ribs spaced between the major ribs. Metal panels for fabrication of wall panels shall be a factory insulated; shop assembled laminated aluminum panels for exterior walls complete with associated trim.
- B. General: Provide factory-formed and -assembled metal wall panels fabricated from two metal facing sheets and insulation core foamed in place during fabrication, and with joints between panels designed to form weathertight seals. Include accessories required for weathertight installation

1. Fire-retardant core: Noncombustible, with the following surface-burning characteristics as determined by testing identical products per ASTM E 84 by UL or another testing and inspecting agency acceptable to authorities having jurisdiction:
 - a. Flame-spread index: 25 or less.
 - b. Smoke-developed index: 450 or less
- C. Aluminum-faced insulated wall panels: Formed with 0.040-inch- thick, coil-coated aluminum sheet facings.
 1. Panel thickness: 3 inch (R21) and 4 inch (R30), at areas indicated on the Design Documents.
 2. Surface texture: Smooth
 3. Width: As indicated on the Design Documents.
 4. Core insulation: One of the following:
 - a. Shall be expanded polystyrene (EPS), report #NER-479, nominal density 1.0 pcf with minimum shear strength of 20 psi.
 - b. Shall be formed isocyanate, nominal density 2.0 pcf with minimum shear strength of 24 psi.
- D. Attachment system components: Formed from extruded aluminum.
 1. Include manufacturer's standard panel stiffeners, panel clips and anchor channels.

2.5 WALL ACCESSORIES

- A. Hollow metal doors and frames: Doors for panic devices: Grade 2, 1-3/4 inches (44 mm) thick minimum 18 gage (1.22 mm) steel face sheets.
 1. Type: Flush.
 2. Frames: Jamb depth, minimum 16 gauge (1.52 mm) steel; self-framing and self-flashing.
 3. U-factor: 0.090A
 4. Weather stripping: At jambs, head and sill, complying with water and air resistance requirements of SDI 115 and SDI 116.
 5. Finish: All doors and frames have a baked-on primer coating meeting ANSI A250.1 standards. Paint test for salt spray, humidity and adhesion.
- B. Window
 1. Type: Refer to drawings
 2. U-factor 0.60 and SHGC 0.80.
 3. Finish as selected by the DB Entity from the manufacturer's standard textures and colors

2.7 INSULATION

- A. Mineral fiber insulation ASTM C553, Type 2, faced with a vapor barrier having a perm rating of not more than 0.5 and with: flame spread Index not to exceed 25 flame spread when tested in accordance with UL 723 or ASTM E 84 test methods; smoke developed index: not to exceed 50 smoke development when tested in accordance with UL 723 or ASTM E 84 test methods. UL Classified.
- B. Continuous roof insulation: Mineral fiber with R value = 22.5 or provide calculations indicating roof assembly U-factor = 0.043.
- C. Continuous wall insulation: Mineral fiber with R value = 12.5 or provide calculations indicating wall assembly U-factor = 0.075.
- D. Thermal blocks: 3/4 inch thick expanded polystyrene over girts and purlins.

2.8 FABRICATION

- A. Fabricate according to manufacturer's standard practice
- B. Fabricate structural members made of welded plate sections by jointing the flanges and webs by continuous automatic submerged arc welding process. Prepare members for bolted field connection by making punched, drilled, or reamed holes in the shop. Mark all fabricated parts, either individually or by lot or group, using an identification marking corresponding to the marking shown on the shop drawings, using a method that remains visible after shop painting.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine the areas and conditions under which work of this Section will be performed. Correct conditions detrimental to timely and proper completion of the Work. Do not proceed until unsatisfactory conditions have been corrected. Verify foundations are properly installed, to correct dimensions and within acceptable tolerances.

3.2 ERECTION OF FRAME

- A. Provide for erection and wind loads. Provide temporary bracing to maintain structure plumb and in alignment until completion of erection and installation of permanent bracing. Locate braced bays as required by manufacturer.
- B. Do not erect frames without complete installation of tie beams and anchorages.
- C. Set column base plates with non-shrink grout to full plate bearing.
- D. Do not field cut or alter structural members without written approval.
- E. After erection, prime bolts, welds, abrasions, and surfaces not primed with primer used in shop painting.

3.3 INSTALLATION OF WALL OF SYSTEM

- A. Install in compliance with manufacturer's instructions.

- B. Exercise care when cutting prefinished material to ensure cuttings do not remain on finish surface.
- C. Fasten cladding system to structural supports, aligned level and plumb.
- D. Locate end laps over supports. End lap panels according to manufacturer's recommendations. Place side laps over adjacent panel and mechanically seam or stitch fastener per erection guidelines.
- E. Use concealed fasteners.
- F. Install sealant and gaskets to prevent weather penetration.
- G. Install system free of rattles, noise due to thermal movement, and wind whistles.
- H. Install door frames, service doors, overhead doors and gutter system in compliance with manufacturer's instructions.
- I. Seal wall watertight and weathertight with sealant in compliance with building manufacturer's standard procedures.

3.4 TOLERANCES

- A. Framing members: 1/4 inch (6 mm) from level; 1/8 inch (3 mm) from plumb
- B. Racking: 1/8 inch (3 mm) from true position. Provide shoring to maintain position prior to cladding installation

3.5 FIELD QUALITY CONTROL

- A. Roof installation inspection by roof manufacturer's representative; as required as part of warranty provision.
- B. Testing by Owner: High Strength Bolted Connections: Specification for structural joints using ASTM A325 or A490 bolts, a minimum of 10% of all bolted connections and at least one bolt per connection shall be tested for proper torque in the bolts.
- C. Testing by Owner: Visual inspection of 100 percent of fillet welds and at least 20% of all fillet welds shall be tested with magnetic particles. Ultrasonic inspection of 100 percent of full penetration welds. 50 percent of partial penetration welds shall be tested with magnetic particles. Where inspection reveals defects, the extent of inspection.

3.6 CLEANING

- A. Upon completion of the work of this Section, make a thorough inspection of the installation and verify that all elements have been installed in accordance with the provisions of this Section. Make necessary adjustments.
- B. Clean surfaces as required for proper application of the specified finishes.

END OF SECTION

SECTION 13340

MODULAR STRUCTURE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work included: This section specifies the following items.
 - 1. New single story modular office (trailer) permanently installed on an engineered raised foundation.
- B. Related work:
 - 1. Section 03300 CAST IN PLACE CONCRETE for the modular structure's concrete foundation

1.2 SUBMITTALS

- A. Product data: For each type of product indicated, including but not limited:
 - 1. Kitchenette appliances, countertop and cabinet information
 - 2. Furniture by type as indicated in the drawings.
 - 3. Door and window types, including hardware
 - 4. Toilet accessories.
 - 5. System items such as thermostat, light fixtures, toilet fixtures and accessories, occupancy sensors, exit signs.
- B. Shop drawings for the following:
 - 1. Trailer layout including architectural, structural, mechanical, plumbing, fire sprinkler, fire alarm, telecommunications, audio-visual and electrical systems information.
 - 2. Exterior wall, roof and partition details
 - 3. Restroom enlarged plans including locations of toilet accessories
 - 4. Energy code compliance calculations.
- C. Samples for verification: For each type and color of the following:
 - 1. Flooring materials
 - 2. Paint color
 - 3. Casework standard finishes and stains
- D. Manufacturer's instructions: Submit manufacturer written installation instructions.
- E. Manufacturer's qualifications: Submit manufacturer documentation, including list of at least three (3) similar buildings in New England that are still in use 25 years after their initial occupancy.

1.3 QUALITY ASSURANCE

- A. Massachusetts State Building Code and by reference applicable sections of accessibility, commercial energy and fire codes.
- B. Modular Building Institute guidelines for permanent modular construction

1.4 DELIVERY, STORAGE, AND HANDLING

- A. The DB Entity shall deliver an unfurnished trailer and shall be responsible to full build-out trailer to meet specifications
- B. Provide and maintain temporary utilities for construction operations and related necessary temporary structures and remove them when they are no longer needed
- C. Pay for connections/disconnection of all temporary utilities; e.g., gas, water, power and telephone.
- D. Be responsible for ensuring that the area (fencing, buildings, grounds, etc.) around the delivered and installed trailer is returned to the state that it was in prior to the delivery and installation of the trailer
- E. Provide and maintain the following as may be required for delivery and installation of the trailer:
 - 1. All scaffolding, staging, runways and similar equipment to complete work
 - 2. Temporary rigging, rubbish chutes, ladders and similar equipment
 - 3. Barricades, lights, and similar safety precautions.

1.5 WARRANTY

- A. The DB Entity shall guarantee in writing to repair or replace any or all work, together with any other work which may be displaced, damaged or marred in so doing, that may prove defective or fail to conform to contract provisions and requirements due to defective materials and workmanship within two (2) years of the date of acceptance of the work by the MBTA. This shall be done without further expense whatsoever to the MBTA. Ordinary wear and tear and unusual abuse or neglect is accepted.

PART 2 - PRODUCTS

2.1 MODULAR TRAILER

- A. Provide one (1) new modular trailer, fully equipped and ready for occupancy.
 - 1. Occupancy: B
 - 2. Type of construction: Refer to drawings
 - 3. Wind load: 150 MPH, exposure "C"
 - 4. Roof live load: As required by code.
 - 5. Floor live load: As required by code

- B. Trailer shall be 24'-0" x 60'-0" and shall include the following provisions unless otherwise noted:
1. Moment-resisting steel frame with bolted connections or other MBTA accepted methods of construction.
 2. Exterior walls made of steel stud walls, exterior aluminum siding and interior heavy duty composite laminate surface.
 3. Interior partitions for offices, toilet area, and conference rooms, etc.
 4. Base and overhead cabinets
 5. Operable insulated windows with insect screens.
 6. Shades or venetian blinds for windows.
 7. Air conditioning and electric heating equipment capable of maintain a temperature of 70 deg.F
 8. Two-tube florescent lighting fixtures as required to provide illumination of 70-foot candles in all work areas, controlled by surface mounted toggle switches located near the entrance of each room of the trailer.
 9. Double convenience receptacles located throughout the trailer
 10. Sanitary facilities including supplying toilet tissue, paper towels and soap.
 11. Ten (10) upright full height lockers.
- C. Arrange for and comply with all necessary local permits and inspections including and incidental costs.
- D. Arrange for electrical service for the trailer and provide the necessary meter connections, fuse box and switch as required by the utility company.
- E. Modular trailer shall be installed on firm bearing ground, engineered concrete foundation and shall be "blocked-up", "leveled off", 36" off the ground with a ventilated crawlspace, enclosed around the perimeter with site installed skirting material that will match the exterior siding material of the building.
- F. Provide approved pressure treated wood steps and ramp with aluminum handrails at the entrances to the trailer.
- G. All electrical and plumbing work shall conform with state and local codes
- H. Provide 3/4" copper tubing for the water service, provided with sufficient pressure to completely expel the contents of the water closet in one operation. Provide approved electrical heating tape, as directed, together with necessary switches and thermostat for each water pipe, to prevent freezing.
- I. Provide suitable septic tank and make proper sanitary connections thereto from the trailer.
- J. Provide fire systems (smoke detectors, pull stations).
- K. Insulate all services where necessary.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine conditions, with DB Entity present, for compliance with requirements for installation tolerances and other conditions affecting performance of work.

1. For the record, prepare written report, endorsed by DB Entity, listing conditions detrimental to performance of work.
 2. Verify that foundations are within tolerances specified.
- B. Before installation, examine rough-in and built-in construction for piping systems to verify actual locations of piping connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected

END OF SECTION

SECTION 14210

ELECTRIC TRACTION ELEVATORS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work included: This Section specifies electric traction elevators.
 - 1. Furnish lintels, sleeves, anchors, inserts, plates and similar items for elevators to concrete trade for installation.

- B. Related Work:
 - 1. Volume 2 Technical Provisions Exhibit 2I, Additional Project Requirements.
 - 2. Section 03300 – CAST-IN-PLACE CONCRETE
 - 3. Section 09900 – PAINTING
 - 4. Section 10424 – SPECIALTY SIGNAGE
 - 5. Section 10426 – TACTILE/BRAILLE SIGNAGE
 - 6. Section 16750 – ELEVATOR EMERGENCY INTERCOM SYSTEM
 - 7. Division 15 – PLUMBING, HEATING, VENTILATION AND AIR CONDITIONING
 - 8. Division 16 – ELECTRICAL

1.2 DEFINITIONS

- A. Authority having jurisdiction (AHJ): Local jurisdiction agency and/or department responsible for issuing certificates for use, testing and inspections.

- B. Beneficial use: When the elevator is placed into service, may be prior to the site being ready for public use.

- C. Burn in testing: Continuous automatic cycling of the elevators for four (4) contiguous days under fully loaded conditions. Burn in shall occur immediately following the elevator certification and prior to beneficial use, and shall be performed under normal power for three (3) days and on backup power for twenty-four (24) hours during non-revenue hours or during station shut downs. The DB Entity shall submit a continuous report for the burn in event, which shall be generated from the elevator controller program.

- D. Code: Codes, standards, publications and other references listed in Article 1.4 of this Section.

- E. Complete set: Shop drawings shall be submitted as a complete set which includes, but is not limited to, all items in Article 1.10, submittals and all other reference to submittal requirements within this specification.

- F. DB Entity: The DB Entity for the project/contract. The DB Entity is responsible for all coordination between the various trades and associated specification Sections for the elevator installation and

operation. The DB Entity is also responsible for all subcontractors to perform the work, testing and inspections as specified within this Section.

- G. Defective elevator work: Operation or control system failure, including excessive malfunctions, performances below specified ratings, excessive wear, unusual deterioration or aging of materials or finishes, unsafe conditions, the need for excessive maintenance, abnormal noise or vibration, and similar unusual, unexpected and unsatisfactory conditions.
- H. Dwell time: The period of time the elevator is at a landing while the doors open, passengers transfer and doors close.
- I. Device or a part of the equipment: References to a device or a part of the equipment applies to the number of devices or parts required to complete the installation.
- J. Elevator: A hoisting and lowering mechanism equipped with a car or platform, which moves in guide rails or racks and serves two or more landings.
- K. Elevator manufacturer/installer: The party selected under this Contract to furnish and install the elevators as a subcontractor to the DB Entity. The phrase elevator manufacturer and/or installer implies that the manufacturer is also the installer or the installer is approved by the elevator manufacturer for the installation of the elevators as specified within this Section.
- L. Elevator nomenclature: ASME/ANSI A17.1, Safety Code for Elevators and Escalators.
- M. Final acceptance: The point at which the Authority accepts the elevator project as being complete, including all submittal requirements. This may be a different point in time than substantial completion.
- N. Gearless elevator: A traction machine, without intermediate gearing, that has the traction sheave and the brake drum mounted directly on the motor shaft.
- O. Heavy-duty elevator: An elevator designed specifically for the harsh environment and duty load cycles common to transportation system usage.
- P. Installer: The responsible party who installs the elevator. The installer shall be either the elevator manufacturer or an approved licensee of the manufacturer, who has not less than five (5) years successful experience with the installation of elevators, and who is currently under contract for the maintenance of elevators in the area, and who maintains a service center within 50 miles of the project site. The elevator installer shall be licensed and strictly governed by applicable local and governmental authorities in order to perform the work.
- Q. Interim maintenance: Maintenance from the point of substantial completion, but prior to revenue service.
- R. Letter of certification: Submitted letter shall be notarized with requested compliance and signed by an officer of the manufacturer and/or Installer as specified.
- S. MSDS: Material Safety Data Sheets, as defined by Occupational Safety and Health Administration (OSHA).
- T. Notice to Proceed (NTP): The date which the elevator installer is notified to proceed with the work.
- U. OEM: Original Equipment Manufacturer.

- V. Authority: The Massachusetts Bay Transportation Authority (MBTA).
- W. Passenger elevator: An elevator used primarily to carry persons other than the operator and persons necessary for loading and unloading.
- X. Project representative: Representatives from the MBTA. Various submittals within this section require review, decisions and information from these representatives that provide resultant review status for the required submittals listed in this Section.
- Y. Revenue service: The station or facility opening date.
- Z. Substantial completion: The point at which the elevator is ready for use, whether the site is finished or not. Jurisdictional inspection usually occurs at this time.
- AA. System: Includes all elevator components, equipment and incidentals specified within this Section, unless otherwise used in context with a referenced system. The system is also inclusive of elevator components not specified in this Section but provided with the manufacturer's elevator operating system.

1.3 APPLICABLE CODES, STANDARDS, ORGANIZATIONS AND PUBLICATIONS

- A. The latest edition of codes, standards and publications shall be used for all criteria listed within this Section. In case of conflict between codes, regulation or standards, the most stringent requirement shall take precedence. In all cases, code shall be the governing factor. Elevator designs and installations shall be of the heavy-duty type and shall comply with the following:
- B. American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI):
 - 1. ASME/ANSI A17.1 2004 "Safety Code for Elevators and Escalators" and A17.1S-2005 with Addenda (hereafter referred to as the code)
 - 2. ASME/ANSI A17.2 2004 "Inspectors Manual for Elevators and Escalators"
 - 3. ASME/ANSI A17.5-M 1991/CAN/CSA-B44.1 "Standard for Elevator and Escalator Electrical Equipment"
 - 4. ANSI Z97.1 "American National Standard for Safety Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test"
- C. National Fire Protection Association (NFPA):
 - 1. NFPA No. 130 "Fixed Guideway Transit and Passenger Rail Systems"
 - 2. NFPA No. 13, 70 and 72
- D. National Electric Code (NEC)
- E. Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG), 2004
- F. American Public Transit Association (APTA) machine room-less (MRL) elevator design guidelines
- G. IEEE 519 Standard Practices and Requirements for Harmonic Control in Electric Power Systems

- H. American Welding Society (AWS)
- I. American Society of Testing and Materials (ASTM)
- J. International Standards Organization, ISO 281/I, 1997 and later editions
- K. American Federation of Bearing Manufacturers Association (AFBMA), Standards 9 and 11
- L. National Electrical Manufacturers Association (NEMA)
- M. The American Insurance Association
- N. Occupational Safety and Health Act (OSHA)
- O. International Code Council / American National Standards Institute (ICC/ANSI), A117.1 2004
- P. Building Officials and Code Administrators International, Inc. (BOCA)
- Q. Massachusetts Architectural Access Board (MAAB), 521 CMR 28.00
- R. Massachusetts State Building Code, 780 CMR
- S. Massachusetts Elevator Regulations, 524 CMR
- T. MBTA Elevator Design Standard (including Appendix B and C for car operating panels, hall stations and lanterns)
- U. Boston Center for Independent Living Agreement (BCIL)
- V. Any additional requirements imposed by local agencies shall be incorporated into elevator installations.

1.4 COORDINATION REQUIREMENTS

- A. Coordination requirements shall include, but not be limited to, the following:
 1. Alterations: DB Entity shall coordinate any alterations required to accommodate elevators with the MBTA.
 2. Cab floor finish: Coordinate floor/finish at the elevator doorsill finish elevation with the required pocket for sill installation and with other appropriate subcontractors and/or trades.
 3. Door rough openings: The elevator manufacturer/installer shall coordinate with the DB Entity for the elevator's required 8" extended door jamb opening until the rails and doorframe are installed.
 4. Electrical: DB Entity shall coordinate all trades regarding the installation of CCTV, communications, smoke detectors, power and cab lighting requirements.
 5. Field measurements: DB Entity and elevator manufacturer/installer shall verify field measurements immediately after each opening is prepared for the elevator installation as indicated on the accepted elevator shop drawings and the Contract Drawings.
 6. Pit drainage: Provide a means to prevent water from accumulating in the pit for outdoor elevators and indoor elevators subject to ground water or station wash downs.
 7. Rigging plan: Installer shall supply a detailed rigging plan that is accepted by the MBTA. Rigging plans shall include, but not be limited to, path of entry/egress, imposed loading on floor surfaces

- and structures, product data of devices to be utilized in the rigging process with reference dimensions and lifting capacities. Rigging plans shall be signed and sealed by a professional engineer registered in the Commonwealth of Massachusetts.
8. Safety training: Installer shall attend appropriate safety training programs provided by the MBTA at no extra cost.
 9. As-Built Drawings: DB Entity shall provide revised shop drawings to reflect actual as-built condition including all structural, architectural, electrical, mechanical and plumbing conditions for the elevators. Submit no later than 3 weeks after the elevators receive a certificate of operation for public use.
 10. Lock cylinders:
 - a. All locks and keys shall be as per MBTA's current standard lock requirements.
 - b. DB Entity shall verify with the MBTA that the requirements for hardware have not been amended or superseded.
 - c. DB Entity shall provide the MBTA with length, finish and camming requirements of each cylinder required.
 11. Methodology: The DB Entity shall meet with the MBTA and provide a written method of installation for approval.
 12. Protection: During installations, and until elevator systems are fully operative, DB Entity shall make necessary provisions to protect systems from damage, deterioration and environmental conditions.

1.5 QUALITY ASSURANCE

- A. OEM's Qualifications: Regularly engaged for the past ten (10) years in the manufacture of major components for machine room-less (MRL) passenger elevators. As a standard of quality the elevator equipment, design and installation shall comply with the code.
- B. Installer's Qualifications: OEM's representative or authorized agent of elevator equipment OEM with minimum ten (10) years experience who is trained and approved for installation of units required for this project.
- C. Source limitations: Obtain elevators through one source from a single manufacturing plant. Buy American provisions are stipulated in the general terms and conditions of this contract.
- D. Welding: Welding shall be performed in accordance with the requirements of AWS. Welders shall produce evidence of current certification by AWS or CWB.
- E. Labeling requirements: Every elevator shall be clearly marked with rated load and speed, manufacturer serial number, and the designated MBTA's identification (EV-1, EV-2, ETC.).
- F. Application, permits, tests and inspections by regulatory agencies:
 1. Elevator manufacturer and/or installer shall obtain and pay for all permits, licenses, fees and testing inspections, and perform such tests with all required equipment and material and/or retests as may be required for acceptance and approval of each elevator by the authority having jurisdiction. The elevator manufacturer and/or installer shall complete all retesting due to improper coordination, preparation or failure of previous tests at no additional cost to the MBTA.

2. Elevator manufacturer and/or installer shall notify the MBTA and proper inspectors a minimum of four (4) Business Days in advance of the scheduled inspection to witness required testing. Supply the required personnel, equipment and materials for tests, inspections and final reviews at no additional cost to the MBTA.

1.6 DESIGN CRITERIA

- A. General: Elevators shall be designed with provisions for thermal expansion and contraction of complete elevator assemblies.
- B. Manufacturer/Installer of elevator systems shall provide system that works with the design as drawn and with performance requirements specified. Provide custom solutions where standard system does not meet requirements of DB Entity's accepted shop drawings. No added cost will be paid by the MBTA for customization required to fit within existing design.
- C. Operational Requirements:
 1. Hours of operation shall be considered as 24 hours per day, 7 days per week.
 2. Elevator components shall be designed based on the following applied duty cycle during operation:
 - a. 3 hours with 100% rated load
 - b. 6 hours with 50% rated load
 - c. 15 hours with 25% rated load
 3. Maximum dwell time per landing in these calculations shall be no more than 10 seconds.

1.7 ENVIRONMENTAL REQUIREMENTS

- A. Elevators shall be designed and constructed to operate while exposed to the natural elements of weather, including sunlight, rain, slush, snow and ice; all conditions of relative humidity while exposed to salt, de-icing chemicals, airborne dust, debris and corrosive elements; and in a dry bulb temperature range of -10 to +125 degrees Fahrenheit.
- B. Sound level: Elevators shall be designed and constructed to operate at or below a 65 decibels sound level, measured 3 feet above the elevator cab floor at any location, with the elevator operating normally, either free running or under load. For multiple elevator installations, the noise measurements shall be made with only one elevator unit in operation, but with the entire installation complete and in operating condition. An ambient level not to exceed 49 decibels shall be maintained prior to units being operated.
- C. Seismic Zone Requirements: The elevator shall be designed and constructed to comply with seismic zone 2 requirements of ASME A17.1 2004 and A17.1S 2005 regardless of edition of ASME A17.1 approved for this project. The sole exception to this requirement is where the structure has been designed for a more stringent seismic requirement.
- D. Bearings: All fixed machine and motor bearing housings shall be provided with a drilled, tapped and spot faced area in the vertical and axial axis to accommodate a transducer that a Fast Fourier Transform (FFT) analyzer requires. Permanently mount transducers on the drive bearings or where recommended

by the machine OEM and run the wires into the controller to a panel with BNC connectors on the ends to accommodate the FFT analyzer.

1. Motor limit: Rigid mount, 15 ips; flex mount, .2 ips.
2. Bearings shall be rated for an AFBMA L10 life as specified, under a fluctuating bearing load. All bearings shall have basic dynamic load ratings.

E. Fasteners:

1. Fasteners shall be compatible with materials being fastened.
2. Fasteners shall be furnished with self locking nuts or retaining rings (spring washers or toothed discs).
3. Fasteners shall be equal to, or of greater corrosion resistance than, the most corrosion resistant metals being fastened.
4. Dissimilar metals to be galvanically separated. Separating substrate shall not be visible in finished condition including through glass.

F. Ride quality:

1. All elevators shall have a maximum decibel reading of 70 decibels with the doors closed during a run in the up direction, measured 5 feet above the floor in the center of the cab.
2. All elevators shall have a maximum vibration of 30 milli-g's in the X, Y and Z axis measured with an A95 filter.

1.8 SUBMITTALS

- A. Submittals and shop drawings shall be furnished no later than 16 weeks after the DB Entity has been provided the Notice to Proceed unless otherwise directed by the MBTA.
- B. Submittals and shop drawings shall be furnished as a "complete set" for each item as required for submittal within this Section. Six (6) sets of each submittal shall be provided unless additional sets are specifically required elsewhere in the Mandatory Specifications. Incomplete sets are not acceptable.
- C. The DB Entity shall submit a letter from the elevator manufacturer indicating that the installer is approved and authorized by the manufacturer for the installation of the elevators as specified. The letter shall be signed by an officer of the manufacturer. If the manufacturer intends to install the elevators, it shall be submitted in letter form and signed by an officer of the manufacturer.
- D. Submit chart with proposed dates for the delivery and installation for each elevator. The chart shall provide the following after shop drawings have been accepted (assume a three (3) week review period by the MBTA):
 1. Weeks for fabrication time and expected delivery to site.
 2. Weeks for installation time based on consecutive installation of elevators and specify whether elevator installation shall be consecutive or simultaneous.
 3. Weeks for any other critical items.
 4. Weeks for inspection and testing and/or retesting.

- E. Product Data: Submit OEM's product data for all products and systems proposed for use. Product data shall include, but not be limited to, the following:
1. Manufacturer's catalog cuts: Fixtures, 2-Speed exhaust fan, door operator, full door height electric eye, lighting fixtures, controller, CCTV camera, sill heater, car top control station, remote intercom system for communication between remote machine rooms and the top of car, door weather stripping and interior car wall panels.
 2. Electrical characteristics and connection requirements.
 3. Expected heat dissipation of elevator equipment in machine room and control areas (BTUs/hr.) based on 60 round trip cycles per hour.
 4. Maintenance programs: Within 60 days after notice to proceed, and prior to installation, submit detailed interim and revenue service maintenance programs, showing functions to be performed and their scheduled frequency.
 5. Machine performance data sheets.
 6. Pre-acceptance test forms.
 7. All proprietary equipment shall be clearly identified in the Manufacturer's literature and manuals.
- F. Shop drawings: Provide large scale shop drawings (minimum of 3/4" = 1'-0" unless otherwise noted) for fabrication, installation and erection of all parts of the work. Provide plans for each equipment room, hoistway, and car in addition to elevations, details of anchorages, connections and accessory items. Drawings shall include, but not be limited to, the following:
1. Car guide rails, buffers and other components in the hoistway.
 2. Maximum rail bracket spacing. Rail brackets shall be located based on actual hoistway construction as shown in the DB Entity's accepted shop drawings.
 3. Maximum loads imposed on guide rails requiring load transfer to the building structure.
 4. Loads on hoisting beams.
 5. Clearances and travel of car and counterweight runby.
 6. Clear inside hoistway and pit dimensions. Location of pit and hoistway to project grids.
 7. Location and sizes of access doors, hoistway entrances and frames.
 8. Car and hall signal and operating features, including dimensioned drawings of the car control panel, position and floor indicator landing control stations, firefighter's keyed switch, access key switch, combination position indicator and hall lantern, supervisory panel, power operation intercom and other related information.
 9. Remote wiring layouts for each elevator.
 10. Refuge space on top of car and pit.
 11. Control room, machine area, pit and hoistway layout.
 12. Cab design, dimensions and layout, showing the arrangement of the elevator control panel, doors, direction indicator, intercom, and other related items. Provide reflected ceiling plan for the car locating the exhaust fan, emergency exit, lighting and other related information. Design information shall include:

- a. Details of car interior wall panels, including material type, panel sizes and thicknesses, installation and anchoring details.
 - b. Sections and details of car roof, including the relationship of the emergency exit and hatch with the exact location of the crosshead.
 - c. Detail of jack attachment to car.
13. Hoistway door and frame details.
14. Complete assembly details of machines, mountings, machine beam assemblies, dead end hitch and beam assemblies, governors, safeties, and counterweights. Provide all associated load calculations.
15. Attachment details of rails and counterweight assemblies.
- G. Samples: Submit samples of materials and products requiring color or finish selection, including but not limited to, the following:
- 1. Stainless steel: Samples shall be provided for landing control stations, door frames, doors, interior car panels, and handrails with wall connections. Samples shall be no less than 3” by 5” and shall be labeled on the unfinished side with the finish, gauge, location and elevator for which the material will be used.
 - 2. Liquid applied floor.
- H. Submit to the authority having jurisdiction elevator plans and documents according to their requirements. The DB Entity shall provide a copy of the letter of transmittal to the MBTA of all documents that were provided to the authority having jurisdiction by the elevator manufacturer/installer. When the elevator permit number is assigned for each elevator, the number shall be forwarded to the MBTA.
- I. Burn in report: Submit in accordance with Article 1.14, acceptance and Warranty. DB Entity shall submit a continuous report for the burn in event, which shall be generated from the elevator controller program.

1.9 OPERATING AND MAINTENANCE MANUALS

- A. Maintenance manuals: Prior to installation, submit four (4) complete sets of operation and maintenance manuals for acceptance. After MBTA’s acceptance and prior to beginning of acceptance testing, twelve (12) sets of the approved manuals shall be provided. Manuals shall include the following:
- 1. Complete table of contents.
 - 2. Complete instructions regarding operation and maintenance of the elevator equipment including controller safety devices and all associated equipment. Include complete illustrated, exploded views of all assemblies and a complete, illustrated exploded view for identifying all system parts.
 - 3. Complete nomenclature of replaceable parts, part numbers, current cost and warehouse location. If product source is another vendor, provide name and address of other vendor.
 - 4. Sample copies of a proposed preventive maintenance chart.
 - 5. Descriptions of safety devices.

6. Safety rules, tests and procedures, including testing of all systems and subsystems.
7. Procedures for adjusting all elevator components, including pictorials.
8. Troubleshooting techniques.
9. Detailed lubrication and cleaning schedule indicating weekly, monthly, quarterly, semiannual and annual lubrication. Include a description of each lubrication point, lubrication type and specification.
10. Control and schematic electrical wiring diagrams of controller, including wiring of safety devices to connections with remote indication and control panels for the elevator.
11. Electrical layout showing placement of lighting, light switches, receptacles, fixtures, disconnect switches and convenience outlets in control areas, machinery spaces and pits.
12. Complete detailed drawings and wiring diagram of elevator system.
13. The installer shall be required to provide certification, in writing and signed by an officer of the organization, that Authority shall be provided with copies of any and all information, correspondence, bulletins, newsletters, manuals, techniques, procedures, drawings, sketches and any other documents related to maintenance, safety, operations, design changes, modifications, retrofits, etc. which relate to any part, component, equipment, system subsystem or material and services applicable to the elevators provided.
 - a. All of the above referenced information shall be provided as it pertains to the original installation and for a period of ten (10) years after final acceptance of the elevators.
 - b. Referenced material shall be provided within 30 days of publication or internal distribution by the elevator manufacturer. The material, even if labeled "PROPRIETARY", shall be delivered to the MBTA without prejudice or delay and at no additional cost.
14. The entire manual shall also be provided in an electronic format that is acceptable to the MBTA.
15. MSDS and product data sheets shall be submitted with an index listing each product, along with application method of product, approximate quantity of product per elevator, and the component the product is applied to or associated with. Allow six (6) weeks for review of MSDS.
16. Maintenance procedure for galvanizing of glass hoistway.

1.10 TEMPORARY AND PERMANENT ELECTRICAL POWER SERVICES

- A. DB Entity shall provide and coordinate all temporary power which shall be available to the Installer at the time of installation. Permanent power shall be made available for testing. All power shall be provided at no cost to installer.
- B. Power for the elevator drive systems shall be 480 volts, 3 phase, 4 wire, 60 Hertz terminating in a disconnect switch within sight of the controller. The lift motor starting current shall not exceed 250% of the full load amperage.
- C. Power for lighting and GFCI receptacles shall be 120 volts, 3 phase, 4 wire, 60 Hertz terminating at the elevator controller location.
- D. Separate disconnect for cab lighting and wiring to cabs shall be 120 volts, 1 phase, 4 wire, 60 Hertz terminating in a disconnect switch within sight of the controller.

- E. Separate service for sill heaters and other ancillary elevator equipment shall be provided where required.

1.11 PRODUCT DELIVERY, STORAGE AND HANDLING

- A. The DB Entity shall coordinate delivery to the site, or other storage area acceptable to the MBTA, and provide adequate secured storage acceptable to the elevator Manufacturer, Installer and the MBTA for the new elevators. Stored elevators and related equipment shall be insured as required by the DB Entity's accepted shop drawings.
- B. Deliver components with factory-installed wooden skids and lifting lugs, and pack components in factory-fabricated protective containers.
- C. Store materials in original protective packaging in a dry area protected from weather.
- D. Protect equipment and exposed finishes during transportation, storage and erection against damage and stains.
- E. Handle components carefully to avoid damage to components, enclosures and finish.
- F. Comply with the OEM's rigging instructions for unloading components and moving components to their final location for installation.

1.12 SPARE PARTS AND STOCK

- A. Spare parts: Elevator Manufacturer/Installer shall provide the following listed spare parts upon the completion of the elevator installation:
 - 1. Four (4) hoistway door rollers.
 - 2. Two (2) cab door rollers.
 - 3. Four (4) hoistway door gibs.
 - 4. Four (4) cab door gibs.
 - 5. One (1) electronic door detector.
 - 6. One (1) set of replacement lights for the elevator cab.
 - 7. One (1) box of each type of fuses.
 - 8. Two (2) complete door interlock assemblies.
 - 9. One (1) door operator motor.
 - 10. Two (2) complete pushbutton assemblies for car operating station and hall stations.
- B. Spare parts shall be delivered to location as determined by the MBTA (within 30 mile radius of project site).

1.13 ACCEPTANCE AND WARRANTY

- A. DB Entity shall submit the burn in report prior to final acceptance. The burn in report will be reviewed against the manufacturer's recommended tolerances. Failure to meet the manufacturer's tolerances shall require immediate corrective actions and a repeat of the burn in report until acceptance.
- B. The OEM shall warrant in writing that all equipment manufactured and installed under this specification, for a period of twelve (12) months from the date of final acceptance by the MBTA, be free of defects in design, materials and workmanship, under normal use and service.
- C. The warranty shall include materials and labor necessary to correct defects. Defects shall include, but not be limited to: noisy, rough or substandard operation; loose, damaged or missing parts; and fluid leaks.
- D. Warranty maintenance requirements:
 - 1. Installer shall provide twelve (12) month preventative maintenance service to coincide with the warranty period.
 - 2. Installer shall provide an interim maintenance service prior to being added into the MBTA's maintenance program.
 - 3. Interim maintenance shall start at the final equipment acceptance and at the time of issuance of the Certificate for Operation by the Commonwealth of Massachusetts Elevator Inspector. Interim maintenance shall be provided for a period of twelve (12) months.
 - 4. Interim maintenance shall include the following tasks:
 - a. Inspection of completed installation and periodic testing to maintain elevator in completely operable condition.
 - b. Operate each elevator at least monthly for a period of two (2) hours (total on-site time). Provide monthly documentation of same to the MBTA.
 - c. Provide lubrication of parts and equipment components as per OEM's recommendation. Charts shall be provided for each elevator indicating when services are provided.
 - d. Perform work without removing elevator from service during peak traffic periods between the hours of 7 a.m. to 10 a.m. and 3 p.m. to 7 p.m.
 - e. Provide 24 hour emergency service during the maintenance period consisting of prompt response (with 2 hours) to emergency request by telephone or other communication from MBTA or designated representative if an elevator is inoperable or in case of injury, entrapment or potential injury to persons.
 - f. Unlimited regular time callbacks shall be included with a required response time of one hour. Regular time will be Monday through Friday, 8 a.m. to 4:30 p.m., exclusive of holidays.
 - g. Annual clean down of the elevator and hoistway enclosure is required. Make necessary arrangements with MBTA in order to minimize any inconvenience and reduction of service.
 - 5. Reporting: Detailed monthly records of tasks performed shall include names of individuals performing the tasks, date and time performed, and other pertinent data. Installer shall be required to conform to the requirements of the MBTA's data base maintenance system.

PART 2 - PRODUCTS

2.1 ELEVATORS - GENERAL

- A. Subject to compliance with the requirements of this section: Provide manufacturer's standard or custom elevator systems as required to meet all performance requirements specified.
1. Global Tardif – 23 Model
 2. Kone, Inc. – Monospace Model
 3. Shindler Elevator Corp. – 400A
 4. Minnesota Elevator Corp.
 5. Approved Equal

2.2 ELEVATOR SCHEDULE

- A. The travel dimension provided in this specification is furnished as a quick reference for operational criteria. Dimension is approximate as indicated by the +/- symbol, and actual dimension must be verified with the Contract Documents.
- B. ELEVATOR ELEV-1 and ELEV-2

Location:	Washington St. Station
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	17'-6 1/2" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 1 and 2
No. of Stops:	2
No. of Openings:	2 (front @ level 1; rear @ level 2)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Remote @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass and steel, concrete
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy

Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Level 1 (grade)
Maintenance Term:	One year

C. ELEVATOR ELEV-3 and ELEV-4

Location	Gilman Square Station (Concourse)
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	17'-6" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 1 and 2
No. of Stops:	2
No. of Openings:	2 (front @ level 1 and level 2)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass, steel, and CMU
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

D. ELEVATOR ELEV-1 and ELEV-2

Location	Lowell St. Station
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	22'-7 7/8" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 1 and 2
No. of Stops:	2
No. of Openings:	2 (Front @ level 1 and level 2)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass, steel, and CMU
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

E. ELEVATOR ELEV-1 and ELEV-2

Location	Union Square. Station
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	18'-6" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 1 and 2
No. of Stops:	2

No. of Openings:	2 (Front for Elev-2@ level 1 and level 2, Front for Elev-1@ level 1, Rear for Elev-1@ level2)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass, steel and concrete
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

F. ELEVATOR ELEV-1 and ELEV-2

Location	Ball Square Station (Headhouse)
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	12'-0" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 1 and 2
No. of Stops:	2
No. of Openings:	2 (Front @ level 1 and Rear at level 2)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H

Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass and steel
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

G. ELEVATOR ELEV-3 and ELEV-4

Location	Ball Square Station (Concourse)
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	17'-10 3/4" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 0 and 2
No. of Stops:	2
No. of Openings:	2 (Front and Rear for Elev-3 @ level 0 and 2, Front for Elev-4 @ Levels 0 and 2)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass and steel
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant

Car Direction Indicator:	features Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

H. ELEVATOR ELEV-1 and ELEV-2

Location	College Avenue Station
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	23'-3" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Levels 1, 2 and 3
No. of Stops:	3
No. of Openings:	2 for Elev 2, 2 for Elev 1, Elev 1 Level 2 Front.
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass and steel
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

I. ELEVATOR ELEV-2

Location	Lechmere Station (North Headhouse)
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	42'-7 1/2" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Level 1 and Level 3
No. of Stops:	2
No. of Openings:	2 (Front @ level 1, Rear @ Level 3)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ Basement
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass and steel
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

J. ELEVATOR ELEV-1

Location	Lechmere Station (North Headhouse)
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	27'-1 1/2" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Basement, Levels 1 and 3
No. of Stops:	3
No. of Openings:	2 (Front @ Basement and level 1, Rear @ Level 3)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway

Controller Location:	Adjacent @ Basement
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass, steel and concrete
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

K. ELEVATOR ELEV-3

Location	Lechmere Station (South Headhouse)
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	31'-11" +/-
Interior Car Size:	5'-0"W x 7'-2"D x 8'-0"H
Service Levels:	Basement, Levels 1 and 2
No. of Stops:	3
No. of Openings:	2 (Front @ levels 1 and 3)
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Adjacent @ Level 1
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed

Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Glass and steel
Cab Enclosure:	Stainless steel and glass, as specified
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons
Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level
Maintenance Term:	One year

L. ELEVATOR ELEV-1

Location	Transportation Building
Service:	Passenger
Capacity:	3000 lbs
Speed:	200 fpm
Travel:	Refer to the Drawings
Interior Car Size:	Refer to the Drawings
Service Levels:	Refer to the Drawings
No. of Stops:	3
No. of Openings:	3; front-back pass through as indicated
Operation:	Selective Collective
Machine Location:	Overhead within hoistway
Controller Location:	Refer to the Drawings
Machine Type:	AC gearless machine room-less
Motor:	20 HP
Power Supply:	480V, 3-Phase, 60 Hertz
Lighting/Signal Power Supply:	120V, 60 Hertz, 20A
Ancillary/Auxiliary Power Supply:	120V, 60 Hertz, 60A
Car/Hoistway Door Size:	3'-6"W x 7'-0"H
Car/Hoistway Door Type:	2-speed slide side opening
Car/Hoistway Door Operation:	Power high-speed, heavy-duty 3 fps minimum opening speed 5 fps minimum closing speed
Door Reversal Device:	Non-contact type
Hoistway Enclosure:	Stainless steel
Cab Enclosure:	Stainless steel
Cab Flooring:	Poured Epoxy
Car Operating Panel:	Type 316L stainless steel #4 finish
Car Position Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Car Direction Indicator:	Type 316L stainless steel #4 finish w/ vandal-resistant features
Hall Call Stations:	Single riser, type 316L stainless steel #4 finish w/ vandal-resistant buttons

Communication System:	Hands-free
Keyed Switch:	In hall call station to shut down elevator
Main Designated Floor:	Platform level

2.3 SPECIAL FEATURES

- A. Elevators shall be of size, arrangement and capacity as shown, and shall comply with design criteria specified in this Section and as shown on the Design Documents, and shall be in accordance with ANSI/ASME A17.1-2004 and A17.1S-2005 w/ Addenda Safety Code for Elevators, hereafter referred to as the Code.
- B. Provide all material and equipment necessary for the complete execution of all elevator work as specified in this Section and as shown on the DB Entity's accepted shop drawings.
- C. Provide hoistway guards for protecting hoistway during construction. Hoistway protection shall include high solid panels surrounding each hoistway opening at each floor.
- D. All electric equipment, conduit, fittings and wiring shall conform to the requirements of ANSI/NFPA 70 National Electric Code.
- E. Provide concrete inserts and other similar anchoring devices for installation of guide rails, machinery and other elevator components. Epoxy ceiling anchors and/or epoxy side wall anchors are not permitted.
- F. Clearance around equipment located in each elevator control room and machine area shall comply with applicable provisions of ANSI/NFPA No. 70 National Electric Code.
- G. Each elevator system shall be provided with a hands-free wireless maintenance communication system that provides for communication from within each elevator car enclosure, car top and control room.

2.4 MATERIALS

- A. Except where product conformance to specific standards is indicated on the DB Entity's accepted shop drawings and in ASME/ANSI A17.1, OEM's standard materials and equipment may be used in elevator construction, subject to acceptance by the DB Entity. Materials cited below are intended to establish the standard of quality for comparable materials used by the elevator manufacturer/installer.
- B. Structural shapes, plates, sheets and tubing: ASTM A36 Steel.
- C. Sheet steel: ANSI/ASTM A446, Grade B.
- D. Stainless steel: ASTM A167, Type 316L.
 - 1. Embossed texture to be rolled into exposed surface, locations as noted.
 - 2. Type 316L, #4 finish, locations as noted.
- E. Aluminum: ASTM B211 or ASTM B221, Alloy 6061, T6.
- F. Glazing panels: 9/16" minimum laminated safety glass conforming to the requirements of ANSI Z97.1 and 16CFR Part 1201.

- G. Flooring: Poured epoxy in accordance with Article 2.10, Cab Enclosures.

2.5 DOOR OPERATOR EQUIPMENT

- A. Provide GAL's MOVFRW-HSL door operator with encoder less VVVF drive, closed loop door operator designed to operate car and hoistway doors simultaneously at the speed specified. Door shall open automatically when car stops at landing to discharge passengers or to answer valid calls and close automatically after predetermined time interval has elapsed. Door shall be capable of smooth and quiet operation without slam or shock. Door operator shall have the following features:
1. 1/2 HP motor and heavy duty sprocket, chain, belt and sheaves.
 2. Closed loop regulated speed performance.
 3. Hand-held keypad programming.
 4. Adjustments can be stored in the keypad and downloaded to another operator.
 5. Adjustable door obstruction reversal.
 6. Optical cams with LED indicators.
 7. Test switches for open, close, nudging and speed zone set up.
 8. Universal inputs for open, close and nudging.
 9. Reversing switch to back up the door reversal device.
 10. Cab door interlock: Cab doors shall be equipped with approved interlocks of the cab unit system type tested as required by code.
 - a. Interlock shall prevent operation of the car away from a landing until doors are locked in the closed position. Interlock shall prevent doors from opening at any position within the hoistway and/or landing from the cab side unless car is at rest at that landing, or is in the leveling zone and stopping at that landing.
 - b. Cab door unlocking devices shall conform to the requirements of the code and shall be provided to permit authorized persons to gain access to hoistway when car is away from landing.
 - c. Provide an electric contact mounted on the car that will prevent the car from moving away from landing unless car doors are closed.
- B. Electronic entrance detector screen door protection: Provide TriTronics electronic door detector device, which projects an infrared curtain of light guarding the door opening. Arrange to reopen doors if one beam of the curtain is penetrated. Unit shall have transmitters and receivers spaced at a minimum distance to provide the maximum amount of protection within the height of the doorway. Systems which have the availability to turn off or on individual zones within the curtain will not be allowed.

2.6 HOISTWAY EQUIPMENT

- A. Guide rails:
1. Guides shall be steel T-section rails. Rail surfaces shall be machined smooth to insure proper operation of guides. Rail ends shall be accurately machined with tongue and matching groove

- centrally located on web. Non-wearing rail surfaces are to be painted at the completion of the elevator work in color selected by Architect.
2. Guides shall be joined and installed in accordance with Section 2.23 of the code.
 3. Guide rails shall not be in view from within the elevator cab.
- B. Car buffers: Spring type with blocking and support.
- C. Counterweight buffers: Spring type with blocking and support.
- D. Roller guides: Roller guides shall be mounted on top and bottom of car and counterweight frames to engage the guide rails.
- E. Suspension means: If steel core ropes are supplied, a means to provide constant lubrication shall be provided. An alarm indicator shall be provided when the oil reservoir is at 25% of capacity.
- F. Machine: AC gearless machine, with permanent magnet synchronous motor, direct current electro-mechanical disc brakes and integral traction drive sheave. Machine to be mounted to the car guide rail or support beam mounted at the top of the hoistway.
- G. Stop switch: An enclosed stop switch, mounted in the pit of each elevator in accordance with Rule 2.2.6 of the Code, shall prevent operation of elevator when switch is activated. Switch shall be of the type described in Rule 2.2.6 of the code.
- H. Emergency auxiliary stop switch: An enclosed stop switch, mounted in the overhead machine area and/or on the machine of each elevator in accordance with Rule 2.7 of the code, shall prevent operation of elevator when switch is activated. Switch shall be of the type described in Rule 2.7 of the code.
- I. Dead end hitch assemblies: Provide dead end hitch assemblies in accordance with OEM's loading requirements.
- J. Counterweight: Counterweight shall consist of a steel frame welded or bolted together and necessary steel weight sections. These weight sections shall be held securely in place within the frame. A minimum of 2 tie rods shall pass through the holes in the weight sections. Submit paint finish of counterweights for approval, color selection as determined by the DB Entity.
1. A required counterweight screen where no compensation is used.
 2. The bottom of the counterweight shall have a buffer striking plate and means to attach knock-off blocks during rope stretch.
 3. Idler sheave: Locate directly above the counterweight frame and integral with counterweight frame. The sheave material shall be accurately machined of semi-steel of hardness BHN 220-250 or as per manufacturer's requirements.
 4. Roller guides shall be mounted on top and bottom of the counterweight frames to engage the guide rails. Counterweight guides shall be of the roller type; each guide shall consist of a set of 3 large diameter polyurethane rollers equipped with sealed preloaded ball bearings. Each roller shall be supported by a pivoted rocker arm that shall automatically adjust itself to guide rail misalignment and prevent excessive lateral car movement.
- K. Governor: Friction type over-speed governor rated for the duty of the elevator specified and to operate the car safely. Finish of pit tension sheave shall be factory paint.

1. Locate the governor where the car or the counterweight in case of over travel cannot strike it, and where there is adequate space for full movement of governor parts.
 2. An electrical governor overspeed protective switch that, when operated, shall remove power from the driving machine motor and brake before or at the time of application of the safety.
 3. Seal and tag the governor with the running speed, tripping speed and date last tested as required by code.
- L. Tension sheave: Provide tension sheave in accordance with OEM's governor and car safety loading requirements.
- M. Terminal limits: Limit switches shall slowdown and stop the car at the terminals if the primary automatic stopping system fails.
- N. Life safety provisions: Life safety hooks and/or other life safety devices for fall protection shall be in accordance with OSHA standards and guidelines. Life safety hooks and/or other safety device locations shall be coordinated with other equipment and installed by the installer.

2.7 MACHINE COMPONENTS

- A. Motor:
1. Bearings shall be rated with an AFBMA L10 life of 65,000 hours.
 2. The motors shall be of the alternating current reversible asynchronous or synchronous type of a design adapted to the severe requirements of elevator service. Motor shall be capable of developing the torque required to meet or exceed an acceleration rate of 2 ft/sec squared for the elevator car.
 3. A means to protect the windings and bearings from airborne dust shall be provided.
 4. Insulation of all windings shall be impregnated and baked to prevent absorption of moisture and oil. The insulation resistance between motor frame and windings shall not be less than one megohm. The motor windings shall stand a dielectric test of twice the normal voltage plus 1000 RMS volts of 60 Hertz alternating current for one minute.
 5. Motor leads in the conduit box shall have the same insulation class as the windings. Motor lead wire shall be rated 125 C and shall be sized for 105 C at the motor nameplate amperes at 1.0 Power Factor per Electrical Apparatus Service Association (EASA) recommendations. Leads shall be numbered for clockwise rotation when facing opposite the shaft end.
 6. The motor shall be designed to stand the severe loads encountered in elevator service and the windings shall have a minimum insulation temperature rating 2 ratings higher than the actual temperature rise of the motor, with a minimum rating of NEMA class F.
 7. The motor shall be designed to ASME/ANSI A17.1 rated load requirements.
- B. Brake: The brake(s) shall be of the self-adjusting fail-safe (spring applied and electrically released) type provided with an external manual brake release and designed to meet the service factor demand of its intended use.
- C. Gearless machine:

1. Sheave: The sheave material shall be accurately machined of semi-steel of hardness BHN 220-250.
2. Antivibrational mounts: For machines that are support beam mounted, an antivibrational mounting pad shall be provided.

2.8 CONTROLLER COMPONENTS

- A. Motion control engineering controller that supports DF1 communication over Ethernet/TCP/IP shall be provided to accomplish the type of elevator operation as indicated herein. Controller shall govern starting, stopping and direction of travel of the elevator. The controller shall utilize solid state start control.
- B. Controller shall protect the motor against current overload, phase reversal and phase failure. A reverse phase relay shall be provided on the controller. Controller shall automatically open the power supply, and bring car to rest if any of the safety devices fail to operate or if the power fails.
- C. Selective collective operation: Shall be as defined by ASME/ANSI A17.1. Pressure upon one or more car buttons shall send the car to the designated landings in the order in which the landings are reached by the car, irrespective of the sequence in which the buttons are pressed, providing the hoistway door interlock and car door switch circuits are completed. During this operation, the car shall also answer calls from the landings which are in the prevailing direction of travel. Each landing call shall be canceled when answered.
 1. Pressure upon a hall button at a floor above the car location shall cause the car to start up and answer any up calls as they are reached by the car, irrespective of the sequence in which the buttons have been pressed. The car shall not stop at floors where only down buttons had been pressed. If no further car or up hall calls are registered, the car shall reverse its direction preference to respond to car calls or down hall calls.
 2. The car shall start down to answer calls below the car and shall not stop where only up calls are registered. When traveling up, the car shall reverse at the highest call and proceed to answer calls below it. When traveling down, the car shall reverse at the lowest call and answer calls above it.
 3. Should both an up and a down call be registered at an intermediate landing, only the call responding to the direction in which the car is traveling shall be canceled upon the stopping of the car at the landing.
- D. Controller shall be provided with starting switches of adequate size, together with all relays and switches to accomplish the type of elevator operation indicated herein. Switches that operate power circuits shall be designed to prevent sticking due to fusing. Overload relay shall be of the manual reset type of suitable size for the motor furnished.
- E. All controller components shall be neatly mounted and wired in a vented NEMA 4X stainless steel enclosure. All terminals and wires shall have identification markings. Steel enclosure shall be supplied with a 6" high base to prevent potential water infiltration.
- F. The elevators shall be connected to a separate battery-powered unit that senses loss of power. Two batteries shall be 12 volt minimum, sealed nickel cadmium or gel cell construction. When loss of power occurs, elevator shall descend to nearest landing and open doors automatically. After a predetermined time, the doors shall close and the elevator shall remain inoperative until power is restored. The door

open and alarm button shall operate under battery power. Reduced speed for evacuation on battery operation is permitted.

- G. The PLC shall communicate directly with the Lift-Net Monitoring System.
1. General: Provide an interactive system to monitor and manage the elevator equipment (“units”), hereinafter called the “system”. Data collection, data storage and real-time monitoring portion of the system shall be based on Microsoft Windows and be able to run on Windows 2000 Pro, XP Pro, or later operating systems. Provide the following features:
 - a. Network based, capable of interfacing with control systems via either serial data link or hardwired interface connections.
 - b. Operate on any TCP/IP based network system including but not limited to an Ethernet, Lift-Net, etc.
 - c. Expansion capability to add unlimited number of monitoring terminals on the network.
 - d. Monitoring terminals shall operate “peer to peer” or with a single client server. Failure of a single network device shall not affect the operation of the remainder of the system.
 - e. Complete backup of system data shall be accomplished at any single terminal/server location.
 - f. Display multiple banks, including multiple buildings, on a single monitoring terminal screen.
 2. Monitoring display: The system shall be capable of simultaneous monitoring of at least 500 units on a single monitoring station utilizing a graphical representation of a plan view of the facility. Each elevator shall be visible on the monitoring system display terminal without the need to scroll. Each individual unit, when operating “normally”, shall be displayed in green. In the event of a malfunction of any individual unit, the unit shall be displayed by a red blinking light on the monitoring system display. Units which are intentionally placed out of service shall be shown as yellow in the display mode. When malfunctioning units, or units intentionally placed out of service, are returned to normal operation, the graphical representation for that unit(s) shall automatically return to green. The user shall have the ability to display additional information, such as the cause of fault/alarm, for all units by selecting the unit with a “mouse click” from the plan view of the facility. All monitored units shall be visible from any monitoring terminal on the network. Entry into the network shall be multi-level password protected.
 3. System capabilities:
 - a. The system shall be capable of real time display of all monitored status points on all monitored equipment. Fault and event notification screens and audible alarms shall be immediately displayed on selected monitoring stations. Different fault and event tables shall be defined on a per-bank basis. The system shall collect and store all status, fault and event information for later reporting and analysis. The system shall provide statistical analysis of hall call response times, traffic patterns, fault conditions, service logs and security usage in graphical and tabular format.
 - b. The system shall maintain a record of every status point change occurring on the monitored equipment, and provide the ability to replay these events in a simulation at a later time in real time, slow speed, single step, reverse or fast forward. This information shall be

retained for a period of at least 26 weeks, and a mechanism shall be provided whereby this information may be archived.

- c. The system shall store traffic fault and statistical data for a period of at least 3 years. The system shall log error type, car number, floor position and major system status points whenever a fault or logged event occurs.
 - d. The system shall provide interactive control of certain features provided in the elevator control system. These features may be revised as the requirements of the building change. Some of these interactive controls may include, but are not limited to, security floor lockouts, entering car and hall calls, firefighters' service, lobby recall, VIP service, up/down peak service, etc.
 - e. In the case of a power failure the system shall be capable of connecting to emergency power back-up unit. The loss of power shall not affect any stored data. The system shall have the capability to detect the loss (disconnect) of any individual unit from the monitoring system by periodically polling all units to ensure that normal communications between the unit(s) and the terminals/server are maintained.
 - f. The system will automatically re-boot the program and continue to operate after a power loss or other system malfunction.
4. **Monitoring Equipment:** The monitoring equipment shall have the following minimum characteristics:
- a. **Monitoring Station Hardware:** Provide 2 monitoring stations with the following characteristics:
 - 1) Central processing unit: IBM compatible microcomputer, desktop or mini tower (multiple machine rooms or lobby displays).
 - 2) Type: Most current high-performance processor.
 - 3) Speed: Most current high-performance.
 - 4) Internal hard drive: Adequate storage for 3 years of data for entire system.
 - 5) Modem: Most current high-performance.
 - 6) Display monitor: 19"-20" LCD flat panel, color, capable of simultaneous display of all monitored units.
 - 7) Printer: current HP Color DeskJet Series
 - 8) Keyboard: MS Windows compatible.
 - 9) Mouse: MS Windows compatible.
 - 10) Power requirements: 90-230 volts AC, 50-60 Hz @ 8A.
 - b. **Monitoring Station Operating System Software:**
 - 1) MS Windows 2000 Pro, XP Pro, or later.
 - 2) MS Windows 2000 Server, or later.
5. **Network Requirements:**
- a. Maximum local network rated distance (2-20 gauge shielded TP): >10 miles
 - b. Maximum number of nodes (combined PC, inputs/outputs): 500

- c. Maximum I/O points per node (input or output): 2040
- d. Access time to status bit change (typical 6-car bank): <25ms
- e. Must be capable of operating on RS485, RS422, Ethernet, Token Ring, Arc-Net, Lift-Net, Fiber Optic and mixed WAN TCPIP Networks.

6. Monitoring Requirements:

- a. Elevator group status:
 - 1) Group operational mode.
 - 2) All units to be monitored on the same screen in a graphical format.
 - 3) In/out of service.
 - 4) Standby power.
 - 5) Supervisory failure.
 - 6) Location and direction of hall calls.
- b. Individual car status – expandable menus:
 - 1) Direction of travel.
 - 2) Independent service.
 - 3) Inspection service.
 - 4) Firefighters' service.
 - 5) Hospital Code Blue service.
 - 6) Position of elevator.
 - 7) Door status (open, opening, closing, closed)
 - 8) Door dwell time.
 - 9) Load by-pass.
 - 10) Standby power.
 - 11) Power on/off.
 - 12) Door detector.
 - 13) Safety circuit.
 - 14) Door zone.
 - 15) Stop switch.
 - 16) Alarm button.
 - 17) Registered car calls.
 - 18) Out of level.
 - 19) Machine room temperature exceeds 90 degrees.
 - 20) Stop counter (number of starts).
 - 21) Car speed.
 - 22) Door open time.

- 23) Door close time.
 - 24) Start to stop motion time.
 - 25) Emergency 2-way communication device.
 - c. Keyboard, mouse and time clock control capabilities:
 - 1) Floor lockouts (car or hall).
 - 2) Lobby recall.
 - 3) VIP service.
 - 4) Firefighters' service.
 - 5) Hospital Code Blue service.
 - 6) Up/Down peak.
 - d. Faults monitored with visual and audible alarm, triggered by combinations of any of the above status points:
 - 1) Safety circuit.
 - 2) Alarm bell.
 - 3) Stop switch.
 - 4) Emergency 2-way communication device.
 - 5) Door reversal device.
 - 6) At least 6 user selectable faults or events (i.e. water in pit, high machine room/cab temperature).
7. Reporting Requirements: System shall provide reports in color graphical format both on-screen and in printed form, with capability of conveniently switching from one report type to another and from one bank to another using minimal mouse clicks and key strokes. Reports shall be displayed after minimal waiting time. Data for all reports shall be continuously recorded and stored. Reports shall be displayed by simply selecting a date and time range, bank of equipment and report type. Date and time range selections shall carry forward from one report selection to the next. Reporting functions shall be sub-divided into the following categories:
- a. Traffic reports:
 - 1) *Number of hall calls* per floor (hall call distribution on a per floor basis).
 - 2) Number of hall calls per hour (24 hour time-line).
 - 3) Hall call waiting times per floor (hall call waiting time distribution on a per floor basis).
 - 4) Hall call waiting times per hour (24 hour time-line).
 - 5) Distributed hall call response graph (24 hour time-line).
 - 6) Detailed hall call response graph (% calls / x seconds).
 - 7) Longest waiting times including floor number, wait time, date, time and direction.
 - b. Fault reports:
 - 1) Ten most recent faults (most recent faults listed per bank).

- 2) Fault log (display the entire fault log for a given time period).
 - 3) Faults per car (fault distribution on a per car basis).
 - 4) Faults per floor (fault distribution on a per floor basis).
 - 5) Faults per day/week/month (fault distribution on a per unit or group basis).
- c. Car use statistics:
- 1) Car use by hour (24 hour time-line of car calls, car starts, door cycles, delayed car, load by-pass).
 - 2) Car use statistics (same as above, shown for an entire bank).
- d. Group service log:
- 1) Cars in service (24 hour time-line with text log of group availability of each car).
 - 2) Group functions (24 hour time-line with text log of actuation of group functions – up peak, down peak, fire service, emergency power, etc.).
8. Interface to third party building management systems: The elevator monitoring system shall be capable of interfacing and exchanging data with a variety of third party building management systems such as Siemens, Landis & Staefa, Johnson Controls, SCADA, and others. Information should be exchanged by Modbus protocol, open protocol or other suitable methods as required.
9. Interactive features: The control system shall be capable where desired of operating interactive control features provided in the elevator control system. These features may be revised as the requirements of the building change. Some of these interactive controls may include, but are not limited to: security floor lockouts, entering car and hall calls, firefighters’ return service, lobby recall, VIP service, up/down peak or Hospital Code Blue service. Local codes may affect the availability or operation of these features.
- a. Security access features: The monitoring system shall be capable of providing security enable/disable of all hall and car calls through on-screen menus at a minimum. The monitoring system shall also be capable of interfacing directly with card readers and security keypads in stand-alone mode, and indirectly through a serial interface with a third party security system. When in stand-alone mode, the monitoring system shall maintain a database of elevator users and security pass codes. When on secure mode the use of each elevator will be recorded in a file together with the time, authorized pass code and destination for each call.
- b. Elevator control features: Each elevator shall be capable of being controlled through the monitoring system. All control points shall be capable of 7 day / 24 hour time clock automatic operation or manual operation from the mouse and keyboard. The control points shall include, but not be limited to, the following (where allowed by local codes):
- 1) Lobby recall.
 - 2) Car call security lockout.
 - 3) Hall call security lockout.
 - 4) Firefighters’ service.
 - 5) Independent service.
 - 6) VIP service.

- 7) Hospital Code Blue service.
 - 8) Standby power to selected car.
 - c. Paging feature: The monitoring system shall be capable of paging a service technician or other personnel base on predefined parameters of elevator faults or conditions. The paging system shall provide the ability to page multiple numbers determined by the type of event triggering the notification and shall be able to page different numbers based on preset times of day (i.e. different shifts). The system shall be capable of sending text messages to full text pagers in addition to supporting standard DTMF pagers.
 - d. Remote access feature: The monitoring system shall be capable of allowing approved individuals under multi-level password control, to access all system features via the local area network, internet, or via modem over the public telephone network to review the performance of the equipment or to evaluate a fault condition. The remote access feature shall be integrated into the monitoring system and shall not use third party “remote control” software products.
 - e. Data transmission to central support location: The system shall be capable where desired of transmitting fault, car usage and other data to a remote service desk or other office location for further processing, technician dispatch or other purposes. The data may be transmitted via the local area network, internet, or via modem over the public telephone network.
- H. Dielectric matting: Dielectric rubber matting shall be supplied on floor in front of controller to prevent accidental shock.

2.9 HOISTWAY ENTRANCES

A. General:

- 1. Hoistway entrances shall be of the horizontal sliding type, with location and number of panels as indicated on the Design Documents.
- 2. All materials and finished surfaces exposed to public view shall be stainless steel with glass panels and finish as indicated on DB Entity’s accepted Shop Drawings and as specified herein. Glass panels shall be flush with door assembly.

B. Hoistway frames and doors:

- 1. Entrance frames shall be of welded and mitered construction for complete one-piece unit assembly. All frames shall be sound deadened and securely fastened to fixing angles mounted in the hoistway and shall be of Type 316L stainless steel with directional grain in the vertical direction. The landing sills shall be extruded stainless steel with a mill finish.
- 2. Entrance frames shall be provided with an extended sill floor plate the full width and depth of each entrance frame assembly. The extended sill floor plates shall be extruded stainless steel with a mill finish.
- 3. Hoistway doors are to be stainless steel with a Rimex #5 S-M finish and shall be reinforced and provided with keyways as required for operating mechanisms and door hangers. Provide glass panels flush with door, as indicated. Each door panel shall have Z-style/shaped stainless steel bottom guides that run in landing sill slots. Guides are to be replaceable without removing door panels.

4. Provide die cast jamb markings (2 per entrance) mounted at 5'-0" above finish floor.
 5. Hoistway door hangers and operator shall be as specified herein.
- C. Struts and closer support angles: For load bearing walls (masonry, concrete, etc.) submit for DB Entity's acceptance shop drawings of the method to be used to support hanger housing and door closers on the wall.
- D. Landing sills: Landing sills shall conform to Rule 2.11 of the Code and shall be extruded stainless steel with a mill finish supplied with grooves and trash slots for door guides and machine planed for minimum clearance. Mount sills on combination of concrete/grout and steel supports anchored to floor construction.
- E. Hanger supports and cover plates: Hanger supports shall be Type 316L 3/16" thick stainless steel bolted to strut angles and closer support angles. Hanger cover plates shall be of type 316L nominal 0.078" thick stainless steel, minimum and shall extend as indicated. Covers shall be made in sections for convenient access when servicing hangers. Hanger sections above door openings shall be removable from within the elevator car.
- F. Dust cover: Dust cover shall be Type 316L nominal 0.078" thick stainless steel with a #4 finish, reinforced as necessary to ensure a flat even surface throughout. Dust cover shall extend at least the full width of door opening on each side and be fastened to hanger housings. Dust cover shall extend above entrance opening as indicated.
- G. Interlocks and contacts:
1. The doors at each hoistway entrance shall be equipped with approved hoistway door interlocks of the hoistway unit system type tested as required by the code.
 2. Interlock shall prevent operation of the car away from a landing until doors are locked in the closed position. Interlock shall prevent doors from opening at any landing from the corridor side unless car is at rest at that landing, or is in the leveling zone and stopping at that landing.
 3. Hoistway door unlocking devices shall conform to the requirements of the Code and shall be provided to permit authorized persons to gain access to hoistway when car is away from landing. Stainless steel ferrules shall be supplied for all hoistway unlocking device keyholes to protect elevator hoistway doors.
 4. Provide an electric contact mounted on the car that will prevent the car from moving away from any landing unless car doors are closed.
- H. Sight guards: Shall be stainless steel to match hoistway entrance finish.
- I. Hoistway sill and extended sill floor plate heat trace/heaters: Provide heat trace/heaters at each hoistway entrance to prevent the accumulation of snow, ice and water. Heaters shall be manufactured by Electro Plastics Inc. (www.warmfloor.com) Model #VEP-30-70W-24V, or approved equal. Heaters shall be provided with the following:
1. Commercial grade PVC-coated polyester tarpaulin.
 2. Thermostatic control: Control shall be mounted next to adjacent wall closest to hoistway and in proximity to elevator controller.
 3. Moisture sensor.

4. Electrical box for direct wiring to 115VAC, 20 Amp separate circuit.

2.10 CAB ENCLOSURES

A. General:

1. Elevator car and car components shall meet the applicable requirements of the code. Car control station and position indicator shall be as specified herein.
2. Entire car assembly, including car frame and platform, shall be free from warps, buckles, squeaks and rattles. Joints shall be lightproof.

B. Car frame and platform:

1. Car frame and platform shall be welded galvanized steel units designed and fabricated in accordance with applicable requirements herein and Rule 2.14 of the code.
2. Protect car platform with fire retardant material. The platform shall be recessed as required to accept the specified floor finish.
3. Sub floor material shall be nominal 1/4" thick galvanized steel to prevent water infiltration between finished floor, cab and platform base.
4. Idler sheaves: Shall be located directly below the car platform and integral with platform frame. The sheave material shall be accurately machined of semi-steel of hardness BHN 220-250 or per OEM's requirements.

C. Elevator car guides: Car guides shall be of the roller type; each guide shall consist of a set of 3 large diameter polyurethane rollers equipped with sealed preloaded ball bearings. Each roller shall be supported by a pivoted rocker arm that shall automatically adjust itself to guide rail misalignment and prevent excessive lateral car movement.

D. Car enclosures:

1. Car top: Car top shall be stretcher leveled, cabinet grade, nominal 0.109" thick furniture sheet steel, reinforced to support 300 lbs. on any one square foot area. An emergency exit shall be installed in the car top in conformance with the code. Interior surface of car top shall be painted reflective white. Exterior surface of car top shall be painted black.
2. Supporting frame size and detail shall withstand design stresses and provide for attachment and support of cladding, housing, ceiling, glass panels and appurtenances. Paint all members after fabrication. Exterior of car glazing shall be accessible for cleaning.
3. Suspended Ceiling:
 - a. Construction: 3/4" nominal overall thickness. Ceiling shall be constructed by bending and forming individual ceiling sections which shall be bolted together. Additional ribbing material on non-exposed side is allowed to be added for reinforcement to panel sections and to compensate for heavy vandal-resistant type light fixtures. Material shall be nominal 0.109" thick stainless steel Type 316L. Finish shall be Rimex Pattern No. 5-SM or

approved equal. All edges shall be deburred and ground smooth. Ceiling shall provide for dedicated location for installation of a security camera.

- b. Lighting: Car lighting shall provide a minimum of 15 foot candles and shall be located as shown on the Design Documents. Car lighting shall be provided with emergency battery backup upon failure or interruption of normal or emergency power. Emergency lighting unit shall provide required lighting for a minimum of 4 hours. Battery charger shall be capable of restoring battery to full charge within 16 hours after resumption of normal power. Provide an external means for testing battery, lamps and alarm bell. Lighting shall be Benfield Electric Luminaire Model RVP 26 PLC (NYC Housing Authority Grade), total quantity of fixtures as indicated. Fixtures shall be supplied with stainless steel face plate and stainless steel backer box. Gasketing/weatherstripping shall be supplied on interior portion of hinged portion of flange to prevent water and dust accumulation when in the closed position. Outer mounting flange to be supplied with welded nuts for vandal-resistant spanner head screw mounting.
4. Interior walls: Interior walls shall be as shown on the DB Entity's accepted shop drawings and in accordance with the following:
 - a. Material shall be Type 316L stainless steel with rigidized textured surface. Finish shall be Rimex Pattern No. 5-SM or approved equal.
 - b. Glazing shall be in accordance with Article 2.4, Materials.
 5. Hinged front and rear returns with piano hinge, transom and entrance column shall be provided with Type 316L stainless steel. Exposed surfaces shall be finished with Rimex Pattern No. 5-SM or approved equal.
 6. Car doors: Car doors shall be supplied with glazed panels as shown on Contract Drawings. Glazed panels shall be flush with door frames. Doors shall be of the horizontal sliding type with operator, number of door panels as indicated. Exposed surfaces are to be finished with Rimex Pattern No. 5-SM or approved equal. Doors shall protect the full width and height of car entrance opening when in the fully closed position. Car door frame shall be integral with front wall of cab.
 7. Car floor and cove base shall be poured epoxy: basis of design: Dur-A-Quartz flooring system by Dura-A-Flex or approved equal. Color selection and samples shall be submitted to DB Entity for acceptance.

E. Car Door Equipment:

1. Door hangers: Door hangers shall be of the 2-point suspension sheave type equipped with grease-packed heavy duty precision ball bearings, eccentric up-thrust rollers and oilers/cleaners. Track shall be of formed cold rolled steel or cold drawn steel with rounded track surface to receive sheaves. Track shall be mounted on an eccentric stud to provide for adjustment.
2. Car/Hoistway door operator: Car and hoistway doors at each landing shall be opened and closed simultaneously, quietly and smoothly by a direct current electric operator.
3. Door protection: Electronic entrance detector screen: Provide TriTronics electronic door detector device, which projects an infrared curtain of light guarding the door opening. Arrange to reopen doors if one beam of the curtain is penetrated. Unit shall have transmitters and receivers spaced at a minimum distance to provide the maximum amount of protection within the height of the doorway. Systems which have the capability to turn off or on individual zones with the curtain will not be allowed.

F. Appurtenances:

1. Handrails: Tubular type 316L stainless steel with #4 satin finish. Tube steel to be 1-1/2" diameter minimum with rolled and tapered ends and supplied with stainless steel spacers. Provide as shown on Design Documents.
2. Bumper rails: Flat stock Type 316L stainless steel with #4 satin finish. Flat stock stainless steel shall be minimum 5" in height to prevent damage to cab walls. Bumper rails shall have rolled and tapered ends and be supplied with stainless steel spacers. Provide as shown on Design Documents.

G. Safety: A governor-actuated mechanical safety device mounted under the car platform and securely bolted to the car sling. The car safety shall be sized for the capacity and speed noted in Article 2.2, elevator schedule.

1. When tripped, the safety mechanism shall engage the rails with sufficient force to stop a fully loaded car with an average rate of retardation within the limits given by the ANSI/ASME A17.1 code for the given capacity.
2. Make provisions to release the car safety. In no event shall the safety be released by downward motion of the car. Raising the car to reset the safety shall be allowed.
3. Include an electrical safety plank switch that will interrupt the power to the hoisting machine when the safety is set. Resetting the plank switch shall be separate from resetting the safety jaws.
4. Install a car safety marking plate of corrosion resistant metal showing the data required by the code.

2.11 SIGNAL DEVICES AND FIXTURES

A. General: Provide signal fixtures and control devices for each elevator. Buttons and signals shall be tamper-resistant illuminated type that light up when activated and remain lit until call or other function has been fulfilled. All signal fixture and control device faceplates shall be of Type 316L, nominal 0.135" thick stainless steel with #4 finish, unless otherwise shown.

B. Car operating station:

1. Provide one main station in front and one auxiliary station at the rear return panel. Car operating panels shall conform to the latest edition of MBTA Elevator Design Standard, Appendix B.
2. Car operating stations shall contain Braille plates that spell out the landings served adjacent to each call button. Coordinate proper landing call outs based on maximum characters as indicated in Article 2.2, Elevator Schedule. Buttons for DOOR OPEN, DOOR CLOSE, ALARM and EMERGENCY PHONE call functions shall be supplied. Buttons shall be vandal-resistant and of the positive stop type. Buttons shall be Monitor Control Model #HPS1300 with rounded edges and 1-3/8" diameter, including rounded rim.
3. Station shall also have keyed switches for car light, ventilation fans, inspection and independent operation.
4. Station faceplate shall be Type 316L stainless steel with #4 finish.
5. Engrave the car operating panel with the following:

- a. No Smoking, minimum 1” high lettering.
 - b. In Case of Fire Do Not Use the Elevator, as per 524 CMR regulations.
 - c. Elevator Capacity: 3000 lbs., minimum 3/8” high lettering.
 - d. Firefighters Operating Instructions.
 - e. No Smoking Symbol.
6. Provide die cast raised markings for the car buttons and car controls in compliance with the “Handicapped Requirements” of ANSI/ASME A17.1. Die cast plates shall be flush with faceplate surface.
 7. Provide die cast raised markings for the elevator and station identification in compliance with the “Handicapped Requirements” of ANSI/ASME A17.1. Die cast plates shall be flush with faceplate surface.
 8. Emergency communication: “Hands-free” ADA compliant telephone/intercom, VPP Model T-1250E.
- C. Top of car operating device: Provide a top-of-car operating device in compliance with the requirements of Rule 2.26 of the code. The device shall have control switches for UP, DOWN, OPERATE/INSPECT and EMERGENCY STOP. The device shall also have an 110V AC outlet for an extension cord and be provided with a light and rigidized guardrail.
- D. Hall stations: Hall stations of the push-button, call-acknowledging, stainless steel, tamper-resistant type shall be recess mounted flush into the wall and/or returns at all elevator landings, as indicated on the Design Documents. Hall stations shall conform to the latest edition of MBTA Elevator Design Standard, Appendix C.
1. Buttons shall be vandal-resistant and of the positive stop type. Buttons shall be Monitor Control Model #HPS1300 with rounded edges and 1-3/8” diameter with red jewel.
 2. Highest landing shall have a single DOWN button. Lowest landing shall have a single UP button. Intermediate landings shall have UP and DOWN buttons with the UP button on top.
 3. All hall stations to be supplied with PUSH FOR HELP button.
 4. Phase 1 Fire Service illuminated fire hat shall be supplied.
 5. Provide die cast raised markings for the hall buttons in compliance with the “Handicapped Requirements” of ANSI/ASME A17.1. Die cast plates shall be flush with faceplate surface.
 6. Provide die cast raised markings for the elevator and station identification in compliance with the “Handicapped Requirements” of ANSI/ASME A17.1. Die cast plates shall be flush with faceplate surface.
 7. Engrave the hall station with the following:
 - a. In Case of Fire Do Not Use Elevator, in compliance with 524 CMR regulations.
 - b. Firefighters Operating Instructions.
 8. “Hands-free” ADA compliant telephone/intercom, VPP model T-1250E, per section 16750 Elevator Emergency Intercom System.
 9. Additional switches for hoistway access, Phase 1 firefighters operation and parking feature shall be supplied. Key switch requirements for Phase 1 firefighters services shall be in accordance

with national and local code requirements. Key switch requirements for hoistway access and Parking feature shall be per MBTA's current standard lock requirements and/or MBTA approval.

10. Faceplate finish shall be Type 316L stainless steel #4 finish.

E. Hall lanterns:

1. Tamper-resistant hall lanterns shall be equipped with illuminated UP and DOWN signal arrows, but provide single arrow where only one direction is possible. Provide units projecting from faceplate for ease of angular viewing. Match materials, finishes and mounting method with hall stations. Lanterns shall conform to the latest edition of MBTA Elevator Design Standard, Appendix C.
2. In conjunction with each hall lantern, provide an adjustable electronic chime signal to indicate that a car is arriving in response to a hall call and to indicate direction of car travel. Signal shall sound one for up direction of travel and twice for down direction.

F. Bell alarm system: Bell alarm system for each elevator shall be properly located within building and audible outside hoistway when activated by the EMERGENCY STOP switch or the ALARM call button on each car control station.

G. Firefighters service system: Shall be provided in compliance with national and local code requirements.

H. In cab CCTV system: Install a corner mount CCTV camera as specified in section 16725 - CLOSED CIRCUIT TV SYSTEMS.

2.12 WIRING AND ELECTRICAL INSTALLATION

A. Electrical installation shall be in accordance with Division 16.

B. Conduit and wiring:

1. Unless otherwise specified, all electrical conductors in the pits and hoistways, except traveling cable connections to the car, shall be provided in rigid zinc-coated steel conduit with steel outlet boxes, except that a small amount of flexible conduit may be used where conduit is not subject to moisture or embedded in concrete. Terminal boxes and other similar items shall be of approved construction, thoroughly reinforced, and in no case less than number 12 USSG. All electrical boxes exceeding 150 cubic inches shall be supported independently of the conduits. Rigid conduit shall conform to the specifications herein before specified. All raceway shall be threaded rigid steel conduit. Flexible heavy-duty service cord, type SO, may be used between fixed car wiring and switches on car doors for door reversal devices.
2. All conduit terminating in steel cabinets, junction boxes, wireways, switch boxes, outlet boxes and similar locations shall have approved insulation bushings. If the bushes are constructed completely of insulation material, a steel locknut shall be installed under the bushing. At ends of conduits not terminating in steel cabinets or boxes, the conductors shall be protected by terminal fittings having an insulated opening for the conductors. All conduits terminating in NEMA 4X boxes shall be backed up with flat rust-resistant steel plates to fit the entire area where the conduit penetrated the box.
3. Conduit fittings and connections using set screws or indentations as a means of attachment are not permitted.

4. Connect motors and other components subject to movement or vibration to the conduit systems with flexible conduit.
5. The DB Entity shall furnish all materials and completely wire all parts of the elevator electrical equipment, including electrical devices on hatch doors.
6. All solid state and electrical components located on top of the car enclosure or in the hoistway shall be installed within NEMA 4X enclosures.
7. The conduits shall be of such size that the wires or cables can be readily installed and replaced, if necessary. No conduit or raceway shall be less than 3/4" trade size, except that for small devices such as door switches, interlocks, etc., 1/2" conduit may be used. The total overall cross sectional area of the wires contained in any conduit shall not exceed 40% of the internal area of the conduit.
8. Conduits shall be neatly and systematically run. All exposed conduit and boxes shall be supported by approved substantial straps, hangers or clamps to the structural steel, reinforced concrete, masonry or other approved supports. Riser conduits in hoistway shall be supported at each floor level.
9. All interlock, hall button and limit switch branch wiring shall be enclosed in flexible steel conduit with covering of liquid tight Type "EF" with connectors having nylon insulated throat.
10. All screws used for terminal connections of all wiring (control room, machine area, hoistway and pit) shall be provided with "star washers" of proper size and type.

C. Conductors:

1. No joints or splices shall be permitted in wiring except at outlets. Tap connectors may be used in wireways provided they meet all UL requirements.
2. All wiring shall test free of short circuits or grounds. Insulation resistance between individual external conductors and between conductors and ground shall be not less than 1 megohm.
3. Provide all necessary conduit and wiring between all remote control rooms, machine areas and hoistway.

D. Traveling Electrical Cable:

1. Shall be Type EO, rated for a maximum of 300 volts, and shall comply with the requirements of UL Standard #62 and Articles 400 and 620 of ANSI/NFPA No. 70.
2. Travel cables shall include separate coaxial cable shielded for the communication system.
3. Provide 10% spares, but not less than 6 spare conductors in each traveling cable.
4. Provide 2 spare CCTV wires and 2 twisted shielded pair.
5. Provide separate traveling cables for car lighting and fan control circuits.
6. Provide traveling cable for telephone in the elevator car. Cable shall extend from junction box in hoistway to telephone box in car.
7. Provide traveling cable for car work lights.
8. All insulated wiring, control wiring and wiring in traveling cables shall be tag coded at their terminals in the motor room or controller location and hoistway junction box, elevator cab junction box, and push-button stations within the cab, and shall agree with the accepted wiring diagrams.
9. Provide spare cable for in-cab intercom system.

- E. Car and hall operating signal circuits shall not exceed 48 volts.
- F. All cabinets containing motor drives, filter boxes, transformers and power reactors shall be supported on rails and isolated from the base building structure with elastomer pads having a minimum static deflection of 3/8" (mason type N, or equivalent). All connections to and from the cabinetry shall be flexible in order not to compromise the isolation system. Use non-rigid conduit for the final electrical connection, with all other conduit supports and clamps provided on a neoprene sponge insert.

2.13 OPERATION

- A. General: Operation shall be selective collective as follows:
 - 1. Operation shall be automatic by means of the car and landing buttons. Stops registered by the momentary actuation of the car or landing buttons shall be made in the order in which the landings are reached in each direction of travel after the buttons have been actuated. All stops shall be subject to the respective car or landing button being actuated sufficiently in advance of the arrival of the car at that landing to enable the stop to be made. The first car or landing button actuated shall establish the direction of travel for an idle car.
 - 2. "Up" landing calls shall be answered while the car is traveling in the up direction and "Down" landing calls shall be answered while the car is traveling down. The car shall reverse after the uppermost or lowermost car or landing call have been answered, and proceed to answer car calls and landing calls registered in the opposite direction of travel.
 - 3. If the car without registered car calls arrives at a floor where both up and down hall calls are registered, it shall initially respond to the hall call in the direction that the car was traveling. If no car or hall is registered for further travel in that direction, the car shall close its doors and immediately reopen them in response to the hall call in the opposite direction. Direction lanterns, if provided, shall indicate the changed direction when the doors reopen.
- B. Independent service: Provide a key switch in the car operating panel which, when actuated, shall cancel previously registered car calls, disconnect the elevator from the hall buttons so that all operation is from the car buttons only.
- C. Non-contact door reopening device operation shall be as follows:
 - 1. The doors shall be prevented from closing from their full open position if any obstruction comes within the zone of detection. The detection zone shall move with the doors and if a person or object enters the zone as the doors are closing, the doors shall reverse and reopen. The doors shall re-close after a minimum time interval. A passenger entering or leaving the car shall not cause the doors to stop and reverse unless the doors reach a predetermined proximity to the passenger.
 - 2. After a stop is made, the doors shall remain open for a time interval to permit passenger transfer, after which the doors shall close automatically. The interval shall be less for a car call stop than for a hall call stop or a coincident car/hall call stop.
- D. Car stall protective circuit: Provide a protective circuit which shall stop the motor and return the car to its first floor landing in the event that the car, while traveling up, does not reach its designated landing within a predetermined time interval. This circuit shall permit a normal exit from the car but prevent further operation of the elevator until the problem has been corrected.

- E. Door operation:
1. Door close shall be arranged to start after a minimum time, consistent with accessibility requirements, from notification that a car is answering a hall call.
 2. Doors shall be arranged to remain open for a time period sufficient to meet accessibility requirements.
 3. The time interval for which the elevator doors remain open when a car stops at a landing shall be independently adjustable for response to car calls and response to hall calls.
 4. An approved positive interlock shall be provided for each hoistway entrance, which shall prevent operation of the elevator unless all doors for that elevator are closed and shall maintain the doors in their closed position while the elevator is away from the landing. Emergency access to the hoistway as required by governing codes shall be provided.
- F. Standby power transfer: Provide logic in each elevator controller when normal power fails and standby power is operational do not allow more than one elevator to start the lift motor within 5 seconds of another elevator. If normal power fails and standby power does not repower the elevator circuits within 20 seconds, then enable the following sequence: Upon the loss of normal power for greater than 20 seconds, provide controls to automatically lower the elevators nonstop to the lowest landing designated by the Fire Department. When arriving at the lowest landing, the elevator doors shall open automatically and remain open until regular door time has expired. The elevator shall then become deactivated.
- G. Battery standby power transfer: If normal power fails and emergency power does not repower the elevator circuits within 20 seconds then enable the following sequence: Upon the loss of normal power for greater than 20 seconds, provide controls to automatically lower the elevators nonstop to the landing designated by the fire department. When arriving at the designated landing, the elevator doors shall open automatically and remain open until regular door time has expired. The elevator shall then become deactivated. The control panel for the automatic lowering device shall be located in the elevator control area. The panel shall contain 2 gel batteries, solid-state controls, charger, monitor lights and a test button. Battery shall be rechargeable with a 5-year life expectancy.
- H. Automatic leveling: Machine room-less gearless machine/motor design shall be coordinated with the control so that car shall slow down and stop automatically at the floor after transition from contract speed. Car level shall be maintained automatically within 1/4" of the landing by an anti-creep leveling device regardless of any deviation that may be caused by the loading or unloading of the car. Landing zone detection shall indicate to the control system the position with respect to the floor level.
- I. Top-of-car operating device: Operation of elevator from top-of-car device shall be subject to applicable electrical protective devices required in Rule 2.26 of the code.
- J. Elevator control room cabinet:
1. A metal cabinet of not less than 20 cubic feet in volume shall be provided and located in the control room. Cabinet shall be rated to hold flammable materials.
 2. Cabinet shall have lockable doors and shall be mounted on legs or a pedestal, minimum 4" off the floor.
 3. Cabinet shall be painted and marked for elevator purposes, as directed by the MBTA, and OEM shall store small parts, supplies, tools and other materials within.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Prior to commencing with the installation of elevator equipment, examine the following and verify that no irregularities exist that would affect the quality of execution of work as specified:
 - 1. Hoistway size and plumbness.
 - 2. Anchor brackets.
 - 3. Sill support.
 - 4. Pit depth.
 - 5. Overhead clearance.
- B. Do not proceed with installation until work in place conforms to Design Documents.

3.2 INSTALLATION

- A. Install elevator in accordance with the OEM's installation procedures and accepted shop drawings.
- B. Verify that electrical wiring installation is in accordance with the OEM's submittal and in accordance with the installation requirements of other Sections of the Mandatory Specifications.
- C. Erect all items square, plumb, straight and accurately fitted with tight joints and intersections.
- D. Coordinate all trades to ensure that the installation of the elevators is not in conflict with the work performed by other trades.
- E. Isolate non-compatible, dissimilar materials from each other by providing vibration isolation, gaskets or insulating compounds.
- F. Provide protective coverings for finished surfaces.
- G. Upon completion, touch up and restore damaged or defaced factory finished surfaces. Touch up any marred finishes or replace as directed by the MBTA.
- H. Remove protective coverings and clean exposed surfaces after completion.
- I. Welding shall comply with AWS D1.1. Identify field welds with welder's identification stamp.
- J. No visible markings on finishes including finishes through glass except required by code or regulation.

3.3 FIELD TESTING

- A. Acceptance testing:
 - 1. General: After installation and before date accepted for start of interim maintenance, inspect and test the elevator and related equipment to the MBTA's satisfaction that operation of every part of equipment complies with applicable requirements of ASME/ANSI A17.1, including sound level

criteria specified in Article 1.8, Environmental Requirements. Elevator shall be inspected in accordance with procedures outlined in ASME/ANSI A17.2 and as required by the Authority having Jurisdiction. Provide test instruments, materials, other necessary facilities and all labor required for acceptance tests specified.

2. Notification Requirements: Notify the DB Entity and the MBTA a minimum of 5 working days prior to each scheduled test.
3. Full load run test: Run elevator continuously a minimum of 24 hours with full specified rated load, during which time car shall be stopped at top and bottom landings with a minimum standing period of 10 seconds at each landing.
4. Speed test: Make tests before and after full load tests. Using a tachometer on guide rail, determine actual speed of car in both directions of travel, both with full specified rated load and no load in car. Tolerances for determining if car speeds meet the specified requirements are as follows:
 - a. Ascending car speed: Not more than 10% above or more than 10% below required speed.
 - b. Descending car speed: Not more than 10% above or more than 10% below required speed.
5. Car leveling test: Determine accuracy of floor landing tests both before and after full load run tests. Minimum of 1/4" leveling must be maintained. Test accuracy of landing at all floors with full load and no load in car, in both directions of travel.
6. Electrical tests: Ensure elevator wiring system is free of short circuits and accidental grounds. Test ground resistance of elevator structure, equipment and raceways for continuity. Using megohm meter, determine that insulation resistance of each circuit is more than one megohm or higher as required by cable manufacturer. Insulation resistance for motors shall be determined under actual conditions after installation.
7. Burn in testing: Conduct in accordance with Article 1.3, definitions, and provide test report in accordance with Article 1.14, acceptance and warranty.
8. Acceptance: Elevator acceptance will be based upon elevators meeting requirements of DB Entity's accepted shop drawings and upon evidence of passing specified acceptance tests and inspections. Final testing and burn in shall occur after elevators are connected to permanent power.
9. Test Reports: Within 5 days after completion of a test, submit a test report stating type of test, test requirements, failures or problems, and name of certifying Engineer and Title. Safety device failure or defective equipment shall be identified, with description of cause and corrective action taken.
10. Failures for any reasons shall be identified with cause(s) and corrective action taken.
11. Retest notification requirements:
 - a. The DB Entity and MBTA shall be notified 10 days prior to the scheduled retest.
 - b. If any equipment is found to be damaged or defective, or if the performance of the elevator does not conform to the requirements of the Contract Specifications or the safety code, no approval or acceptance of elevators shall be issued until all defects have been corrected. When the repairs and adjustments have been completed and the discrepancies corrected, the MBTA shall be notified and the elevator shall be reinspected. Rejected elevators shall not be used until they have been reinspected and approved.
12. The certificate of inspection for operational use will be issued to the MBTA by the enforcing inspection agency. The certificate shall be posted in the elevator control room and the car operating station.

- B. Any deficiencies and defects discovered during the field-testing shall be corrected, repaired, replaced and retested to the satisfaction of the MBTA.

3.4 ADJUSTING AND CLEANING

- A. Immediately upon the completion of the elevator installation, thoroughly clean each elevator including car and hoistway doors and install 3/4" fire-retardant plywood on wood studs 2'-0" o.c. to protect all hoistway doors, frames and sills. This protection shall be maintained until the MBTA orders its removal, just prior to acceptance. At that time the installer shall perform a complete re-cleaning of the elevators, including hoistways, cars, car enclosures, entrances, operating and signal fixtures, and trim of dirt, oil, grease and finger marks.
- B. Remove all items and debris not necessary for the elevator's operation that could cause safety problems.
- C. Keep areas orderly and free from debris during the progress of the work.
- D. Remove all loose materials and filings resulting from the work from hoistway surfaces, pits and control room spaces.
- E. Clean control room floor of dirt, oil and grease.

3.5 MBTA COORDINATION

- A. Check operation of elevators with MBTA's personnel present and just prior to date of elevator turnover. Determine that operation systems and devices are functioning properly.
- B. Engage OEM authorized service representative to train MBTA's maintenance personnel to operate elevators.
- C. Check operation of elevators with MBTA's personnel present not more than one month before the end of warranty period. Determine that operation systems and devices are functioning properly.

END OF SECTION

SECTION 14450

VEHICLE LIFTS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity shall be provided at no additional cost to the agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Hoist, LRV, in-ground, w/ body stands, rotating hoists (EQ ID: 9400)
- E. The work specified in this section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The DB Entity shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 – SITE WORK of the Mandatory Specifications
 - 2. Division 3 – CONCRETE of the Mandatory Specifications
 - 3. Division 5 – METALS of the Mandatory Specifications
 - 4. Division 15 – MECHANICAL of the Mandatory Specifications
 - 5. Division 16 – ELECTRICAL of the Mandatory Specifications

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
 - 1. Operations and maintenance manual: Provide a complete parts, operating, and maintenance manual covering the equipment at the time of installation, including but not limited to:
 - a. Description of system and components.

- b. Schematic diagrams of any electrical, plumbing, or compressed air systems.
 - c. The manufacturer's printed operating instructions.
 - d. A printed listing of periodic preventive maintenance items and the recommended frequency required to validate warranties.
2. All material submitted to the MBTA will be reviewed for accuracy and detail, and shall be accepted by the MBTA.
 3. Assemble and provide copies of the manual in 8 ½" x 11" format. Fold out diagrams and illustrations are acceptable. The manual is to be reproducible by dry copy method. The manuals shall also be provided in Microsoft Word on CD so reproducing to original quality can be performed. Provide Five (5) copies of each manual, appropriately labeled in a three (3) ring binder.
- B. Shop Drawings
1. Submit shop drawings in accordance with Volume 2, Section 2.0.
 2. Submit the foundation design including drawings depicting the anchor bolt layout, structural loads, and all dimensions of the pit and embedments to be incorporated into the foundations.
 3. Submit drawings showing details of any caisson design and fabrication.
 4. Submit drawings depicting all system components, assembly dimensions, and all services required to connect with equipment, to include detailed wiring schematics and controls diagrams.
 5. Submit drawings showing equipment and component layout.
 6. Submit necessary installation details, including infrastructure items that may be furnished by others.
 7. Submit drawings showing all dimensions and clearances for interface with the MBTA's LRVs. These include, but are not limited to, the following: Lifting jack pads, jack pad centerlines, LRV truck center lines, truck axle spacing, and the LRV body.
 8. Submit catalog cuts of all purchased components.
- C. Submit a maintenance spare parts list for the LRV hoist systems as recommended by manufacturer. The quantity of spares to be provided in the list shall be sufficient to support the manufacturer's maintenance program for a two (2) year duration, based on the predicted rate of failure of all components. The DB Entity shall develop and submit a spare parts list to the MBTA for acceptance thirty (30) days prior to the scheduled delivery of the specified equipment.
- D. Thirty (30) days prior to testing, a comprehensive procedure for testing the equipment and documenting this testing shall be submitted to the MBTA.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment. A list of comparative installations currently in operation for a period of at least one (1) year prior to the bid date, including the names and phone numbers of the authorities using these systems, shall be provided.
- B. At any time during the fabrication of the lift system and body stands, and subject to reasonable notice, the MBTA and their representatives may visit the manufacturer's facility to inspect the fabrication and quality control processes.

C. Manufacturer's representative:

1. Installation: Provide a qualified manufacturer's representative on site to supervise the work related to equipment installation, check out, and start up.
2. Training: Provide a technical representative for training the MBTA's maintenance personnel in the operation and maintenance of the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the DB Entity.
- B. Substitution approval: Prior to delivery or installation, submittals for each item by equipment identifier shall be provided in accordance with Volume 2, Section 2.0.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Items shall be preassembled in the manufacturer's shop to the greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation.
- B. Prior to shipment, the equipment manufacturer shall make the equipment ready for a pre-shipment inspection and test if so desired by the MBTA.
- C. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during shipment and storage in humid and/or dusty conditions.
- D. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; abnormal deterioration of finish; and any failure of the system to operate as designed. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with the Contract Documents.

1.8 EQUIPMENT LABELING

- A. The manufacturer shall securely attach in a prominent location, on each major item of equipment, a non-corrosive nameplate showing the manufacturer's name, address, model number, serial number, and pertinent utility or operating data.
- B. All electrical equipment and materials shall be new and shall be listed by the Underwriter's Laboratories, Inc. (UL) in categories for which standards have been set by that agency and labeled as such in the manufacturer's plant.

PART 2 – PRODUCTS

2.1 HOIST, LRV, W/ BODY STANDS, ROTATING HOIST (EQ ID: 9405)

- A. Manufacturer's reference:
 - 1. Prime manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Ray-Jurgen Company, LLC, Bristol, CT (860) 585-0111
 - 1) Model: Custom
 - 2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Volume 2, Section 2.0, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Whiting Corp., Monee, IL - (800) 861-5744
 - b. Macton Corporation, Oxford, CT - (301) 829-6227
 - c. Railquip Inc., Atlanta, GA - (800) 325-0296
- B. General description:
 - 1. The hoist system shall be designed and constructed to lift one of the MBTA's Type 7, Type 8, and Type 9 LRVs and shall be capable of supporting each LRV type with body stands using the jacking pads located on the permanent structure of these LRVs.
 - 2. One (1) complete system shall be furnished and installed at the GLX Vehicle Maintenance and Storage Facility (VMSF). The hoist system shall be furnished in place as a complete operational system with all of the necessary components that may be required to meet the requirements of these specifications. This contract includes all infrastructure and services to make a complete and operational system for the GLX VMSF.
 - 3. Railcar hoist stands shall be of a C-frame design, which shall allow the passage of a removed truck under the raised and supported car after hoists have been lowered.
 - 4. The system shall include three (3) pits with car hoists and body stands in each pit.
 - 5. Each of the holding cylinders will be equipped with pads designed to contact and safely support the body of the lifted rail car when the trucks are being changed.
 - 6. The lift operation shall be controlled by a PLC (programmable logic controller) that will maintain equalized travel of each cylinder within ½"

7. The lifts specified herein shall comply with all requirements of ANSI standard B153.1, "Safety Requirements for the Construction, Care and Use of Automotive Lifts," as published by the American National Standards Institute.
8. All electrical components shall be UL/CSA approved.
9. A PPG Alkyd enamel industrial coating will be applied to all unprotected metal surfaces.

C. Capacities/Dimensions:

1. Car hoist:

- a. System shall be capable of lifting any of the MBTA LRV Types previously mentioned.
- b. Lift capacities: 20 tons (per individual hoist)
- c. Lifting and lowering speed: 4.5 ft./min. (minimum)
- d. Hoist rise: 5'-6"
- e. Track gauge: 4'-8 1/2"
- f. The car hoist system shall take into account and be compatible with the truck wheel base for all MBTA LRV types previously mentioned.
- g. The car hoist system shall take into account and be compatible with the truck centers for all MBTA LRV types previously mentioned.
- h. Each hoist shall have the ability to be rotated at least 90 degrees while in an intermediate height position, and then lowering to floor level so as to allow rolling the removed truck away on tracks installed perpendicular to the main tracks.

2. Body stands:

- a. A minimum of eight (8) body support stands are required per LRV system. The (8) body support stands shall have rotating heads to accommodate the different vehicle types. Twelve (12) Additional body support stands will be allowed only if the manufacturer cannot accommodate the different vehicle types with the use of eight (8) stands.
- b. The end pits shall each have two body stands, the center pit requires four body stands.
- c. The heads of the body stands shall be configured to mate with the vehicle lifting pads and shall also accommodate any pocket inserts required by the different cars.
- d. Stand capacities: Fifteen (15) tons per pair of body support stands.
- e. Lifting and lowering speed: 4.5 ft./min. (minimum)
- f. Stand rise: As required when the car hoist is raised to a maximum height. The body stand screw length shall be the same for all body stands in the system in order to allow interchangeability.

D. Features/Performance/Construction:

1. Wheel base

- a. All posts will be fixed front to rear to provide the safe alignment of lifting points with rail car pick up points.

2. Adapter Adjustment

- a. The lifting adapters will be designed to safely engage all rail cars lifting points specified.
3. Hydraulic power units
- a. The electric hydraulic power unit will be 230/460 or 575v/3 phase
 - b. *Design Requirements:*
 - 1) The power unit shall be mounted in the control console cabinet in accordance with the lift manufacturer recommended installation instructions.
 - c. *Capacity and Dimensions:*
 - 1) Motors: four (4) 3 HP.
 - 2) Pumps: (4) - 1 GPM
 - 3) Hydraulic fluid displacement: 1 gallon.
 - 4) Overall dimensions: 32 ¼” Width, X 15 7/16” Depth, X 47 15/16” Height
 - 5) An optional remote control pendant shall be supplied with 50’ cable (or wireless remote) to allow the operator to raise and lower all cylinders (optional front or rear) with clear visibility of the vehicle being lifted.
 - d. *Features and construction:*
 - 1) Configuration: Unit shall consist of geared pumps each coupled to a 3HP motor assembly complete with relief valves, and check valves mounted on an appropriately sized hydraulic fluid reservoir. All components shall be factory assembled and tested. The motors shall be direct coupled to the pumps with a common shaft/coupling arrangement.
 - 2) Operation: The pumps shall provide hydraulic pressure through electric solenoid controlled valves to raise or lower any combination of the cylinders within the lift system simultaneously synchronized to within plus or minus 1/2” of each other throughout their full stroke. Equalization of rate of lifting or lowering of the cylinders shall be automatically controlled by the PLC controller so that the operator will not be required to make any adjustments during operation.
 - 3) Magnetic motor starter: A full voltage, 3 pole, reversing magnetic type for 3 phase, 60 cycle motor control with manual reset and “UP / DOWN / STOP” push-buttons in cover. NEMA 12 enclosure for floor mounting.
 - 4) The hydraulic power units will be a minimum 3HP each, and of a North American manufacture, with a minimum of 1 GPM flow. Electrical requirements: 230/460 or 575volts 60cycle 3phase.
4. Design requirements:
- a. *Lifting unit:*
 - 1) Pick up adapters: The lifting cradle and adapters will be designed to provide a sufficient engagement that will not require the operator to have to crawl under the vehicle to make adjustments.

- 2) The adapters shall be recessed in the floor and not extend higher than the surface of the floor when the cylinders are fully lowered.
- 3) (Cylinder and Casing Assembly): There will be a one piece that does not require adjustment or lubrication.
- 4) The lifting pistons will be manufactured of 3/8" wall chrome plated machined steel tube, finished and polished over its entire surface. There will be safety stops welded to the bottom of the cylinder to prevent it from leaving the casing. The cylinder shall be removable for inspection and/or replacement.
- 5) The outer casing shall be steel pipe with flanges welded to the top and bottom. The casing assembly shall have a removable bearing assembly. The bearing will provide minimum cylinder to bearing friction for smooth operation and insure maximum rigidity and support for design loads.
- 6) Cover plates will be provided to keep the trench opening covered at all times. Cover plates will be made of diamond plate steel capable of withstanding the drive over loading of the typical vehicle being lifted.

b. *Controls:*

- 1) The PLC control console will include out of level monitoring, synchronization and rail car positioning. There will be a remote control pendant provided with a lower, raise and park position with sufficient cable to allow the operator safe visibility of the rail cars being lifted. The pendant control will have an active "E stop". Controls shall have UL/ CSA certification.

c. *Lift Locks:*

- 1) The locking legs shall be rated at same capacity as the corresponding cylinders capacity. The legs shall be constructed of rectangular tubing and a minimum wall thickness of 3/8" to prevent rotation out of alignment with load holding device. Round notched struts are not acceptable. Each strut shall have a 3/8" steel plate welded to it with a minimum of 26 locking slots spaced at 1.5 " increments. The locking latches shall be spring loaded to the locked position and shall be released at the control console location. The lift locking leg shall be attached to the cradle to prevent unintended rotation during use, and insuring proper location of releases at all times. The locking latch shall be removable for on-site replacement of the latch at any time. The locking latches will be automatically released for lowering.

5. Warranty

- a. Lifts shall be warranted to be manufactured from sound materials in a workman like manner and guaranteed against failure due to defective materials and workmanship for a period of two years on parts and one year on labor. There will be a limited corrosion warranty of seven years. Structural components will be warranted for twenty (20) years.

6. Descriptive data

- a. An installation-operation-service manual and complete repair parts list showing illustrations of individual components shall be furnished by the manufacturer.
- b. Installation shall be provided by factory trained and authorized technicians.
- c. Inspection warranty service, continued maintenance and repair shall be available by local factory trained and authorized personnel who are ALI Certified as well. Emergency service shall be available within eight hours. Local service firm shall maintain an inventory of common replacement parts.

2.2 VARIATIONS

- A. Alternate equipment may be proposed. In all cases the DB Entity shall provide in writing at the time of bid submission sufficient technical description of the alternate units(s) to enable MBTA to determine if the proposed equipment is equal to that specified.

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.
- C. Report in writing to the MBTA any damaged, missing, or incomplete scheduled equipment and improper rough-in or utility stub-outs.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the DB Entity or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 - 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 - 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 - 3. Anchorage: Attach equipment as directed by the DB Entity or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the DB Entity or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the DB Entity or designated representative for acceptance inspection.

3.5 TRAINING

- A. Prior to installation the DB Entity shall submit for review a program which shall adequately train MBTA maintenance personnel to correctly operate and maintain the equipment. The DB Entity shall be responsible for supplying all materials required for the program, in addition to the materials and training required to train an MBTA trainer.
- B. Direct the technical representative to provide training to the designated MBTA's maintenance personnel in the operation and maintenance of the equipment. Coordinate, with the MBTA, the training schedule and list of personnel to be trained.
- C. The training period shall start after the system is functionally completed but prior to final acceptance. Course instructions shall cover pertinent points involved in operating, starting, stopping and servicing the equipment, including all major elements of the operations and maintenance manual. Course instructions shall demonstrate all routine maintenance operations such as lubrication and general inspections. The MBTA shall be given at least two (2) weeks advance notice for training.
 - 1. Provide training session of a minimum of four (4) hours in the operation of the hoist system.
 - 2. Provide training session of a minimum of eight (8) hours in the inspection and maintenance of the hoist systems.
 - 3. The DB Entity will provide a suitable LRV for these training sessions.
 - 4. Provide DVD formatted material conveying the essential information contained in the training sessions.
- D. Obtain from the technical representative, a list of the MBTA's personnel trained in equipment operations and maintenance.

3.6 FINAL ACCEPTANCE

- A. Final acceptance shall be granted when the following items have been satisfactorily completed:
 - 1. The equipment installation is complete.
 - 2. Equipment testing is complete and any and all deficiencies have been remedied.
 - 3. A spare parts list has been submitted.

4. Final versions of the Operation and Maintenance manual have been provided.
5. Equipment training is complete.

END OF SECTION

SECTION 14500

MATERIAL HANDLING EQUIPMENT

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the work in this section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Forklift, electric, Very Narrow Aisle, 4,000 lbs (incl. battery & charger) (EQ ID: 9307)
- E. The work specified in this section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The DB Entity shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 3 – CONCRETE of the Mandatory Specifications
 - 2. Division 15 – MECHANICAL of the Mandatory Specifications
 - 3. Division 16 – ELECTRICAL of the Mandatory Specifications

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.

- B. Operations and maintenance manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the DB Entity.
- B. Substitution approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided. Acceptance will be based on the technical requirements herein as determined by the MBTA.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the equipment identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from Contract Substantial Completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.

PART 2 – PRODUCTS

2.1 FORKLIFT, ELECTRIC, VERY NARROW AISLE, 4,000 LB W/CHARGER (EQ ID: 9307)

A. Manufacturer's reference:

1. Prime manufacturer: Specifications are based on furniture identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Landoll, Marysville, KS, (717) 485-5161
 - 1) Model: Bendi B40VAC
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in the Mandatory Specifications, furniture produced by other manufacturers, including the following, may be considered as equal.
 - a. Caterpillar, Houston, TX, (713) 365-1000
 - b. Yale Materials Handling Corporation, Greenville, NC, (252) 931-5100

B. General description:

1. A forklift truck (also called a lift truck, a fork truck, or a forklift) is a powered industrial truck used to lift and transport materials.

C. Capacities/Dimensions:

1. Capacity at 24" load center: 4,000 lbs.
2. Weight with battery: 13,770 lbs.
3. Travel Speed
 - a. Loaded: 6.5 mph
 - b. Unloaded: 7 mph
4. Lift Speed
 - a. Loaded: 90 fpm
 - b. Unloaded: 110 fpm
5. Lowering Speed
 - a. Loaded: 100 fpm
 - b. Unloaded: 90 fpm
6. Mast tilt
 - a. Mast tilt-back / fwd: 2/1 degrees
7. Lost load center: 9.2 in.
8. Wheelbase: 62.2 in.
9. Overall length to face of forks: 100.1 in.
10. Underclearance - under mast: 3 in.
11. Operator floor height: 31 in.

12. Overhead guard height: 87 in.
 13. Chassis width: 48 in.
 14. Right angle stacking aisle - with 48"L x 40"W Load: 78 in.
 15. Intersecting aisle - with 48"L x 40"W Load: 108 in.
 16. Gradeability - loaded / unloaded: 15%
 17. Hydraulic motor rating (AC) - continuous duty rating: 12 kw
 18. Traction control type – induction: AC
 19. Wheel sizes
 - a. Front 2 each smooth poly-dia. x face: 12 x 5 in.
 - b. Rear 2 each smooth rubber-dia x face: 18 x 7 in.
 20. Front articulation: 180 degrees.
 21. Provide one battery meeting the manufacturer’s recommended specifications:
 - a. Battery weight: 2,600 lbs. (min) – 3,100 lbs. (max)
 - b. Battery designation: 24-85-19, 48 V, 765 AHC (6 Hour Rate)
 - c. Nominal size: 25 15/16” x 44 9/16” x 22 5/8”
 22. Provide with Battery Charger
 23. Mast Dimension: Select mast lift height to allow the handling of pallets at the highest level of pallet rack provided in the storage and racking rooms.
- D. Features/Performance/Construction:
1. High visibility 3-stage mast
 2. Integral 10.31" stroke sideshifter and 36" high load backrest
 3. Dual inside / outside capability
 4. Large diameter smooth rubber drive tires
 5. Discharge indicator and hour meter
 6. Horn and seatbelt
 7. Hydraulic power steering
 8. Safety deadman seat switch
 9. Capable of freezer operation to -22°F (-30°C)

PART 3 – EXECUTION

3.1 INSPECTION

- A. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the DB Entity or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the DB Entity or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the DB Entity or designated representative for acceptance inspection.

END OF SECTION

SECTION 14610 - VEHICLE HOIST SYSTEM

PART 1 – GENERAL

1.1. DESCRIPTION

- A. The lift specified shall be of a high pressure (low oil volume) design that minimizes the use of oil below ground through high pressure hydraulic system and use of structural cylinder casing as containment.
- B. The lift shall consist of four (4) lifting cylinders installed in existing pit structure in the center of the track and eight (8) holding cylinders installed in existing structure four on each side of the track directly under lifting points of the rail cars in line with each other.
- C. Each of the four (4) lifting cylinders will be equipped with rail lifting frame to safely lift the two rail cars simultaneously or one rail car at the time.
- D. Each of the holding cylinders will be equipped with pads designed to contact and safely support the body of the lifted rail car when the trucks are being changed.
- E. The lift operation shall be controlled by a PLC (programmable logic controller) that will maintain equalized travel of each cylinder within 1/2”
- F. Each cylinder will have an internally mounted hydraulic ram style piston with chrome plated plunger, and velocity fuse.
 - 1. The structural cylinder casing will be galvanized for rust protection.
 - 2. The lifts specified herein must comply with all requirements of ANSI standard B153.1, "Safety Requirements for the Construction, Care and Use of Automotive Lifts," as published by the American National Standards Institute.
- G. All electrical components must be UL/CSA approved.
- H. A PPG Alkyd enamel industrial coating will be applied to all unprotected metal surfaces.
- I. All current operational features of the lift must be included in the replacement system.

1.2. QUALITY ASSURANCE

- A. The DB Entity shall be certified in vehicle hoist, material handling equipment refurbishment, shop equipment refurbishment, and installation with a minimum of five (5) years of experience providing these specified services.

- B. The DB Entity shall provide a technical representative to instruct and train MBTA's personnel in operation and maintenance of the new hoist.

1.3. SUBMITTALS

- A. Submit one (1) reproducible drawing and five (5) prints of each shop drawing. Complete catalog information and dimensioned shop drawings. Tolerances, clearances, and dimensions shall follow the system of ounces, pounds, gallons, inches, and feet, as used in the United States (metric conversions may be provided parenthetically). Shop drawings shall include, but not necessarily be limited to, the following:
 - 1. Control schematic and detail diagrams showing vehicle hoist system operation.
 - 2. Electric power requirements with wiring diagrams and any new conduit runs.
 - 3. Outline dimensions of equipment.
 - 4. Equipment and component layout.
 - 5. Details of equipment and controls.
 - 6. Other necessary installation details, including infrastructure items that maybe furnished by others.
 - 7. Catalog cuts of all purchased components.
- B. Submit for MBTA's review, data such as technical descriptions, performance specifications, working drawings or other appropriate data, on new accessories, components, and systems to be added or replaced on or to equipment (Programmable Logic Controllers).
- C. Provide at the time of installation, complete parts, operating, and maintenance manuals covering any new accessories, components, or systems. All material submitted to the MBTA will be reviewed for accuracy and detail, and must be accepted by the MBTA. Manuals shall include those listed in Section 2.6.

1.4. DELIVERY, STORAGE AND HANDLING

- A. Vehicle hoist systems equipment and components shall be suitably crated to prevent damage in transit or during handling. Items shall be carefully stored at the site as required in a manner to avoid misalignment or distortion, and shall be adequately protected against damage by weather or other cause.

- B. Special precautions shall be taken to prevent damage to electrical components such as motors, controls and conductors.

1.5. WARRANTY

- A. Lifts shall be warranted to be manufactured from sound materials in a workman like manner and guaranteed against failure due to defective materials and workmanship for a period of two years on parts and one year on labor. There will be a limited corrosion warranty of seven years. Structural components will be warranted for twenty (20) years.
- B. The warranty for work specified herein shall be for one year from final acceptance of the vehicle hoist systems and shall warranty against defects in function, materials, and workmanship.
- C. The warranty shall cover all materials and labor necessary to correct defects.
- D. Defects shall include but not be limited to noisy, rough, or substandard operation, incorrect installation, loose, damaged, and missing parts, abnormal deterioration of finish and any failure of the system to operate as designed.
- E. The warranties shall be submitted in writing to the MBTA at time of completion and final acceptance of modification and refurbishment of each vehicle hoist system.
- F. All parts shall be readily available locally in the United States. (Applies to new or replaced systems or components only)

1.6. EQUIPMENT LABELING

- A. Securely attach in a prominent location, nameplate showing manufacturers name and address, date of refurbishment, and other pertinent data.
- B. All electrical equipment and materials shall be new and shall be listed by Underwriter's Laboratories, Inc. (U.L.) in categories for which standards have been set by that agency and labeled as such in the manufacturer's plant.

PART 2 - PRODUCTS

2.1 CAPACITY AND DIMENSIONS

- A. The overall lifting capacity of the electric/hydraulic system will be a minimum of 160,000 lbs. with 40,000 lbs. in each of the posts when supplied with a maximum operating pressure of 3200psi.

2.2 WHEEL BASE

- A. All posts will be fixed front to rear to provide the safe alignment of lifting points with rail car pick up points.

2.3 ADAPTER ADJUSTMENT

- A. The lifting adapters will be designed to safely engage all rail cars lifting points specified.

2.4 HYDRAULIC POWER UNITS

- A. The electric hydraulic power unit will be 230/460 or 575v/3 phase.

1. Design requirements:

- a. The power unit shall be mounted in the control console cabinet in accordance with the lift manufacturer recommended installation instructions.

2. Capacity and dimensions:

- a. Motors: four (4) 3 HP.
- b. Pumps: (4) - 1 GPM
- c. Hydraulic fluid displacement: 1 gallon.
- d. Overall dimensions: 32 ¼" width, X 15 7/16" depth, X 47 15/16" height
- e. An optional remote control pendant shall be supplied with 50' cable (or wireless remote) to allow the operator to raise and lower all cylinders (optional front or rear) with clear visibility of the vehicle being lifted.

3. Features and Construction

- a. Configuration: Unit shall consist of geared pumps each coupled to a 3HP motor assembly complete with relief valves, and check valves mounted on an appropriately sized hydraulic fluid reservoir. All components shall be factory assembled and tested. The motors shall be direct coupled to the pumps with a common shaft/coupling arrangement.
- b. Operation: The pumps shall provide hydraulic pressure through electric solenoid controlled valves to raise or lower any combination of the cylinders within the lift system simultaneously synchronized to within plus or minus 1/2" of each other throughout their full stroke. Equalization of rate of lifting or lowering of the cylinders shall be automatically controlled

by the PLC controller so that the operator will not be required to make any adjustments during operation.

- c. Magnetic Motor Starter: A full voltage, 3 pole, reversing magnetic type for 3 phase, 60 cycle motor control with manual reset and “UP / DOWN / STOP” push-buttons in cover. NEMA 12 enclosure for floor mounting.
- d. The hydraulic power units will be a minimum 3HP each, and of a North American manufacture, with a minimum of 1 GPM flow. Electrical requirements: 230/460 or 575volts 60cycle 3phase.

2.5 DESIGN REQUIREMENTS

A. Lifting unit:

1. Pick up adapters: The lifting cradle and adapters will be designed to provide a sufficient engagement that will not require the operator to have to crawl under the vehicle to make adjustments.
2. The adapters shall be recessed in the floor and not extend higher than the surface of the floor when the cylinders are fully lowered.
3. (Cylinder and casing assembly): There will be a one piece that does not require adjustment or lubrication.
4. The lifting pistons will be manufactured of 3/8” wall chrome plated machined steel tube, finished and polished over its entire surface. There will be safety stops welded to the bottom of the cylinder to prevent it from leaving the casing. The cylinder shall be removable for inspection and/or replacement.
5. The outer casing shall be steel pipe with flanges welded to the top and bottom. The casing assembly shall have a removable bearing assembly. The bearing will provide minimum cylinder to bearing friction for smooth operation and insure maximum rigidity and support for design loads.
6. Cover plates will be provided to keep the trench opening covered at all times. Cover plates will be made of diamond plate steel capable of withstanding the drive over loading of the typical vehicle being lifted.

B. Controls:

1. The PLC control console will include out of level monitoring, synchronization and rail car positioning. There will be a remote control pendent provided with a lower, raise and park position with sufficient cable to allow the operator safe visibility of the rail cars being lifted. The pendant control will have an active “E stop”. Controls must have UL/ CSA certification.

C. Lift locks:

2. The locking legs shall be rated at same capacity as the corresponding cylinders

capacity. The legs shall be constructed of rectangular tubing and a minimum wall thickness of 3/8" to prevent rotation out of alignment with load holding device. Round notched struts are not acceptable. Each strut shall have a 3/8" steel plate welded to it with a minimum of 26 locking slots spaced at 1.5 " increments. The locking latches shall be spring loaded to the locked position and shall be released at the control console location. The lift locking leg shall be attached to the cradle to prevent unintended rotation during use, and insuring proper location of releases at all times. The locking latch should be removable for on-site replacement of the latch at any time. The locking latches will be automatically released for lowering.

2.6 SUPPORT MATERIALS

A. Installation, operation, and maintenance manual

1. Manuals shall include but not be limited to the following:
 - a. Description of system or component.
 - b. Schematic diagrams.
 - c. Manufacturer's printed operating instructions.
 - d. Printed listing of periodic preventive maintenance items and recommended frequency required to validate warranties.
 - e. List of original manufacturer's parts, including supplier's part numbers and cut sheets, recommended spare parts quantity, and local parts and service source.
2. Shall be assembled and copies of manuals in 8-1/2 by 11 inch format provided. Foldout diagrams and illustrations are acceptable. The manuals shall be a quality that copies can be reproduced by dry copy method. Five (5) copies of each manual, appropriately labeled in a three (3) ring binder. The manuals should also be provided in Microsoft Word on CD so reproducing to original quality can be performed.

PART 3 - EXECUTION

3.1 TRAINING

- A. Prior to installation the DB Entity shall submit for review a program which shall adequately train MBTA maintenance personnel to correctly operate and maintain the equipment. The DB Entity shall be responsible for supplying all materials required for the program, in addition to the materials and training required to train an Authority trainer.

- B. A complete training class of minimum two (2) hours duration for up to ten (10) trainees including test materials and manuals provided to the Authority in Microsoft Word format on CD. Training shall be comprised of hands-on training.

3.2 INSTALLATION

- A. Installation must be provided by factory trained and authorized technicians.
- B. Inspection warranty service, continued maintenance and repair must be available by local factory trained and authorized personnel who are ALI certified as well. Emergency service must be available within eight hours. Local service firm must maintain an inventory of common replacement parts.

3.3 DESIGN-BUILDER TASKS

- A. The DB Entity shall provide barricades, dust shields, warning signs, and other safety devices necessary to protect MBTA and other personnel working in the area.
- B. The DB Entity shall be responsible for proper disposal of all equipment and parts removed during this work.
- C. The DB Entity shall provide appropriate safety caps, wrapping, or other appropriate protection on utility source stub outs in order to protect personnel, equipment and the utility supply.

END OF SECTION

SECTION 14630

BRIDGE CRANES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of DB Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the DB Entity shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Top running single girder bridge crane, 10-Ton (EQ ID: 9105)
 - 2. Top running single girder bridge crane, 7½ -Ton (EQ ID: 9126)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The Design-Builder shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 3 – CONCRETE of the Mandatory Specifications
 - 2. Division 15 – MECHANICAL of the Mandatory Specifications
 - 3. Division 16 – ELECTRICAL of the Mandatory Specifications

1.3 REFERENCES

- A. American Institute of Steel Construction (AISC): Manual of Steel Construction, Part 5; Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts.
- B. American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME)
 - ANSI / ASME HST-4 - 1999 Performance Standard for Overhead Electric Wire Rope Hoists
 - ANSI / ASME B30.16 – 2003 Overhead Hoists (Underhung)
 - ANSI / ASME B30.2 - 2001 Overhead and Gantry Cranes
(Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)

ANSI / ASME B30.11 – 2004 Monorails and Underhung Cranes
ANSI / ASME B30.17 – 2003 Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist)

- C. American Society for Testing and Materials (ASTM) Publications:
- D. ASTM A36 - Carbon Structural Steel.
- E. ASTM A490 - Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength.
- F. American Society of Mechanical Engineers (ASME):
- G. ASME HST-4M - Performance Standards for Electric Wire Rope Hoists.
- H. American Welding Society (AWS).
- I. AWS D14.1 - Welding of Industrial and Mill Cranes and Other Material Handling Equipment.
- J. Crane Manufacturer's Association of America (CMAA):
Specifications for Top Running and Under Running Single Girder Electric Overhead Cranes Utilizing Under Running Trolley Hoist - No. 74 (2004)
- K. National Electric Code (NEC).
- L. National Electric Manufacturer's Association (NEMA)
- M. Occupational Safety and Health Administration (OSHA):
Specification 1910.179 – Overhead and Gantry Cranes
Specification 1926.554 – Overhead Hoists
- N. MMA – Monorail Manufacturers Association.

1.4 SUBMITTALS

- A. Product Data - Submit product data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. Product data for crane and accessories. Describe capacities, performance, operation, and applied forces to overhead support framing.
- C. Design: Manufacturer's standard pre-engineered load tables and other data annotated to identify Project selections and conditions. Indicate type, size, material, spacing, and other attributes of components being provided to accommodate performance requirements.
- D. Shop drawings showing crane configuration, dimensions, wiring diagrams, and fabrication and installation details.
- E. Copy of warranty required for review by DB Entity.
- F. Manufacturer's installation instructions.

G. Operations and maintenance manual:

1. Provide a complete parts, operating, and maintenance manual covering the equipment at the time of installation, including but not limited to:
 - a. Description of system and components.
 - b. Schematic diagrams of any electrical, plumbing, or compressed air systems.
 - c. The manufacturer's printed operating instructions.
 - d. A printed listing of periodic preventive maintenance items and the recommended frequency required to validate warranties. Failure to provide maintenance information will indicate that preventive maintenance is not a condition for validation of warranties.
 - e. A list of the original manufacturer's parts, including suppliers' part numbers and cut-sheets, recommended spare parts stock quantities, and local parts and service sources.
2. Assemble and provide copies of the manual in 8 ½" x 11" format. Fold out diagrams and illustrations are acceptable. The manual is to be reproducible by dry copy method. Provide copies of the manual per the provisions stated in Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions.

H. Shop drawings

1. Submit drawings depicting all system components, assembly dimensions, and all services required to connect with equipment, to include detailed wiring diagrams and structural attachment details.

- I. Submit a maintenance spare parts list for the monorail/hoist as recommended by manufacturer. The quantity of spares to be provided in the list shall be sufficient to support the manufacturer's maintenance program for a two (2) year duration, based on the predicted rate of failure of all components. The Design-Builder shall develop and submit a Spare Parts List to the MBTA for acceptance thirty (30) days prior to the scheduled delivery of the specified equipment.

1.5 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment. A list of comparative installations currently in operation for a period of at least one (1) year prior to the bid date, including the names and phone numbers of the authorities using these systems, shall be provided.
- B. Single source responsibility: Single company shall design, fabricate, and supply all major components for monorail crane including track, track suspension system, bracing, auxiliary framing, track electrification, trolleys, motor drives, hoists, controls, track curves, switches, lifting beams, transfer sections, lift and drop sections, and installation fittings and hardware.
- C. Installer: Company experienced in assembly and installation of cranes with five (5) years successful experience and acceptable to crane manufacturer.
- D. Crane shall be designed, fabricated, and installed in accordance with ANSI B30.11, ANSI B30.16, and OSHA 1910.179.

- E. Hoists shall be designed, fabricated, and installed in accordance with ASME HST-4M.
- F. Service class: Design crane to perform in operating conditions defined in ANSI MH27.1: Class A - Infrequent use.
- G. Impact allowance: Base crane structural design on live load capacity plus 0.5 % of rated load for each foot per minute of hoisting speed with 15 % minimum and 50 % maximum. For bucket and magnet applications, impact allowance shall be 50 % minimum of rated load.
- H. Perform welding by certified operators in accordance with AWS D14.1.
- I. Bolted connections shall be in accordance with torque tightening procedures specified in AISC Manual, Part 5.
- J. Clearly label crane with rated load capacity. Place label at height and location easily read from floor level and loading position.
- K. Manufacturer's representative:
 - 1. Installation: Provide a qualified manufacturer's representative on site to supervise the work related to equipment installation, check out, and start up.
 - 2. Training: Provide a technical representative for training the MBTA's maintenance personnel in the operation and maintenance of the specified equipment.

1.6 PRODUCT SUBSTITUTIONS

- A. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the DB Entity.
- B. Substitution Approval: Prior to delivery or installation, submittals for each item by equipment identifier shall be provided in accordance with Volume 1 Contract Terms and Conditions and Volume 2 Technical Provisions. Acceptance will be based on the technical requirements herein as determined by the MBTA.

1.7 DELIVERY, STORAGE AND HANDLING

- A. Items shall be preassembled in the manufacturer's shop to the greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation.
- B. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- C. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- D. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.8 WARRANTY

- A. Warrant work specified herein for two (2) years from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Volume 1 Contract Terms and Conditions.

1.9 EQUIPMENT LABELING

- A. The manufacturer shall securely attach in a prominent location, on each major item of equipment, a non-corrosive nameplate showing the manufacturer's name, address, model number, serial number, and pertinent utility or operating data.
- B. All electrical equipment and materials shall be new and shall be listed by the Underwriter's Laboratories, Inc. (UL) in categories for which standards have been set by that agency and labeled as such in the manufacturer's plant.

PART 2 – PRODUCTS

2.1 CRANE, BRIDGE, TOP RUNNING, 10 TON (EQ ID: 9105)

- A. Manufacturer's reference:
 - 1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer's name and model to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. R & M Materials Handling Inc., 4501 Gateway Blvd., Springfield, OH (937) 328-5100
 - (i) Model: QXSka10-Ton
 - 2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Mannesman Demag, Cleveland, OH (440) 248-2400
 - b. KCI Konecranes, Santa Fe Springs, CA (949) 248-549
- B. General requirements:
 - 1. Top running single girder electric overhead traveling cranes shall be designed and manufactured as per CMAA specification #74, Revised 2000.
 - 2. In addition, the crane design and installation shall meet all the applicable local, state, and federal laws and OSHA regulations having jurisdiction.

3. Cranes shall operate in the given spaces and shall match the runway dimensions and rails indicated.
4. The crane shall be designed and manufactured to meet the appropriate service conditions based on the particular application. The crane service class shall be clearly indicated by the manufacturer at the time the crane proposal is submitted.

C. Capacities/Dimensions:

1. Lifting capacity: 20,000 pounds
2. Lower load block or assembly of hook, swivel bearing sheaves, pins and frames suspended by the hoisting ropes shall not be considered part of the rated capacity.
3. CMAA service class: Crane shall be designed and constructed to CMAA specification #74 (revised 2004) for Class "C" service requirements and operation in a non-hazardous environment.
4. Crane dimensions - Field verify required dimensions prior to fabrication:
 - a. Span: Per plans
 - b. Runway length: Per plans
 - c. Clear hook height: Per plans
 - d. Lift: Hoist design shall maximize hook coverage, hook vertical travel (i.e. end approach), and clear hook height (i.e. headroom). The use of a low headroom hoist is mandatory.
 - e. Rated speeds (FPM) $\pm 10\%$:
 - f. Hoist: Maximum high 20; Minimum low 3 FPM
 - g. Trolley: Maximum high 65; Minimum low 65 FPM
 - h. Bridge: Maximum high 130; Minimum low 130 FPM

D. Features/Performance/Construction:

1. Hoists and trolleys
 - a. All top running single girder cranes shall utilize low headroom electric wire rope hoists as manufactured by R&M Materials Handling Inc., Springfield, OH., or approved equal.
 - b. The hoist shall be equipped with an electro-mechanical load-limiting device that shall prevent lifting more than 110% of the rated load.
 - c. Hoist and trolley motors shall be per capacities and dimensions above, as applicable.
 - d. Hoisting motor(s) shall be two-speed/two winding squirrel cage type with a speed ratio of 6:1.
 - e. Hoisting motor(s) shall be totally enclosed with IP55 protection, minimum class F insulation, Klixon type bimetal switch for thermal protection and shall have a 60% ED rating.
 - f. Trolley shall be furnished with an adjustable frequency inverter drive and two-step or infinitely variable speed control for smooth acceleration and deceleration.
 - g. Trolley motors shall be inverter duty motors with minimum class "F" insulation and motor enclosures shall be TENV [totally enclosed non-ventilated].
 - h. Rotary cam type limit switch equipped with 4 micro-switches shall be provided. Limit switch shall provide upper and lower limit of hoist travel, hoist slow down prior to reaching upper limit

and phase sequence supervision at upper limit. An additional block operated limit shall be included.

- i. Hoist motor brake shall be DC disc type with adequate torque to stop and hold over 125% of the hoist rated load.
 - j. Large diameter rope drum with a minimum of 36:1 drum to wire rope diameter ratio. Groove depth shall be at least 35% of rope diameter. The rope drum shall be equipped with a rope guide to help keep the rope aligned in the grooves of the drum.
 - k. Wire rope shall be constructed from galvanized steel having a minimum safety factor of 5.
 - l. Hoist reeving shall be single reeved. Lateral hook drift shall not exceed 1/8 inch per foot of vertical travel on single reeved models.
 - m. The hoist nameplate is to carry a CSA c/us rating. The actual hoist control enclosure rating shall be at least equivalent to IP55 / NEMA 4 type.
 - n. Hooks shall be made of forged alloy steel (34CrMo4QT or 34CrNiMo6QT) and shall be fitted with a spring-loaded flipper-type safety latch.
 - o. Hoist shall have a duty rating suitable for the load class and load cycles of occasional use.
 - p. AGMA quality class 12 machine cut, hardened and precision ground hoist gearing. The gears inside the hoist gearboxes on models up to 5 ton capacity are lubricated by semi-fluid grease. On models over 5 ton capacity the gears inside the hoist gearbox are lubricated with semi-fluid grease or oil.
 - q. AGMA quality class 10, hardened and precision ground trolley drive gearing, lubricated by semi-fluid grease.
 - r. Trolleys shall have safety drop lugs and energy absorbing bumpers.
 - s. Any proposed equivalent shall meet or exceed the dimensional and performance specification of the above-mentioned products.
2. Bridge girder:
- a. Bridge girder shall be per capacities/dimensions above, as applicable.
 - b. Bridge girders shall be constructed from welded box girders or Structural beams, Steel, ASTM A36 or A992, as required.
 - c. High-strength bolted connections shall utilize SAE Grade 5 bolts with corresponding lockwashers and nuts, conforming to requirements of AISC S329 bolts. Bolts, nuts, and washers shall conform to ASTM 325 bolts. Galvanized bolts are not acceptable.
3. Bridge end trucks and bridge drive:
- a. End trucks shall be designed in accordance with CMAA specifications as applicable (reference appendix B)
 - b. End trucks shall be bolted to bridge girder.
 - c. Bridge drive shall be dual-motor (A-4 arrangement per CMAA).
 - d. Bridge drive shall be designed to stop the bridge within CMAA specifications.
 - e. End trucks shall be equipped with rail sweeps and energy-absorbing rubber bumpers.

- f. Travel limit switches to be provided as necessary for safe operation.
- g. Bridge shall be furnished with an adjustable frequency inverter drive and two-step or infinitely variable speed control for smooth acceleration and deceleration.
- h. Bridge motors shall be inverter duty motors with minimum class “F” insulation and motor enclosures shall be TENV [totally enclosed non-ventilated].
- i. AGMA quality class 10, hardened and precision ground bridge drive gearing, lubricated by semi-fluid grease.

2. Power supply

- a. Power supply for the hoist shall be 460 volt, 3 ph., 60 Hz. All power required for the operation of the hoist, trolley, and end trucks shall be developed from this source.
- b. Runway electrification shall be 4-bar safety type rigid conductors as manufactured by Insul-8, Duct-O-Wire Company or Wampfler. Wall mounted disconnect switch and power to runway conductors provided by the DB Entity.
- c. Cross bridge electrification shall be flat cable style festoon system with terminal box, multi-conductor cord, plug connectors (when available) and accessories. Cables are to be hardwired when plug connectors are not available.

3. Controls

The following controls shall be used as applicable:

- a. Six-way operation, plug-in pushbutton pendant suspended from independent festoon track. Radio control may be quoted as an option.
- b. Pendant shall include start (momentary) button and emergency stop (push to maintain, turn to release) that controls a mainline contactor in the bridge control panel.
- c. Pushbutton shall be clearly marked with hoist, trolley and bridge travel directions.
- d. Hoist shall be 2 speed magnetic reversing type (standard) or variable frequency inverter control (optional) and the trolley and bridge controls shall be variable frequency inverter control (standard), as required per above sections.
- e. Electrical control enclosures shall be IP55 or NEMA 4 type. Pushbutton enclosure shall have a rating of IP65, NEMA 4X, 4 or 5.

4. Labeling:

- a. Two capacity plates including the crane capacity in tons are required, one secured to each side of bridge crane. Each capacity plate shall be fabricated of steel or a quality/ fade-resistant stick-on label with letters large enough to be easily read from the floor. Capacity plates shall be placed in a location visible to pendant operator’s position after the crane has been installed.
- b. Readable warning labels shall be affixed to each lift block or control pendant in a readable position in accordance with ASME B30.16, ASME B30.2 and ASME B30.17. The word “warning” or other legend shall be designed to bring the label to the attention of the following information concerning safe-operating procedures: operating the hoist when the hook is not centered under the hoist; operating hoist with twisted, kinked or damaged rope; with a rope that

is not properly seated in its hoist drum groove; lifting people; lifting loads over people; and removing or obscuring the warning label.

5. Crane runway rail: Manufacturer to provide crane runway rail to match end truck wheel assembly and include crane stops as required.

B. Finish:

1. Bridge crane including bridge, trolley, hoist, and all attached items shall be painted (2-part epoxy) in accordance with the manufacturer's standard practices.
2. Bridge shall be shop cleaned, primed, and painted per manufacturer's standards.
3. The following items shall not be painted:
 - a. Rail surfaces in contact with wheels
 - b. Wheel running surfaces
 - c. Hoist wire rope
 - d. Conductor bar, festoon cables and supports

2.2 CRANE, BRIDGE, TOP RUNNING, 7.5 TON (EQ ID: 9126)

A. Manufacturer's reference:

1. Prime manufacturer: Specifications are based on equipment identified herein by manufacturer's name and model to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. R & M Materials Handling Inc., 4501 Gateway Blvd., Springfield, OH (937) 328-5100
 - (i) Model: QXSka7.5-Ton
2. Alternate manufacturers: Contingent upon compliance with these specifications and documentation requirements set forth in submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Mannesman Demag, Cleveland, OH (440) 248-2400
 - b. KCI Konecranes, Santa Fe Springs, CA (949) 248-549

B. General requirements:

1. Top running single girder electric overhead traveling cranes shall be designed and manufactured as per CMAA Specification #74, Revised 2000.
2. In addition the crane design and installation shall meet all the applicable local, state, and federal laws and OSHA regulations having jurisdiction.
3. Cranes shall operate in the given spaces and shall match the runway dimensions and rails indicated.

4. The crane shall be designed and manufactured to meet the appropriate service conditions based on the particular application. The crane service class shall be clearly indicated by the manufacturer at the time the crane proposal is submitted.

C. Capacities/Dimensions:

1. Lifting capacity: 15,000 pounds
2. Lower load block or assembly of hook, swivel bearing sheaves, pins and frames suspended by the hoisting ropes shall not be considered part of the rated capacity.
3. CMAA service class: Crane shall be designed and constructed to CMAA Specification #74 (revised 2004) for Class "C" service requirements and operation in a non-hazardous environment.
4. Crane dimensions - Field verify required dimensions prior to fabrication:
 - a. Span: Per plans
 - b. Runway length: Per plans
 - c. Clear hook height: Maximize hook height; at a minimum the crane shall be able to lift equipment loads from vehicle roofs.
 - d. Lift: Hoist design shall maximize hook coverage, hook vertical travel (i.e. end approach), and clear hook height (i.e. headroom). The use of a low headroom hoist is mandatory.
 - e. Rated speeds (FPM) $\pm 10\%$:
 - f. Hoist: Maximum high 20; Minimum low 3 FPM
 - g. Trolley: Maximum high 65; Minimum low 65 FPM
 - h. Bridge: Maximum high 130; Minimum low 130 FPM

D. Features/Performance/Construction:

1. Hoists and trolleys
 - a. All top running single girder cranes shall utilize low headroom electric wire rope hoists as manufactured by R&M Materials Handling Inc., Springfield, OH, or approved equal.
 - b. The hoist shall be equipped with an electro-mechanical load-limiting device that shall prevent lifting more than 110% of the rated load.
 - c. Hoist and trolley motors shall be per Capacities and Dimensions above, as applicable.
 - d. Hoisting motor(s) shall be two-speed/two winding squirrel cage type with a speed ratio of 6:1.
 - e. Hoisting motor(s) shall be totally enclosed with IP55 protection, minimum class F insulation, Klixon type bimetal switch for thermal protection and shall have a 60% ED rating.
 - f. Trolley shall be furnished with an adjustable frequency inverter drive and two-step or infinitely variable speed control for smooth acceleration and deceleration.

- g. Trolley motors shall be inverter duty motors with minimum class “F” insulation and motor enclosures shall be TENV [totally enclosed non-ventilated].
 - h. Rotary cam type limit switch equipped with 4 micro-switches shall be provided. Limit switch shall provide upper and lower limit of hoist travel, hoist slow down prior to reaching upper limit and phase sequence supervision at upper limit. An additional block operated limit shall be included.
 - i. Hoist motor brake shall be DC disc type with adequate torque to stop and hold over 125% of the hoist rated load.
 - j. Large diameter rope drum with a minimum of 36:1 drum to wire rope diameter ratio. Groove depth shall be at least 35% of rope diameter. The rope drum shall be equipped with a rope guide to help keep the rope aligned in the grooves of the drum.
 - k. Wire rope shall be constructed from galvanized steel having a minimum safety factor of 5.
 - l. Hoist reeving shall be single reeved. Lateral hook drift shall not exceed 1/8 inch per foot of vertical travel on single reeved models.
 - m. The hoist nameplate is to carry a CSA c/us rating. The actual hoist control enclosure rating shall be at least equivalent to IP55 / NEMA 4 type.
 - n. Hooks shall be made of forged alloy steel (34CrMo4QT or 34CrNiMo6QT) and shall be fitted with a spring-loaded flipper-type safety latch.
 - o. Hoist shall have a duty rating suitable for the load class and load cycles of Occasional Use.
 - p. AGMA quality class 12 machine cut, hardened and precision ground hoist gearing. The gears inside the hoist gearboxes on models up to 5 ton capacity are lubricated by semi-fluid grease. On models over 5 ton capacity the gears inside the hoist gearbox are lubricated with semi-fluid grease or oil.
 - q. AGMA quality class 10, hardened and precision ground trolley drive gearing, lubricated by semi-fluid grease.
 - r. Trolleys shall have safety drop lugs and energy absorbing bumpers.
 - s. Any proposed equivalent shall meet or exceed the dimensional and performance specification of the above-mentioned products.
2. Bridge girder:
- a. Bridge girder shall be per Capacities/Dimensions above, as applicable.
 - b. Bridge girders shall be constructed from welded box girders or Structural beams, Steel, ASTM A36 or A992, as required.
 - c. High-strength bolted connections shall utilize SAE Grade 5 bolts with corresponding lockwashers and nuts, conforming to requirements of AISC S329 bolts. Bolts, nuts, and washers shall conform to ASTM 325 bolts. Galvanized bolts are not acceptable.
3. Bridge end trucks and bridge drive:
- a. End trucks shall be designed in accordance with CMAA specifications as applicable (reference appendix B)

- b. End trucks shall be bolted to bridge girder.
- c. Bridge drive shall be dual-motor (A-4 arrangement per CMAA).
- d. Bridge drive shall be designed to stop the bridge within CMAA specifications.
- e. End trucks shall be equipped with rail sweeps and energy-absorbing rubber bumpers.
- f. Travel limit switches to be provided as necessary for safe operation.
- g. Bridge shall be furnished with an adjustable frequency inverter drive and two-step or infinitely variable speed control for smooth acceleration and deceleration.
- h. Bridge motors shall be inverter duty motors with minimum class “F” insulation and motor enclosures shall be TENV [totally enclosed non-ventilated].
- i. AGMA quality class 10, hardened and precision ground bridge drive gearing, lubricated by semi-fluid grease.

2. Power supply

- a. Power supply for the hoist shall be 460 volt, 3 ph., 60 Hz. All power required for the operation of the hoist, trolley, and end trucks shall be developed from this source.
- b. Runway electrification shall be 4-bar safety type rigid conductors as manufactured by Insul-8, Duct-O-Wire Company or Wampfler. Wall mounted disconnect switch and power to runway conductors provided by DB Entity.
- c. Cross bridge electrification shall be flat cable style festoon system with terminal box, multi-conductor cord, plug connectors (when available) and accessories. Cables are to be hardwired when plug connectors are not available.

3. Controls

The following controls shall be used as applicable:

- a. Six-way operation, plug-in pushbutton pendant suspended from independent festoon track. Radio control may be quoted as an option.
- b. Pendant shall include start (momentary) button and emergency stop (push to maintain, turn to release) that controls a mainline contactor in the bridge control panel.
- c. Pushbutton shall be clearly marked with hoist, trolley and bridge travel directions.
- d. Hoist shall be 2 speed magnetic reversing type (standard) or variable frequency inverter control (optional) and the trolley and bridge controls shall be variable frequency inverter control (standard), as required per above sections.
- e. Electrical control enclosures shall be IP55 or NEMA 4 type. Pushbutton enclosure shall have a rating of IP65, NEMA 4X, 4 or 5.

4. Labeling:

- a. Two capacity plates including the crane capacity in tons are required, one secured to each side of bridge crane. Each capacity plate shall be fabricated of steel or a quality/ fade-resistant stick-on label with letters large enough to be easily read from the floor. Capacity plates shall be placed in a location visible to pendant operator’s position after the crane has been installed.

- b. Readable warning labels shall be affixed to each lift block or control pendant in a readable position in accordance with ASME B30.16, ASME B30.2 and ASME B30.17. The word “warning” or other legend shall be designed to bring the label to the attention of the following information concerning safe-operating procedures: operating the hoist when the hook is not centered under the hoist; operating hoist with twisted, kinked or damaged rope; with a rope that is not properly seated in its hoist drum groove; lifting people; lifting loads over people; and removing or obscuring the warning label.
5. Crane runway rail: Manufacturer to provide crane runway rail to match end truck wheel assembly and include crane stops as required.

B. Finish:

1. Bridge crane including bridge, trolley, hoist, and all attached items shall be painted (2-part epoxy) in accordance with the manufacturer’s standard practices.
2. Bridge shall be shop cleaned, primed, and painted per manufacturer’s standards.
3. The following items shall not be painted:
 - a. Rail surfaces in contact with wheels
 - b. Wheel running surfaces
 - c. Hoist wire rope
 - d. Conductor bar, festoon cables and supports

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.
- C. Report in writing to the MBTA any damaged, missing, or incomplete scheduled equipment and improper rough-in or utility stub-outs.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the DB Entity or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer’s instructions:
 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.

2. **Fitting:** Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. **Anchorage:** Attach equipment as directed by the DB Entity or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. It shall be the responsibility of the manufacturer to provide grounding for the equipment to the nearest grounding electrode as shown on the electrical drawings.
 - D. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the DB Entity or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the DB Entity or designated representative for acceptance inspection.

3.5 TRAINING

- A. Direct the DB Entity to provide training to the designated MBTA's maintenance personnel in the operation and maintenance of the equipment. Coordinate, with the MBTA, the training schedule and list of personnel to be trained.
- B. The training period shall start after the system is functionally completed but prior to final acceptance. Course instructions shall cover pertinent points involved in operating, starting, stopping and servicing the equipment, including all major elements of the operations and maintenance manual. Course instructions shall demonstrate all routine maintenance operations such as lubrication and general inspections. The MBTA shall be given at least two (2) weeks advance notice for training.
- C. Obtain from the DB Entity, a list of the MBTA's personnel trained in equipment operations and maintenance.

3.6 FINAL ACCEPTANCE

- A. Final acceptance shall be granted when the following items have been satisfactorily completed:
 1. The equipment installation is complete.
 2. Equipment testing is complete and any and all deficiencies have been remedied.
 3. A spare parts list has been submitted.

4. Final versions of the operation and maintenance manual have been provided.
5. Equipment training is complete.

END OF SECTION

SECTION 16100

POWER UTILITY COORDINATION FOR THE TRACTION POWER SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work included: This section specifies the coordination requirements between the DB Entity, the MBTA and EVERSOURCE.
- B. Each Traction Power Substation (TPSS) (Red Bridge and Pearl Street (formerly Gilman Square)) will be supplied power from the local utility company (EVERSOURCE Electric) at 13.8kV. The main equipment within each TPSS will be the MBTA owned equipment and coordination with EVERSOURCE is therefore required. All equipment required by EVERSOURCE in relation to accepting these power supplies at each Substation is the responsibility of this contract.
- C. EVERSOURCE interfaces include:
 - 1. 13.8kV Utility power infeeds at each TPSS (except Ball Square).
 - 2. 13.8kV AC switchgear line circuit breakers, controls and relay protection.
 - 3. 13.8kV AC switchgear line metering equipment.
 - 4. 13.8kV EVERSOURCE grounding and test device
 - 5. EVERSOURCE revenue metering equipment requirements at each TPSS. Refer to specification 16311 2.1.G and Appendix A of this section.
 - 6. TPSS relay and protection coordination study.
- D. The requirements related to EVERSOURCE's interfaces for the traction power system are laid out in these specifications. Compliance with the specifications and the associated submittals shall meet the interface requirements stated above.
- E. Submissions of information to EVERSOURCE related to these interfaces and requirements will be by the MBTA. The Design-Builder shall allow an additional 4 weeks for the review the affected submittals to allow time for the EVERSOURCE review to be completed.
- F. Related work: Refer to the following sections:
 - 1. Related requirements are included in, but not limited to, the following sections.
 - a. Section 16201, Basic Materials and Methods for Electrical Work for the Traction Power System
 - b. Section 16203, Traction Power Equipment General Requirements
 - c. Section 16300, Ductbanks and Ductbank Manholes for the Traction Power System
 - d. Section 16311, Traction Power Electrical Equipment
 - e. Section 16495, Electrical Acceptance Tests for the Traction Power System

1.2 SUBMITTALS

- A. Provide submittals in accordance with Volume 2 Technical Provisions Subsection 2.8, Construction Submittal Requirements.
- B. The following submittals shall be required to be submitted for the acceptance of EVERSOURCE and the MBTA in accordance with Contract Technical Provision Subsections 2.7 and 2.8.
 - 1. Manhole details
 - 2. Ductbank details
 - 3. Revenue metering equipment, layout and connections
 - 4. Cable pulling calculations
 - 5. Ductbank and manhole layouts
 - 6. Product submittals for all components proposed to be used by the Design-Builder.
 - 7. Power system protection coordination studies and relay settings including a PE stamped executive summary document clearly stating all information:
 - a. Table of contents
 - b. Executive summary
 - c. Input data report
 - d. Short circuit study report
 - e. Equipment evaluation
 - f. Analysis of the time current curves
 - g. Time current curves
 - h. Protective device setting reports
 - i. Protective relay setting schedules
 - j. One-Line diagram
 - 8. Electrical Equipment in accordance with Specification Section 16311. Including 13.8kV switchgear submittals for metering and circuit breakers – layouts, schematic and wiring details, and 13.8kV switchgear EVERSOURCE ground and test device.
- C. The MBTA will provide all relevant submittals to EVERSOURCE for review. The MBTA review period for submittals shall be extended by four weeks to allow EVERSOURCE to provide comments on all relevant submittals. The MBTA will identify the submittals which will be forwarded to EVERSOURCE for their review.

1.3 SCOPE OF WORK AND WORK LIMITS

- A. The DB Entity shall develop all required information and coordinate with the MBTA to make utility applications to ensure that Eversource work orders are in place in a timely manner to facilitate the project. Any existing work orders a, active or inactive, shall be the responsibility of the DB Entity to progress, replace, modify or cancel as necessary.
- B. The DB Entity shall coordinate the work limits with EVERSOURCE and the MBTA.

- C. DB Entity shall install all manhole and ductbanks from the EVERSOURCE-MBTA demarcation point to each traction power substation. Expected demarcation is the EVERSOURCE manhole on public property. The DB Entity shall install all infrastructure on MBTA property.
- D. DB Entity shall install and connect all electrical equipment within the MBTA substation.
- E. Coordination is required to connect the utility metering equipment to EVERSOURCE requirements.
- F. EVERSOURCE will supply and install the AC incoming supply cable in the DB Entity installed ductbanks and manholes. EVERSOURCE will terminate the cables at the AC switchgear. MBTA, DB Entity and EVERSOURCE shall coordinate the schedule for all activities, scheduling shall be DB Entity led.

1.4 RESPONSIBILITIES

A. Limits of EVERSOURCE responsibility:

1. EVERSOURCE is responsible for (but not limited to):

a. General:

- 1) Review of AC switchgear submissions for incoming line breakers and all associated control, relays, protection and indications, and ground and test devices.
- 2) Review of all utility metering equipment submittals
- 3) Provision of utility line fault data for use in the relay protection & coordination study.
- 4) Inspection of DB Entity installed facilities to ensure compliance with EVERSOURCE requirements.
- 5) EVERSOURCE to supply the revenue meters (wireless).
- 6) Review and acceptance of testing & commissioning reports.
- 7) Review and acceptance of relay coordination and protection setting reports.

b. Red Bridge:

- 1) Providing interface manhole in Water Street.
- 2) Providing ductbanks from EVERSOURCE Sta. 850 to the interface manhole in Water Street.
- 3) Support to EVERSOURCE for installing power cables from EVERSOURCE power source to EVERSOURCE interface manhole.

c. Pearl Street

- 1) Providing interface manhole in School Street.
- 2) Providing ductbanks from EVERSOURCE supply substation to the interface manhole in School Street.
- 3) Support to EVERSOURCE for installing power cables from EVERSOURCE power source to EVERSOURCE interface manhole.

- B. The DB Entity is responsible for:
1. Coordination and changes to Eversource work orders as necessary including support to the MBTA for all related matters.
 2. Compliance with Eversource technical requirements.
 3. Coordination with Eversource for utility fault information in order to complete studies and equipment assessments.
 4. 13.8kV Switchgear and associated submittals.
 5. Relay protection and coordination study.
 6. Procurement, installation of 13.8kV manholes and ductbanks from utility interface point to each TPSS.
 7. If required by EVERSOURCE, procurement, installation and termination of high voltage 13.8kV cables from utility interface point to each TPSS, under EVERSOURCE supervision
 8. If required by EVERSOURCE, splicing utility power cables in the interface manhole, under supervision of EVERSOURCE personnel.
 9. Procurement, installation and connection of utility metering equipment, cables and conduits. See Appendix A for revenue metering requirements.
 10. Providing 120V ac supply to the EVERSOURCE revenue meters.
 11. Testing and commissioning.
 12. Scheduling and notifying all parties in advance of work commencement.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Refer for specifications 16300 and 16311 for equipment and product requirements.
- B. Refer to appendix A of this section for the layout and typical requirements of the revenue metering panel.

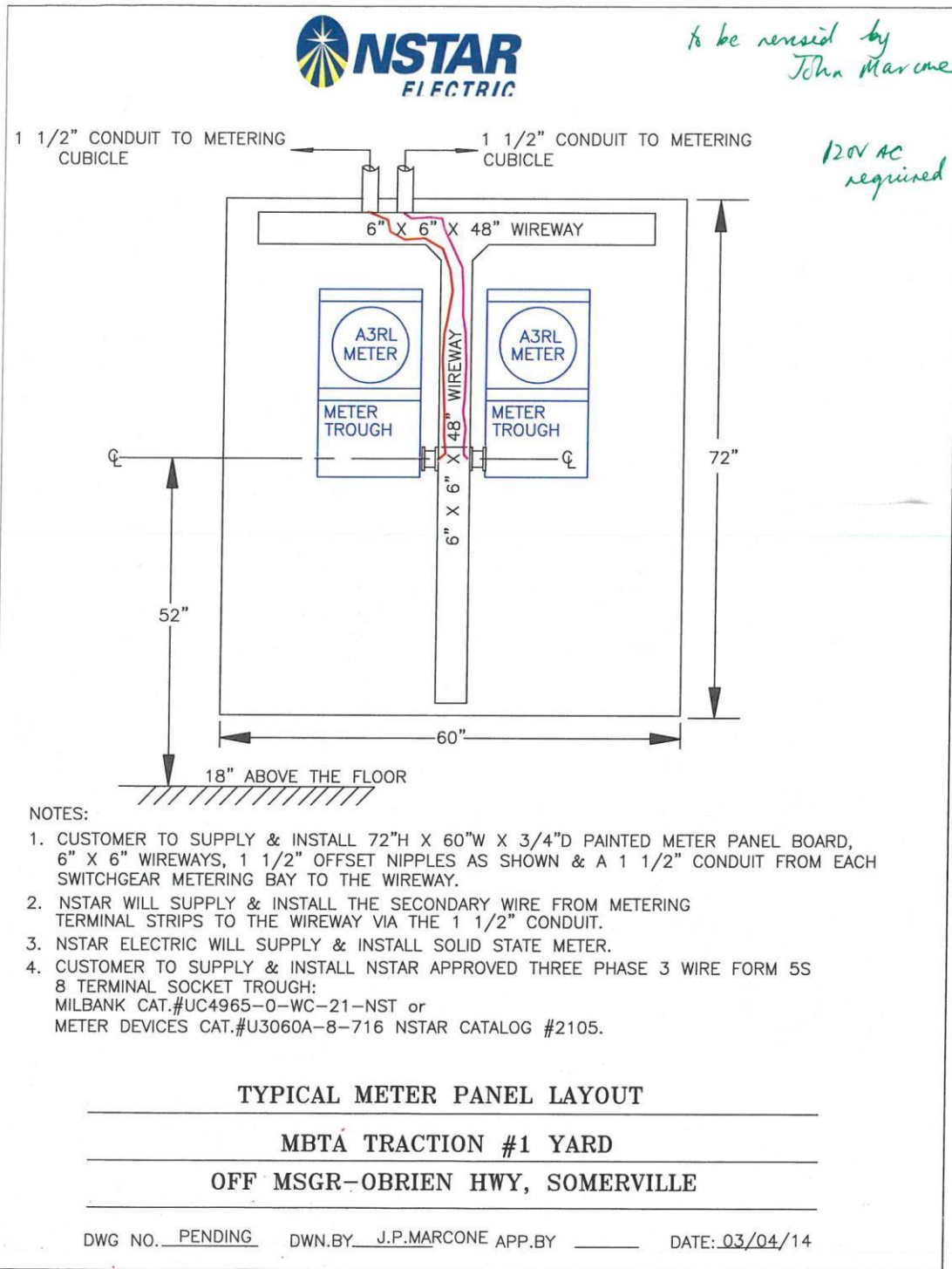
PART 3 - EXECUTION

3.1 GENERAL

- A. Refer for specifications 16300, 16311 and 16495 and this Section for equipment installation and testing requirements.

APPENDIX A

EVERSOURCE Typical Revenue Metering Panel Layout at MBTA Traction Power Substations.



END OF SECTION

SECTION 16120

MEDIUM VOLTAGE POWER CABLE FOR THE TRACTION POWER SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing, installing and testing of medium voltage power cable including cable terminations.
1. Medium voltage power cable includes the following:
 - a. 15kV EPR insulation, PE covered cable (133% insulation) for MBTA use (Ring Feeder Cables, Units Substation Feeder cables and Rectifier Transformer Feeder Cables).
 - b. Utility Supply Cables supplying MBTA substations.
 - 1) Eversource shall supply and install cable from the utility interface point to the Eversource/MBTA interface point. The interface point shall be within the last utility manhole before the traction power substation. Eversource shall splice the cable in the manhole.
 - 2) The DB Entity shall supply and install the cable and accessories (identical to the Eversource cable, see Appendix A) from the last manhole to the AC switchgear in the traction power substation. DB Entity shall terminate cable at the AC switchgear and test the cable.
- B. The medium voltage power cables shall be installed aerially or in conduits as stated in the accepted Drawings. Aerial cables shall be supported on a copperweld messenger wire.
- C. Related works are included in, but not limited to, the following Sections:
1. Section 16201: BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK FOR TRACTION POWER SYSTEM.

1.2 REFERENCES

- A. ANSI/IEEE C2, National Electrical Safety Code.
- B. ICEA (Insulated Cable Owners Association) standards including S-93-639 and S-97-682
- C. IEEE 48, Test Procedures and Requirements for High Voltage Alternating Current Cable Terminations.
- D. UL 1072, Medium-Voltage Power Cables
- E. ASTM B-496
- F. NETA (National Electrical Testing Association)
- G. MBTA Standard Specifications (reference numbers to be advised)
- H. EVERSOURCE Material Standard M1601

1.3 SUBMITTALS

- A. Submittals shall be in accordance with Volume 2 Technical Provisions Subsections 2.7 and 2.8, except as modified herein.
- B. Product Data/Catalog Cuts
 - 1. Cable
 - a. Include data on manufacturer's cold weather temperature limitations.
 - 2. Stress cones / Cable Terminations
 - 3. Fire proofing tape (See MBTA Standard Specifications for requirements)
 - 4. Cable Splices – as applicable
- C. Cable Test Reports
 - 1. Manufacturer's standard physical and electrical test reports.
 - a. Submit test reports (minimum of 2 weeks) prior to shipment of cable from manufacturer.
 - 2. Field Tests
 - a. Independent testing company shall submit testing procedure a minimum of two (2) weeks prior to testing and written reports no later than two (2) weeks after testing was performed.
- D. Certificates of Compliance
 - 1. Cable
 - a. Submit certificates of compliance prior to shipment of cable from manufacturer.
- E. Manufacturer's Instructions
 - 1. Cable terminating procedures.
 - 2. Cold weather installation procedures for cable.
 - 3. Cable splicing procedures, as applicable.
 - 4. Cable shield installation and termination procedures.

1.4 DELIVERY, HANDLING, TRANSPORTATION, STORAGE AND PROTECTION

- A. Delivery, handling, transportation, storage and protection shall be in accordance with Contract Technical Provisions Exhibit 21, except as modified herein.
 - 1. Cable shall be unloaded in a manner such that the unloading equipment used does not come into contact with the cable surface and protective wrap.
 - 2. Cable reels shall be stored on a hard surface so that the flanges do not sink into the soil and allow the weight of the reel and cable to rest on the cable surface.
 - 3. Cable reels shall be stored in an area where construction equipment, falling or flying objects or other material shall not come into contact with the cable, and where chemicals, and petroleum products shall not be spilled or sprayed on the cable.
 - 4. Cable shall be stored in an area away from open fires and sources of high heat.

5. When a reel of cable is to be rolled from one point to another, the surface over which the reel of cable is to be rolled shall be examined for objects which could contact and damage the cable surface or protective wrap.
 - a. Remove objects prior to moving the reel of cable.
6. If a length of cable has been cut from the reel, the cable end shall be immediately resealed to prevent the entrance of moisture.

1.5 QUALITY ASSURANCE

A. Environmental Requirements

1. When cables are to be installed in cold weather, the cables shall be stored in a heated area for a minimum of 24 hours prior to installation.
2. Cold weather temperature installations shall be in accordance with the manufacturer's recommendations. Submit manufacturer's cold weather temperature limitation data, including, but not limited to, data on temperature ranges.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. The cable shall be suitable for use in wet and dry locations in conduit and underground duct systems.
- B. The cable shall be rated for 90°C normal, 130°C emergency and 250°C short circuit operating conditions.
- C. Utility Supply Cables Feeding MBTA Substations
 1. The DB Entity shall supply and install cable from the utility interface point to the MBTA substation.
 2. DB Entity shall terminate cable at the AC switchgear and shall provide all cable supports, terminations and accessories.
 3. The infeed cable connecting to the EVERSOURCE supply cable at the EVERSOURCE/MBTA interface point shall match the EVERSOURCE cable being installed.
 4. EVERSOURCE shall supply the cable splice, and splice the cables in the manhole at the EVERSOURCE/MBTA interface point. DB Entity shall provide support as necessary.
 5. 700 kcmil flat strap primary Copper cables in accordance with EVERSOURCE material specification M1601 included in Appendix A of this Section.

2.2 ETHYLENE-PROPYLENE RUBBER INSULATED CABLE

- A. MBTA Cable shall be as follows:
 1. Between 15kV AC switchgear and the Rectifier Transformer
 - a. 350kcmil three 1-phase, shielded, ethylene-propylene rubber insulated cables rated 15 kV, 133% insulation.
 2. Ring Feeder / MBTA distribution feeders

- a. 500kcmil three 1-phase, shielded, ethylene-propylene rubber insulated cables rated 15 kV, 133% insulation. Where installed aerially, the installation shall comprise the 3 1-phase cables per circuit supported on the same messenger wire. The cable shall be suitable for use aerially or underground in ductbanks.
- 3. Unit Substation Feeders
 - a. #4/0AWG three 1-phase, shielded, ethylene-propylene rubber insulated cables rated 15 kV, 133% insulation. Where installed aerially, the installation shall comprise the 3 1-phase cables per circuit supported on the same messenger wire. The cable shall be suitable for use aerially or underground in ductbanks.
- B. Basic Construction: Basic construction shall be 3-1/C Class B strand copper, extruded semiconducting ethylene-propylene rubber strand shield, EPR insulation and semiconducting ethylene-propylene rubber insulation shield, copper shield tape/concentric neutral, binder tape and covered with low smoke zero halogen jacket or PE jacket. The cable shall be rated for use on the MBTA 15 kV system in accordance with MBTA Standard Specifications (reference number to be advised).
- C. Conductor Shield
 - 1. Conductor shield shall be an extruded layer of semi-conducting EPR thermosetting compound applied directly over the conductor and shall have a volume resistivity not in excess of 100-ohm meters at 90°C.
 - 2. The compound shall have a minimum elongation after an air oven test at 136°C for 168 hours of 100% and a brittleness temperature not warmer than minus 40°C.
- D. Insulation
 - 1. Insulation shall be a red colored flexible thermosetting dielectric based on an ethylene-propylene elastomer. The ethylene content of the elastomer used in the insulation compound shall not exceed 72% by weight of ethylene nor contain polyethylene.
 - a. The insulation shall be compounded by the cable manufacturer in their own facility using a closed system.
 - b. Ingredients shall be mixed, screened through a 120 mesh screen pack and then treated with an accelerator or cross linking agent to insure complete blending and uniformity of the final compound.
- E. Insulation Thickness
 - 1. The minimum average insulation thickness shall be as specified. The minimum thickness at a cross-section of the insulation shall not be less than 90% of the specified minimum average thickness.

Minimum Average Insulation Thickness, mils		5 Minute AC Withstand kV		15 Minute AC Withstand kV	
100%	133%	100%	133%	100%	133%
175	220	35	44	70	80

F. Insulation Screen

- G. The insulation screen shall be an extruded semiconducting EPR compound. The extruded shield must be clean stripping and have a peel strength from the insulation between 6 and 18 pounds per half-inch width.
- H. The thickness of the insulation screen shall be per AEIC standards, and shall be continuously printed with contrasting colored ink, "semiconducting- remove when splicing or terminating."
- I. Metallic Shield/Concentric Neutral
 - 1. The insulation semiconducting shield shall be covered with an uncoated copper tape. The uncoated copper tape shall be applied helically with 12.5% overlap.
 - 2. A concentric neutral comprising flat copper straps or metallic shield shall be applied over the bare copper tape.
- J. Jacket
 - 1. A low smoke zero halogen thermoplastic jacket shall be extruded over the copper tape shield/concentric neutral. The jacket color shall be black.
 - 2. An identifying legend shall be printed on the jacket in contrasting ink with the following information: manufacturer, plant number, conductor size, conductor material, EPR, UL type MV- 105, voltage, insulation thickness and year of manufacture. Indent printing may be substituted for ink marking.

2.4 STRESS CONES

- A. Stress relief cones shall be manufactured by G & W Electric Specialty Co., Thomas & Betts, Raychem, or approved equal. Cable manufacturer shall recommend the cable terminations for use with the cable. DB Entity shall submit proposed cable terminations.
- B. Connectors shall be long barrel compression type.
- C. Cable terminations shall be rated at 15 kV phase to phase.

2.5 FIRE PROOFING TAPE

- A. Fire proofing tape shall be manufactured by 3M Company, Scotch Brand 77; Plymouth Brand Ply-Are; Elastimold, fire and arc proofing tape, or approved equal. Refer to MBTA Standard Specifications for further requirements. Cable manufacturer shall recommend the cable terminations for use with the cable. DB Entity shall submit proposed cable terminations.

2.6 AERIAL CABLE

- A. The messenger wire shall be high strength copperweld wire. Unless otherwise specified, the messenger size shall be based on 150 foot spans at equal elevation and heavy loading conditions or per the Design Documents and OCS pole spacing.
- B. The messenger shall be applied parallel to the cable axis and bound by a strap covered with min. 40mils of PVC. The dimensions and material for the binder strap shall be determined by the manufacturer for agency approval.
- C. The assembled cable shall be tightly wound on take-up reels so that the messenger is parallel and equal in length to the cable axis.

2.7 SOURCE QUALITY CONTROL

- A. Cable Testing
 - 1. Cable shall receive the manufacturer's standard physical and electrical tests prior to shipment from the factory. Testing, shall be in accordance with ICEA S-68-516.
 - a. Conductor resistance: In accordance with AEIC, paragraph 1.2
 - b. AC withstand (5 minutes): 15 kV - 44 kV
 - c. IR constant (at 15.6°C), minimum: 50,000 megohms/MFT
 - d. DC withstand (15 minutes): 15 kV - 80 kV

PART 3 - EXECUTION

3.1 INSTALLATION

- A. The cable installation shall be in accordance with Section 16201 and MBTA Power Division standard specifications, except as modified herein.
- B. Hardware
 - 1. Hardware shall be assembled and installed as shown on accepted drawings. Nuts shall be tightened with locknuts and cotter pins properly installed. Nuts and cotter pins shall be oriented toward the pole or downward as applicable.
 - 2. Hardware shall be inspected for missing parts and visual defects prior to installation. All metal shall be free of dirt, corrosion or damage to the galvanizing.
- C. Cable Stringing
 - 1. Cables shall be handled with care. Cables shall not be run over by vehicles or any other object that could damage the insulation or conductors. Each reel shall be examined for cuts, kinks, or other damage. Damaged portions shall be removed and replaced or repaired as directed by the MBTA.
 - 2. Temporary guard structures shall be installed as required to maintain adequate clearance over roads and other lines.

3. Scrap materials such as timbers or other supports, shall be gathered up and disposed of in a manner satisfactory to the MBTA. The scrap cable pieces shall be salvaged and returned to the MBTA.
4. The cable shall be inspected continuously as it leaves the reel. If severe cuts are detected, the stringing operation shall be stopped until the damage is repaired. Repair sleeves may be used only with permission of the MBTA. Damaged cable shall not be installed without re
5. No splices shall be permitted in spans over road crossings. In other spans, only one splice per span will be permitted in each wire and this splice shall not be within 10 feet of any structure. Splices shall not be pulled through stringing sheaves or sagging blocks.
6. Stringing tension shall be adjusted to correspond to the conductor temperature as recommended by the manufacturer. The conductor temperature shall be measured after taping a bulb type thermometer in contact with the bare conductor and shading the thermometer from direct sunlight. The DB Entity shall record conductor temperature and tension at each end of the cable length and any temperature variations during sagging operation. These records shall be retained and copies submitted daily to the MBTA. All cables in the same span, whether existing or new, shall be sagged evenly. The DB Entity shall correct any cable length installed at incorrect tension.
7. All equipment such as sheaves, clamps, pulling devices, and tension stringing equipment shall be in good condition. Any such equipment that, in the opinion of the MBTA could result in damage to the cables shall be removed from the work site.
8. Stringing blocks shall be properly mounted on the pole or crossarm in such a manner that no binding shall occur while stringing. Stringing blocks that are not properly maintained shall not be used and shall be removed from the job site.

D. Aerial Cable Splicing and Terminating

1. The DB Entity shall splice the aerial cables as described herein.
2. In order to obtain optimum electrical contact and adequate insulation at the points of connection of each cable, only the most highly skilled cable splicers shall be employed. Cable splicers shall have experience in making splices of similar cables for similar applications. The DB Entity shall submit the name of the individual, with the number of years and type of experience on similar projects. The DB Entity shall obtain prior approval of all individuals who will be making splices.
3. Each splicer shall be accepted for the job by the MBTA prior to any splicing activities. The MBTA may request the splicer to make test splices in the presence of the MBTA before the acceptance is granted.
4. All faulty, imperfect, or damaged splices found during or after installation, shall be removed and replaced. New splices shall be subject to the same tests as are required for the cables after initial installation.
5. The DB Entity shall splice the aerial cables using a full tension compression type connector recommended by the cable manufacturer for the conductor size and expected service conditions and shall cover the joint and seal the cable insulation using heat shrinkable insulating tubing.
6. Full tension cable splices shall be installed with the cable laid out in a straight line for approximately 10 feet on each side of the connection.
7. Ends of the aerial cable shall be sealed or terminated at equipment as shown on the Design Documents.

- E. Stress Cones
 - 1. Stress relief cones shall be made at cable terminations in 15 kV switchgear, at transformers, outdoor load centers and 15 kV switches.
 - 2. Terminations shall be made in accordance with cable manufacturer's instructions, with high-voltage, ozone-resistant self-fusing tape.
 - 3. For Utility infeed cables, ring feeder cables and unit substation feeder cables, the shields shall only be grounded at one end. The grounded ends shall be as shown in the Design Documents. The shield at the opposite end of each cable shall be pulled back and insulated for possible future connection if required.
- F. Splices will not be permitted in the 15 kV cable, except at designated manholes.
- G. Splicing procedures, if allowed, shall be in accordance with the manufacturer's instructions.
- H. Fireproofing of Cables
 - 1. All terminations and open cables (cables in manholes and junction boxes) shall be fireproofed with fire proofing tape.
 - 2. All splices shall be wrapped with fire proofing tape.
- I. Cable Identification Tags
 - 1. Install standard cable tags on all feeder cables at the feeder tap locations. The aerial cable tag shall be the standard MBTA embossed aluminum tag and will identify the power section. The cable tag in switch boxes shall identify the cable number as described in the Mandatory Specifications and to MBTA Standards of cable identification.

3.3 TESTING

- A. General
 - 1. The DB Entity shall provide all instruments, materials, and labor required for tests specified herein on the dc traction feeder cable furnished and installed for the Project.
 - 2. The DB Entity shall formulate an overall test program for the installation, which shall include, but not be limited to, the tests specified in this Section to ensure equipment and material compliance with the relevant standards, this specification and satisfactory and reliable performance in actual intended operation.
- B. Conditions for Tests
 - 1. Prior to testing of any cable and the installation, the following conditions shall be fulfilled by the DB Entity:
 - a. The DB Entity shall have in his possession, all the shop drawings duly accepted by the MBTA.
 - b. The DB Entity shall have submitted testing procedures for the MBTA's acceptance at least 45 days in advance of the testing.
- C. Witnessing Tests
 - 1. The MBTA will witness complete field- testing on all cable installations.

2. Responsibility

- a. The DB Entity shall assume full responsibility during field-testing of all cable installation provided under the Contract Documents. Should there be any loss or damage to such cable or installation as a result of these tests, the DB Entity shall be fully responsible for replacing the damaged cable. Replacement of damaged cable shall include all costs, including, but not limited to, removal of damaged cable, furnishing of, transportation of, and installation of replacement cable.

D. Rejection and Retesting

1. Failure of cable or splice to withstand tests or to meet ratings shall be sufficient grounds for rejection of the item tested.
2. Any cable or splice rejected shall be retested in the presence of the MBTA after rectification.
3. If it is not possible to rectify rejected cable to the satisfaction of the MBTA, new cable shall be installed.

E. Costs of Tests

The price for conducting all field tests and checkouts in the presence of the MBTA, including entire cost of rectification, retesting, and/or supplying of new items shall be deemed to be included in the Contract Price.

F. Field Tests

1. All DB Entity installed cables shall be tested to ascertain that the cable insulation has not been impaired during installation, that splices and terminations are properly made, and demonstrate that the integrity of the cable system prior to energization is adequate.
2. The DB Entity shall perform continuity tests, insulation resistance tests, high-potential tests on each cable installed. Each circuit shall be tested separately while other equipment is grounded.
3. Tests after cable installation shall be performed with latest NETA-ATS by the independent test company. Refer to Mandatory Specifications 16495 and 16311 for requirements.
4. Independent testing company shall submit testing procedure a minimum of four (4) weeks prior to testing and written reports no later than two (2) weeks after testing was performed.

APPENDIX A

EVERSOURCE MATERIAL SPECIFICATION – M1601

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M1601R5

*** Supersedes: BECO E2.9-27.4 and COM 1-0696, 2-0196, & 5-0385 ***

#2 AWG to 1000 KCMIL CONCENTRIC NEUTRAL JACKETED CABLES
RATED 5 - 35 kV

1.0 Scope

These Specifications cover single conductor "Tree Retardant" Crosslinked Polyethylene Insulated (TRXLP) and Ethylene Propylene Rubber (EP Rubber or EPR) Insulated Concentric Neutral Jacketed Cables having either a "standard" or "reduced" overall diameter. These Cables shall be suitable for installation in underground ducts and direct burial in earth in wet and dry locations. The operating voltages and system BIL levels shall be as follows:

<u>Cable Voltage Rating</u>	<u>System Voltage</u>	<u>System BIL</u>
5 kV	2.4/4.16 kV & below	65 kV
15 kV	8.0/13.8 kV & below	110 kV
25 kV (NSTAR South)	13.2/22.9 kV	150 kV
25 kV (NSTAR North)	13.8/24.0 kV	125 kV

- The general system category is in accordance with Table 4-4, Note C of ANSI ICEA S-94-649 (i.e., 100% level).
- 35 kV rated cable will be used at the 13.2/22.9 kV voltage level

2.0 General

2.1 The cable shall be manufactured and tested in accordance with the latest edition of the ANSI/ICEA Standard S-94-649 "Standard for Concentric Neutral Cables Rated 5 through 46 kV" and AEIC Specification CS-8 except as otherwise required by this material specification.

2.2 If a conflict occurs between any of the Standards, Specifications and Publications referenced herein, they shall supersede each other in the following order of priority, except that the referenced AEIC Specification shall take priority over ICEA/ANSI for the Materials Qualification Test.

- A. NSTAR Material Specification M1601 R5
- B. ANSI/ICEA S-94-649
- C. AEIC CS8

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2.0 General, cont'd

Conductors shall be in accordance with the following, as specified by the Purchase Order:

Aluminum

- #1 AWG – 1/0 AWG Solid Aluminum
- 4/0 AWG – 1000 kcmil, Class B Compressed Stranded Aluminum

Copper

- #2 AWG – 4/0 AWG, Class B Compressed Stranded Bare Copper
- 250 kcmil - 1000 kcmil, Compact Round Stranded Bare Annealed Copper

3.0 Conductor Shield (Stress Control Layer)

For cables having compact round conductors, the manufacturer may reduce the conductor shield thickness in accordance with the referenced ANSI/ICEA Standard, paragraph 3.2.1.

4.0 Insulation

- 4.1 Insulation materials shall be qualified by the manufacturer in accordance with AEIC CS8 and specifically approved by the Company. Cables shall have either TRXLP or EPR insulation as specified in the cable ordering specifications on the purchase order. Specific compound or formulation shall be subject to Company approval. AEIC Qualification Long Form Test Report shall be submitted for this approval. Compound supplier and formulation must also be provided and is not subject to change without Company authorization.
- 4.2 The insulation thickness and diameter over the insulation for #2 AWG, #1 AWG, 1/0 AWG, 4/0 AWG, 250 kcmil, 500 kcmil, 750 kcmil and 1000 kcmil 5kV - 35 kV "standard diameter" cables shall be in accordance with the referenced ANSI/ICEA Standard. The 133% level of insulation shall be furnished for #2 AWG & #1 AWG 15 kV cables and 4/0 AWG 5 kV cables while all other 5 kV – 35kV cables shall have the 100% level of insulation.

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4.0 Insulation, cont'd

4.3 The insulation thickness for 1000 kcmil copper "standard diameter" 15kV and 25 kV cables having the 100% level of insulation shall be in accordance with the referenced ANSI/ICEA Standard except that the diameter over the insulation for the 25kV cable shall be 1.605" minimum to 1.700" maximum.

4.4 The Minimum, Maximum and Nominal Insulation Thickness and diameter over the insulation for "reduced" diameter" cables shall be in accordance with the following:

<u>Conductor Size/ Voltage Rating</u>	<u>Minimum Point</u>	<u>Maximum Point</u>	<u>Nominal</u>
350 - 700 kcmil, 15 kV**	0.155"	0.195"	0.165"
350 - 700 kcmil, 25 kV**	0.230"	0.275"	0.240"

Diameters over the Insulation for "Reduced Diameter" Cables

<u>Conductor-Voltage, Ins. Tk</u>	<u>Minimum</u>	<u>Maximum</u>
350 kcmil cpt-15 kV, 0.165" Nom.**	0.965"	1.050"
500 kcmil cpt-15 kV, 0.165" Nom.**	1.070"	1.155"
700 kcmil cpt-15 kV, 0.165" Nom.**	1.235"	1.325"
350 kcmil cpt-25 kV, 0.240" Nom.**	1.110"	1.195"
500 kcmil cpt-25 kV, 0.240" Nom.**	1.235"	1.325"
700 kcmil cpt-25 kV, 0.240" Nom.**	1.385"	1.480"

** Insulation and jacket thickness have been reduced to fit into existing conduit

5.0 Extruded Insulation Shield for 15kV to 35kV Cables

5.1 The Insulation Shield for 15 kV to 35 kV rated cables shall comply with the referenced ANSI/ICEA Standard except that the Thickness and Indent Requirements for all 250 kcmil – 1000 kcmil copper conductor cables shall be as follows: (The Minimum Point Thickness does not apply to locations at metallic shield indents)

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5.0 Extruded Insulation Shield for 15kV to 35kV Cables – cont'd

<u>Minimum Point</u>	<u>Maximum Point</u>	<u>Maximum Indent</u>
0.024"	0.048"	0.015"

5.2 Metallic Shield grooves or indents on the outer surface of the insulation shield shall not appear on the outer surface of TRXLP cables and shall not exceed a depth of 0.003" on EPR cables.

6.0 Semi – Conducting Fabric Tape Insulation Shield (5 kV Cables Only)

6.1 For 5 kV rated cables only, the insulation shield shall be a black semi – conducting fabric tape that is conspicuously labeled "semi – conducting" over its entire length. The tape shall be applied so that it can be removed without leaving traces of semi conducting material on the underlying insulation. The manufacturer shall not apply a semi-conducting coating or paint to the surface of the underlying insulation.

6.2 The semi – conducting tape insulation shall not protrude or indent inward toward the conductor from the outer surface of the insulation by more than 0.005" on EPR cables.

7.0 Marker Tape

Cables having a "reduced" overall diameter shall have the Company Name and Year of Manufacture durably applied to a longitudinal, non-hydroscopic marker tape applied directly over the insulation shield. This marker tape may be applied to, but is not required for, cables having a "standard" overall diameter.

8.0 Concentric Neutral

8.1 The concentric neutral for #2 AWG copper and #1 AWG - 1000 kcmil aluminum cables shall consist of a serving of round annealed bare copper wires in accordance with the following table:

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8.0 Concentric Neutral- cont'd

<u>Conductor Size & Voltage Rating</u>	<u>Concentric Neutral X-Section (Appx) Equivalent</u>	<u>Concentric Wires Number & Size</u>
15 kV, #2 AWG Copper	#2 AWG Cu	16 - #14 AWG
15 kV, #1 AWG Aluminum	#4 AWG Cu #3 AWG Cu*	10 - #14 AWG 13 - #14 AWG*
15 kV, 4/0 AWG Aluminum	#3 AWG Cu	12 - #14 AWG
25 kV 1/0 AWG Aluminum	#2 AWG Cu 24.66 kcmil Cu **	16 - #14 AWG 6 - #14 AWG**
25 kV 500 kcmil Aluminum	1/0 AWG Cu	16 - #12 AWG
35 kV 1000 kcmil Aluminum	258.5 kcmil Cu	25 - #10 AWG
* Acceptable Alternative	**When specifically Specified	

8.2 The concentric neutral for 4/0 AWG - 1000 kcmil copper cables shall consist of flat annealed bare or tinned copper straps. The concentric neutral cross section area shall be equivalent to #2 AWG Copper for 4/0 AWG - 500 kcmil cables and 1/0 AWG copper for 700 kcmil - 1000 kcmil cables.

9.0 Jacket

9.1 The jacket thickness for "standard" and "reduced" diameter cables, as measured over the round wires or flat straps shall be in accordance with the following, unless otherwise specified by the Company's Purchase Order.

<u>Conductor-Voltage Rating</u>	<u>Overall Diameter</u>	<u>Minimum Point Thickness</u>	<u>Maximum Point Thickness</u>
4/0 - 500 kcmil - 5 kV	Standard	0.040"	0.075"
#2-750 kcmil-15 kV	Standard	0.045"	0.080"
1000 kcmil-15kV, 25 kV, & 35 kV	Standard	0.070"	0.120"
350-700 kcmil-15 kV & 25kV**	Reduced	0.025"	0.050"

** Insulation and jacket thickness have been reduced to fit into existing conduit

9.2 Jackets over round wire concentric neutral wires for "standard" diameter cables shall be extruded to fill. The material shall be linear low-density polyethylene.

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- 9.3 Jackets over flat strap concentric neutral wires for "standard" diameter cables shall be sleeved and vacuum drawn to, as much as practical, fill the spaces between the flat straps. The portion of jacket material between the flat straps that is in contact with the insulation shield shall be free stripping. The material shall be linear low-density polyethylene.
- 9.4 Jacket material for low smoke cables (specified in the ordering specs on purchase order) shall be a black, non-halogen, flame retardant, thermoplastic, low smoke, low corrosive and low toxic compound.
- 9.5 Jackets for "reduced" diameter cables shall be extruded to overlay the underlying flat straps, without a separator tape over the flat straps. The material shall be a high temperature, high tensile strength, and abrasion resistant compound such as a polyethylene/polypropylene blend that has been specifically approved by the Company.
- 9.6 If the diameter over the insulation and/or concentric neutral of a particular length(s) of single conductor cable is such that the maximum diameter requirements of Section 11.0 of this Specification cannot be met, the manufacturer may seek specific approval from the Company to make appropriate adjustments in the jacket thickness of cables having either a "standard" or "reduced" overall diameter.
- 9.7 The outer surface of all jackets shall be ink indent printed (or approved equal) with the information required by Part 8 of the referenced ANSI/ICES Standard. Jackets for all #2 AWG copper, #1 AWG & 4/0 AWG aluminum conductor 15 kV cables and all aluminum conductor 25 kV - 35 kV cables shall have three equally spaced red stripes extruded along the length of the cable. These stripes shall be approximately 0.3" wide and 5 mil deep and shall not affect the jacket integrity.
- 9.8 The outer jacket surface of one single conductor cable on each parallel lay or triplexed reel put up and all single cable per reel put ups shall have ink indented (or approved equal) sequential footage markings.
- 9.9 The outer jacket surface of each single conductor cable of a parallel lay or triplexed reel put up shall be ink indent printed with **1 1 1**, **2 2 2**, and **3 3 3** respectively for phase identification.
- 9.10 The outer jacket surface of each cable on the reel shall be ink indent printed with the name NSTAR at 2 foot intervals. This requirement applies

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to all 15 & 25 kV, cables, 250 kcmil and larger and any other cables as may be specified on the purchase order.

- 9.11 The outer jacket of each cable on the reel of low smoke cables shall have 3 equally spaced yellow stripes for identification.

10.0 Maximum Cable Diameters

To facilitate installation of three single conductor triplexed or paralleled cables in existing conduit, the maximum overall diameter of the single conductor cable shall not exceed the following:

<u>Conductor-Voltage, Ins. Tk</u>	<u>Maximum Cable Diameter</u>
4/0 AWG-5kV, 0.115" Nom	1.03"
500 kcmil-5kV, 0.090" Nom.	1.21"
#1 sol & #2 str AWG-15 kV, 0.220" Nom.	1.20"
4/0 AWG - 15 kV, 0.175" Nom.	1.21"
1/0 AWG - 25 kV, 0.260" Nom.	1.29"
500 kcmil str - 25kV, 0.260" Nom.	1.85"
250 kcmil cpt - 15 kV, 0.175" Nom.	1.21"
350 kcmil cpt - 15 kV, 0.165" Nom. **	1.21"
500 kcmil cpt - 15 kV, 0.175" Nom.	1.43"
500 kcmil cpt - 15 kV, 0.165" Nom. **	1.35"
700 kcmil cpt - 15 kV, 0.165" Nom. **	1.51"
750 kcmil cpt - 15 kV 0.175" Mom.	1.63"
350 kcmil cpt - 25 kV, 0.240" Nom. **	1.39
500 kcmil cpt - 25 kV, 0.240" Nom. **	1.51"
700 kcmil cpt - 25 kV, 0.240" Nom. **	1.66"
1000 kcmil cpt - 15kV, 0.175" Nom	1.89"
1000 kcmil cpt -25 kV, 0.260" Nom.	2.06"
1000 kcmil str -35 kV, 0.345" Nom.	2.45"

** Insulation and jacket thickness have been reduced to fit into existing conduit

11.0 Drawings

Drawings shall be submitted for approval. Drawing details shall include reference to applicable NSTAR and industry specifications, NSTAR cat id, diameters of individual layers and overall diameter for triplexed assemblies. Conductor or shield wire Stranding compressed/compact and diameters.

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12.0 Factory Tests

- 12.1 The Manufacturer shall satisfactorily complete all tests required by this specification and all referenced industry Standards, Specifications and Publications. The 5 minute AC withstand production test for all cables and the partial discharge test for 15 kV – 35 kV partial discharge free cables shall be performed in accordance with referenced ANSI/ICEA Standard. The test voltage levels shall be at the 133% voltage rating level for the #2 - #1 AWG conductor sizes and at the 100% voltage rating level for all 1/0 - 1000 kcmil cables (i.e., both “*standard diameter*” and “*reduced diameter*”).
- 12.2 The 5 kV cables having a semi – conducting fabric tape insulation shield shall be tested in accordance with the referenced ICEA/ANSI Standard and AEIC Specification except that maximum level of partial discharge shall be 5 Pico coulombs at 4.8 kV (2X the system voltage to ground) rather than the 200 volts/mil of nominal insulation thickness required for cables having an extruded insulation shield.
- 12.3 The manufacturer shall furnish a certified certificate of compliance stating that each shipping length has been tested in accordance with this specification and that the results of the tests comply with this specification and all applicable industry Standards, Specifications and Publications. The certificate of compliance shall include the information required by AEIC CS8 (except that gross tare and net weight may be omitted), the Company Stock Code and the starting and ending sequential footage marks for each reel.
- 12.4 The Manufacturer shall maintain a paper and/or electronic file of Certified Test Reports in accordance with the referenced AEIC Specification for a minimum of 7 years after the date of shipment. These Certified test reports shall be available to the Company upon request.

13.0 Packaging

- 13.1 All copper conductor cables shall be packaged with one cable per reel or three cables in a triplexed configuration, on steel reels unless otherwise specified. The reels shall have a maximum flange diameter of 84 inches and a maximum width of 57 inches. The maximum width shall include the arbor hub, bolts, and protruding ends. The trailing end of triplexed cables

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shall protrude through an opening in the drum rather an opening in the reel flange. The maximum weight of cable on the reel shall not exceed 16,000 lbs.

13.2 Aluminum conductor cables shall be packaged with one cable per reel or three cables in a parallel put up on wood reels unless otherwise specified.

13.3 The trailing end of all cables shall be tied to reel drum using double rope with two half-hitches spaced two feet apart. Duct tape shall be wrapped over the jacket in the area where the rope is to be applied to prevent slippage. The assembled half - hitches shall be covered with an additional wrapping of duct tape and a tie down rope should be covered by a protective sleeve until it is clear of the drum opening. Use 1/4" 3 Ply Polypropylene Rope, Super Danline manufactured by Tubbs Cordage or approved equal.

13.4 All reels shall have a weatherproof tag or marking showing all information required by AEIC CS8, the Company cat id and the starting and ending sequential footage marks for reel of triplexed or parallel lay cable

14.0 Cable End Seals

Cable ends shall be sealed with sealing mastic and heat shrink caps or approved equal to prevent the entry of moisture.

15.0 Exceptions

If the manufacturer wishes to take exceptions to provisions of this specification or offer alternatives, his proposal shall clearly describe his exceptions and/or recommended alternates.

16.0 Delivery

Shipping lengths and delivery location shall be specified on the Company's Purchase Order.

Approved by: Amin Jessa
Director, Distribution Engineering

END OF SECTION

SECTION 16121

INSULATED CONDUCTORS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing and delivery of insulated conductors for use in feeder taps, jumpers and other assemblies as part of an overhead contact system with a nominal voltage of 600 volts dc as indicated in Section 11.

1.2 REFERENCES

- A. Insulated conductors shall be manufactured and tested in accordance with the pertinent provisions of the most current applicable standards of the American Society for Testing and Materials (ASTM), Insulated Cable Engineers Association (ICEA), National Electrical Manufacturer's Association (NEMA), National Electric Safety Code (NECS), National Electric Code (NEC), Association of American Railroads (AAR), and other recognized standards including, but not limited to those listed below:

ICEA No. S-68-516/NEMA No. WC8-1976 - Standards Publication for Ethylene-Propylene Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

ASTM-B8 - Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-hard or Soft

ASTM-B33 - Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes

ASTM-B172 - Standard Specification for Rope-Lay-Stranded Copper having Bunch-Stranded Members for Electrical Conductors

ASTM-B173 - Rope-Lay-Stranded Copper Conductors having Concentric-Stranded Members for Electrical Conductors

ASTM-B174 - Specification for Bunch-Stranded Copper Conductors for Electrical Conductors

NEMA WC26 - Wire and Cable Packaging

One copy each of the above standards shall be furnished to the MBTA for their use and permanent record.

1.3 SUBMITTALS

- A. The following information shall be submitted in accordance with Volume 2 Technical Provisions Subsection 2.8, Construction Submittal Requirements.
1. Shop drawings, catalog cuts, and other forms of descriptive data delineating the construction of the cables specified herein.
 2. Special storage instructions, if applicable.
 3. Recommended splicing, repair materials and procedures.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Shipping shall take place in conformance with appropriate industry standards for packing, sealing and shipping. The DB Entity shall ensure that all materials furnished are suitably packaged and protected against damage during delivery and transportation. All conductors shall be shipped on reels, suitable for the weight of the conductors and shall be protected from damage. The diameter of drum shall be

sufficiently large so as to minimize difficulty with waves or kinks when the conductor is strung.

- B. The conductors shall be handled and otherwise used in accordance with the manufacturer's instructions, so as to ensure that the products are not damaged or misused prior to installation.
- C. Any damage to the conductors in transit shall be the DB Entity 's responsibility, and all repairs and replacements shall be accomplished by the DB Entity at no cost to the MBTA.
- D. Each reel shall consist of one continuous, unspliced conductor and shall have the required length of conductor within a tolerance of plus 50 feet and minus zero feet.
- E. Each reel shall have a strong, weatherproof tag or marker securely fastened to it, showing the size and type of conductor as well as the ASTM designation, name and mark of the manufacturer, total reel length, weight and manufacturer's special instructions.
- F. Reels shall be tagged with material description and purchase order number.

1.5 WARRANTY

- A. The DB Entity shall guarantee that the cable furnished under this Contract is of first-class material and workmanship throughout and agrees to replace any length of cable failing during normal and proper use, within one year of date of placing in service which shows defects of material or workmanship, provided, in each case, that immediate written notice of such failure is given to the MBTA with all reasonable opportunity to inspect such failure.
- B. The date of placing in service shall be interpreted as the date on which operating voltage was first applied.

PART 2 - PRODUCTS

2.1 4/0 AWG, EXTRA FLEXIBLE, INSULATED CONDUCTOR

- A. Cable shall be used for feeder tap connections on an overhead contact system with nominal voltage of 600V. The cable shall be in accordance with MBTA Specification P-179, except as modified herein, which shall be included as Appendix A to this Section.
- B. The cable conductor shall be single conductor, black, extra flexible ethylene-propylene rubber insulated, neoprene or hypalon jacketed in accordance with applicable requirements of ICEA No. S-68-516/NEMA No. WC8-1976, 5/64 inch insulation and 3/64 inch jacket and rated 1,000 volts, 90°C.
- C. The conductors shall be 4/0 AWG, 259 strands minimum, tinned copper in accordance with ASTM-B33 with Class H stranding as specified in ASTM-B173.
- D. The cable shall be marked at intervals of no more than 36 inches to show manufacturer's name, year of manufacture, AWG size, voltage class, type and thickness of insulation (mils), and type and thickness of jacket (mils).

2.2 500 KCMIL INSULATED CONDUCTOR

- A. Cable shall be used for feeder tap connections on an overhead contact system with nominal voltage of 600 volts. The cable shall be in accordance with MBTA Standard Specification P-25A, except as modified herein, which shall be included as Appendix B to this Section.

2.3 1000 KCMIL INSULATED CONDUCTOR

- A. Cable shall be used as feeder cable for supplying power to the rail vehicles for an overhead contact system

with nominal voltage of 600 volts. The cable shall be in accordance with MBTA Standard Specification P-118A, except as modified herein, which shall be included as Appendix B to this Section.

2.4 NO. 2 AWG INSULATED CONDUCTOR

- A. Cable shall be used for track switch heater connections for an overhead contact system with nominal voltage of 600 volts. The cable shall be in accordance with MBTA Specifications for 2,000 volt low smoke cable except as modified herein, which shall be included as Appendix B to this Section.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Insulated conductors shall be installed either separately or as part of one or more assemblies.

END OF SECTION

SECTION 16122

TROLLEY AND MESSENGER WIRE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies furnishing and delivery of No. 4/0 AWG grooved bronze trolley wire conforming to ASTM B9 for use in an overhead contact system with a nominal voltage of 600 volts direct current, as indicated in Technical Provision 11.1 Traction Power. Trolley wire shall conform to MBTA Standard Specification P-102B with exception of the material makeup being Cu Mg as defined herein and other provisions within this specification.
- B. This section also specifies furnishing and delivery of 4/0 Copperweld Type EK messenger wire for use in an overhead contact system with a nominal voltage of 600 volts dc as indicated in Technical Provision 11.1 Traction Power System. Messenger wire is to be used for catenary suspension of a contact wire and shall conform to MBTA Standard Specification P-178 and this specification.

1.2 REFERENCES

- A. Conductors shall be manufactured and tested in accordance with the pertinent provisions of the applicable standards of the American Society for Testing and Materials (ASTM), Insulated Power Cable MBTAs Association (IPCEA), National Electrical Manufacturers Association (NEMA), National Electrical Safety Code (NESC), Institute of Electrical and Electronics Engineers (IEEE), and National Electric Code (NEC), and other recognized standards including, but not limited to, those listed below:
 - 1. ASTM-B9 - Specification for Bronze Trolley Wire
 - 2. ASTM-B193 - Resistivity of Electrical Conductor Materials, Test Method
 - 3. ASTM-B229 – Standard Specification for Concentric-Lay-Stranded Copper and Copper-Clad Steel Composite Conductors
 - 4. ASTM-B258 - Standard Nominal Diameters of Cross-Sectional Areas of AWG Sizes of Solid Round Wires used as Electrical Conductors
 - 5. IEEE Standard for Identification of Contact Wire used in Overhead Contact Systems 1896-2016

1.3 SUBMITTALS

- A. The following information shall be submitted in accordance with Section 2.
 - 1. The DB Entity shall submit shop drawings prior to trolley wire manufacture, which shall include, but not be limited to, the following:
 - a. Physical Characteristics, chemical content and Parameters
 - b. Size
 - c. Type
 - d. Material
 - e. Dimensions of wire
 - f. Overall diameter
 - g. Cross section area

- h. Weight per foot
 - i. Rated breaking strength
 - 2. Electrical Characteristics
 - a. Rated current carrying size (AWG/ kcmils)
 - b. Resistance per unit length
 - B. The DB Entity shall submit certification verifying that the wire has been designed, manufactured, inspected and tested in accordance with applicable portions of the referenced standards, these Mandatory Specifications, and Section 11.
 - C. The DB Entity shall submit three (3) certified copies of test reports for the specific conductors furnished, which shall include the following:
 - 1. Initial and Final Modulus of Elasticity (E)
 - 2. Coefficient of Thermal Expansion (CTE)
 - 3. Yield stress
 - 4. Hardness values
 - 5. Chemical content
 - 6. Breaking strength
 - D. One copy of ASTM-B9 shall be furnished to the Authority for their use and permanent record.

1.4 DELIVERY, STORAGE, AND HANDLING OF TROLLEY WIRE

- A. Shipping shall take place in conformance with appropriate industry standards for packing, sealing and shipping. The DB Entity shall ensure that all trolley wire furnished is suitably packaged and protected against damage during delivery and transportation. The wire shall be wound on the reel without crossing itself and shall lay parallel and tight against each coil. The vertical axis of the trolley wire, when installed on the reel shall be at 90° to the axis of the reel with the small lobe on the outside facing up. Vertical axis deviation in excess of 5° will be cause for rejection of the wire and reel. All trolley wire shall be shipped on reels with designated lengths and shall be protected from damage. Reels shall be constructed of wood for insulation purpose and the diameter of reel rims shall be 46 inches and have sufficient clearance between the top of the rim and the top coil of wire to prevent damage to the wire when the reels are rolled about and shall have sufficient strength to prevent the reel from bulging out or collapsing. Each disc or head of the reel shall be provided with an iron plate or cast iron bushing in the center of which shall be a circular hole not less than 2-1/8" in diameter. The plates or bushings shall be fastened to the head of the reel by means of bolts through the head. The contact wire on the reel shall be electrically insulated by the construction of the reel from any metallic hardware used in the reel construction. The inner end of the wire shall be securely fastened to the reel so that it will not loosen when the inner layers of wire are being strung out during installation.
- B. Trolley wire reel lengths shall be determined by the DB Entity so that during installation these reel lengths may be cut without waste. Each reel shall have the length of contact wire on it marked clearly and in indelible ink or paint on the side of the reel.
- C. The contact wire shall be handled and otherwise used in accordance with the manufacturer's instructions, so as to ensure that the products are not damaged or misused prior to installation.
- D. Contact wire shall have identifying marks placed on the upper lobe as spelled out in IEEE Standard 1896-2016. The agency mark shall be: MBTA. This is included for the identification of the type of wire and for theft prevention.

- E. Any damage to the wire in transit will be the DB Entity 's responsibility, and all repairs and replacements shall be undertaken by the DB Entity at no cost to the Authority.
- F. A stripe in any contrasting color approximately one inch wide shall be painted across the outermost layer on each reel prior to shipping from manufacturing plant. Any visible conductor shift at this line, upon receipt at the job site, will be treated as indicating relative wire movement during shipment, and is cause for wire and reel rejection.
- G. Each reel shall have a strong, weatherproof tag or marker securely fastened to it, showing the wire number, length of wire on the reel and type of conductor as well as the ASTM designation, name and mark of the manufacturer, total reel weight, manufacturer's special instructions, and contract number.

1.5 DELIVERY, STORAGE, AND HANDLING OF MESSENGER WIRE

- A. Shipping shall take place in conformance with appropriate industry standards for packing, sealing and shipping. The DB Entity shall ensure that all messenger wire furnished is suitably packaged and protected against damage during delivery and transportation. The wire shall be wound on the reel without crossing itself and shall lay parallel and tight against each coil. Deviation will be cause for rejection of the wire and reel. All messenger wire shall be shipped on reels with designated lengths and shall be protected from damage. Reels shall be constructed of wood for insulation purpose and the diameter of reel rims shall be 48 inches in height, 28 inches in width overall and the inside reel drum diameter shall be 20 ¼ inches. There shall be sufficient clearance between the top of the rim and the top coil of wire to prevent damage to the wire when the reels are rolled about and shall have sufficient strength to prevent the reel from bulging out. Each disc or head of the reel shall be provided with an iron plate or cast iron bushing in the center of which shall be a circular hole not less than 3" in diameter. The plates or bushings shall be fastened to the head of the reel by means of bolts through the head as shown on MBTA Drawing SK-595 or approved equal. The messenger wire on the reel shall be electrically insulated by the construction of the reel from any metallic hardware used in the reel construction. The inner end of the wire shall be securely fastened to the reel so that it will not loosen when the inner layers of wire are being strung out during installation.
- B. Messenger wire reel lengths shall be determined by the DB Entity so that during installation, the reel lengths may be cut without waste. Each reel shall have the length of messenger wire on it marked clearly and in indelible ink or paint on the side of the reel.
- C. The messenger wire shall be handled and otherwise used in accordance with the manufacturer's instructions, so as to ensure that the products are not damaged or misused prior to installation.
- D. Any damage to the wire in transit shall be the DB Entity's responsibility, and all repairs and replacements shall be undertaken by the DB Entity at no cost to the Authority.
- E. A stripe in any contrasting color approximately one inch wide shall be painted across the outermost layer on each reel prior to shipping from manufacturing plant. Any visible conductor shift at this line, upon receipt at the job site, will be treated as indicating relative wire movement during shipment, and is cause for wire and reel rejection.
- F. Each reel shall have a strong, weatherproof tag or marker securely fastened to it, showing the wire number, length of wire on the reel and type of conductor as well as the ASTM designation, name and mark of the manufacturer, total reel weight, manufacturer's special instructions, and contract number.

1.6 WARRANTY

- A. The DB Entity shall guarantee that the wire and cable furnished under this Project are of first-class material and workmanship throughout and agrees to replace any length of cable failing during normal and proper use, within one year of date of final inspection which shows defects of material or

workmanship, provided, in each case, that immediate written notice of such failure is given to the DB Entity with all reasonable opportunity to inspect such failure.

PART 2 – PRODUCTS

2.1 TROLLEY WIRE

A. The trolley wire shall be No. 4/0 AWG grooved ASTM B9 alloy 80 magnesium-bronze trolley wire (minimum conductivity 80%) in accordance with MBTA Specification P-102B, (which is included as Appendix to this Section) except as modified herein.

1. Trolley wire shall be composed of the following elements:

(1) Magnesium (Mg) Max 0.3-Min 0.1

(2) Phosphorus (P) ≤ 0.01

(3) Others ≤ 0.1

(4) Remainder Copper (Cu)

2. Splicing of rods used in drawing down process into the finished trolley wire shall not be permitted.

3. Grooved Cu Mg 0.2 trolley wire shall incorporate identification on the upper lobe of the wire according to IEEE Standard 1896-2016.

4. Tensile properties of Cu Mg 0.2 shall meet or exceed the requirements of ASTM B9.

5. Electrical Conductivity @ 20°C shall be equal to or greater than 80% IACS.

6. Testing shall be in accordance with ASTM B9.

2.2 MESSENGER WIRE

A. The messenger wire shall be 4/0 Copperweld Type EK wire in accordance with MBTA Standard Specification P-178, except as modified herein, which is included as Appendix to this Section.

B. Messenger wire repair shall be undertaken only if strands become damaged after installation and at the acceptance and direction of the MBTA. In the event the completed messenger wire has broken strands, a preformed repair assembly may be used to contain and strengthen the messenger wire. The preformed assembly shall be of bronze wires and designed to impart the full breaking strength of the messenger wire when placed onto the messenger. Where the messenger wire cannot be repaired due to too many broken strands (three or more), the wire shall be cut and spliced with a full tension messenger wire compression splice as accepted by the MBTA.

PART 3 – EXECUTION

3.1 INSTALLATION

- A. Trolley and messenger wire shall be installed in accordance with Section 16123 – OVERHEAD CONTACT SYSTEM INSTALLATION.

END OF SECTION

SECTION 16123

OVERHEAD CONTACT SYSTEM INSTALLATION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the furnishing and installation of an overhead contact system (OCS) over all tracks to be constructed as shown and described in the DB Entity accepted Design Documents and as specified herein. Furnishing and delivery of trolley wire and messenger wire shall be in accordance with Section 16122 – TROLLEY AND MESSENGER WIRE.
- B. The work consists of the following:
1. Installation of new overhead contact system poles, back guys, pole and anchor foundations, crossbeam portal structures, structural steel, concrete, bridge attachments, sound wall supports, and all else associated with the OCS system shown and described in the DB Entity's accepted Design Documents.
 2. Installation of a new catenary overhead system, including the messenger wire, contact wire, overlaps, balance weights, constant tension springs, standard springs, cantilevers, pulloffs, span wires, deadend assemblies, insulators, catenary hangers, section insulators, special catenary system at vertical curves, pole clamps, bridge supports, suspension assemblies, cross contact clamps, jumpers and all else required for a new catenary system, as described herein and the DB Entity's accepted Design Documents.
 3. Installation of a new single contact wire system including contact wire, deadends, suspension assemblies, span wires, inclined pendulum hangers, stitch supports, balance weights, deadend tension springs, section insulators, elastic arms, cross contact clamps, jumpers, insulators, bridge supports and pulloffs, and all else as required for a new single contact wire system as described herein and the DB Entity's accepted Design Documents.
 4. Installation of new 600 volt aerial DC feeder cable and feeder tap system for the new overhead system, including disconnect switches, surge arrestors, aerial feeder cables, crossarms, messenger support ties, crossarm supports and braces, pole clamps, feeder taps, bridge ground wire system, surge arrestor ground wire system, head guys, surge arrestors, and all else required for a new aerial feeder system as described herein and the DB Entity's accepted Design Documents.
 5. Revisions to the OCS and disconnect switches on the Historic Viaduct by separating the power sections. Work to include temporarily installing catenary deadends to hold the existing OCS at Land Boulevard, removing cross taps between inbound and outbound catenary, removing common top buss of disconnect switches so that each switch and feeder tap feeds the appropriate power section, isolating the existing OCS from the new OCS at Land Boulevard with temporary section insulators and making the OCS safe to run trains from the historic Viaduct onto the new viaduct as described herein and the DB Entity's accepted Design Documents.
 6. Installation of a new 13,800 volt AC aerial cable system as indicated on the DB Entity's accepted Design Documents and as described herein and specified in Section 16120 – MEDIUM VOLTAGE POWER CABLE, including all cable with self-supporting messenger wire, pole clamps, messenger wire terminations, back guys, cable splices, messenger support ties, messenger wire splices, and all else required for a new aerial AC cable system as described herein and the DB Entity's accepted Design Documents.
 7. Installation of an aerial fiber optic cable system as described herein and in the DB Entity accepted Design Documents including all cable with supporting messenger guy wire, pole clamps,

messenger wire terminations, back guys, guy wire splices, messenger support ties, and all else required for a new aerial fiber optic cable system as described herein and the DB Entity's accepted Design Documents.

8. Installation of new traction power disconnect switches with associated cabling, supports, and hardware. Work pertaining to the 600VDC distribution and switching systems is shown on the DB Entity accepted Design Documents and as described herein and specified in Section 16120 – MEDIUM VOLTAGE POWER CABLE. Work shall include but not be limited to installation of cables, pole clamps, support structures for enclosures, cable anchors, disconnect switches in enclosures, switch box signs, cable tags, cable supports, insulated bushings, and all else required for a new traction power disconnect system as described herein and the DB Entity's accepted Design Documents.
 9. Testing of the OCS for alignment, height, stagger, tension, and performance as described herein and the DB Entity's accepted Design Documents.
 10. Testing of the OCS for electrical continuity, integrity of insulation and isolation between power sections as described herein and the DB Entity's accepted Design Documents.
- C. The DB Entity accepted Design Documents are intended to convey all work required to construct an overhead contact system. Where the plans or specifications do not exactly state the method, assembly, alignment, component or other exact direction for construction, the DB Entity shall determine what is necessary to install the OCS to obtain a fully functioning and operationally compliant system. All connections shall be verified and if dimensions are not correct, the DB Entity shall be responsible for corrections. If assemblies are inappropriately specified in the DB Entity's accepted Design Documents, the DB Entity shall install the correct assembly. It shall be the DB Entity's responsibility to design the OCS system, make the system work and construct it with the information available on the Mandatory Specifications and DB Entity's accepted Design Documents and from manufacturer's instructions and recommended practices.

1.2 REFERENCES

A. Codes and Standards

1. Standards applicable to the overhead contact system installation that have been listed in other sections of this Specification shall also apply to this section.
2. Comply with the most current provisions of the following, except as otherwise indicated. If there is a conflict between specifications and standards or between the various standards, then the most stringent requirement shall apply.
 - a. American National Standards Institute (ANSI)
 - b. National Electrical Safety Code (NESC)
 - c. Occupational Safety and Health Act of 1970 (OSHA)
 - d. National Electrical Manufacturers' Association (NEMA)
 - e. Institute of Electrical and Electronics Engineers (IEEE)
 - f. Rules and regulations of the MBTA for performing work on MBTA property.
 - g. National Electrical Testing Association, Inc. (NETA)
 - h. American Institute of Steel Construction (AISC)

1.3 SUBMITTALS

- A. The following information shall be submitted in accordance with Volume 2 Technical Provisions Subsection 2.8 “Construction Submittal Requirements.
1. Submit individual component and/or assembly drawings in detail of each component or assembly proposed. Each component or assembly shall be on its own drawing. The DB Entity may, if space provides, without cluttering or confusing the assembly, include several variations of the same assembly on one drawing. All assemblies and variations shall be clear and concise for ease of interpretation. A parts list shall be provided on the drawing in an easily readable matrix fashion that clearly identifies:
 - a. The part;
 - b. The quantity for each assembly;
 - c. The number it refers to on the drawing; and
 - d. Where the part itself can be found to review for detail.
- B. The DB Entity shall submit to the MBTA, descriptions and sketches explaining proposed methods and procedures for new OCS and trolley wire and support system installation. These submittals shall include, but not be limited to, the following:
1. Sequential phases of the work
 2. Equipment to be used
 3. Procedure for temporarily supporting new wire, if required
- C. The DB Entity shall submit a detailed sequence of work at least one month in advance and updated as frequently as need be to keep one month in advance. The sequence shall show how many crews will be working, when, where and what equipment will be utilized, and define the area of work and the proposed limits. This will be reviewed by the MBTA for reasonableness so that MBTA requirements can be evaluated and set up. An alternate plan for work shall be submitted in the event that the DB Entity is restricted from the planned location of work.
- D. The DB Entity shall utilize qualified personnel to perform all aspects of the work. Journeymen linemen, groundmen, cable splicers, and all others performing the construction of the total overhead contact system, shall be trained in the work and have adequate experience in general line work, electrical work and trolley line work. As such, only trained IBEW electrical workers shall work on the electrical system. The foreperson in charge of the work shall have experience with trolley line work and shall work closely with the DB Entity’s Catenary Engineer to direct crews for the proper and safe installation of the OCS system.

1.4 QUALITY ASSURANCE

- A. The DB Entity shall examine the condition of the overhead components and/or assemblies for condition and completeness. Parts shall be examined for missing components, broken hardware, cracks, quality workmanship, bad galvanizing, bolt and nut thread interface, lockwasher construction, shipping damage, improperly constructed components, defective castings and all else that would be considered not acceptable for use in an overhead contact system or that could potentially fail in service. Any and all bad parts shall be returned to the manufacturer for new parts which shall then be examined as stated herein. The DB Entity shall inform the MBTA of any bad parts, assemblies or components that are returned to the supplier or manufacturer. Return of components shall be done at the DB Entity’s expense and at no cost to the MBTA.
- B. General: Examine the conditions under which the components of the overhead contact system are to be installed.
- C. Notify the MBTA of conditions encountered or unforeseen, which could affect the proper and correct installation of the overhead contact system.

1.5 CATENARY ENGINEER

- A. The DB Entity shall have on their staff and dedicated to the Project, the services of a Catenary Engineer. The Catenary Engineer will provide the design of the OCS and assist the DB Entity's line construction forces with the construction of all catenary wires, aerial feeder cables, disconnect switches, surge arrestor assemblies, riser cables, feeder taps, balance weights, constant tension spring devices, pole installations, pole rake, clearance and fit issues, assembly allocations, contact wire offsets and alignments and all else required to ensure that the overhead system and components function as an integral system and provide safe and reliable operation.
- B. The Catenary Engineer shall evaluate the OCS design and make alterations and changes where warranted if conflicts arise with other systems or the catenary system itself. Due diligence and sound engineering practices must be exercised in the OCS design and in the preparation of the Design Documents and the Mandatory Specifications and in the event any discrepancies occur, the DB Entity's Catenary Engineer shall identify and make known to the Project such situations, and shall present an alternative method of construction, if required, but shall ensure compatibility and workability of the catenary system as designed and specified herein and on the DB Entity's accepted Design Documents.
- C. The Catenary Engineer shall oversee all testing of wires, cables, poles, staggers, offsets, energizing of the OCS, and certifications. The Catenary Engineer shall ensure that the system is fully functional and have the final recommendation on the worthiness and acceptability of the OCS.
- D. The DB Entity /Catenary Engineer shall bring to the attention of the MBTA any problems or incompatibilities discovered during the shop drawing process and the construction period and present a proposed method of construction if one is needed. If components utilized do not fit together or do not function to the intent of the design, the DB Entity shall fix the problem without cost to the Project. Where a situation arises that is beyond the DB Entity's ability to make a situation work, the DB Entity shall inform the MBTA of the situation and take direction.
- E. The Catenary Engineer shall be familiar with catenary systems for both transit and electric railroads and shall be intimately familiar with the MBTA's complete traction power system including catenary, underground cabling, aerial cabling, and substation operation and design. The DB Entity shall submit to the MBTA the name of the Catenary Engineer with their resume for review and approval. The Catenary Engineer shall have a minimum of 20 years of experience.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Items shall be furnished that are of the materials, design, sizes and ratings shown on the DB Entity's accepted Design Documents and as specified herein, and required by the installation specified in Sections 16122, and 16124 and required by the installation section specified in this Section.
- B. In order to ensure compatibility with MBTA requirements and the existing overhead contact system, to provide continuity and interchangeability of hardware throughout the entire MBTA overhead network. The DB Entity shall not substitute manufacturer specific components with other manufacturer's components or types of overhead hardware. DB Entity shall verify that indicated components function properly as indicated on the DB Entity's accepted Design Documents. Substitutions of "as equal" shall be per approval of the MBTA.
- C. All assemblies and components shall be installed as described in the DB Entity's accepted Design Documents and the manufacturer's installation recommendations. It is the MBTA's preference to have all OCS span wire sized to 3/8 inch for standardization of fittings.

PART 3 - EXECUTION

3.1 INSTALLATION OF POLES AND FOUNDATIONS

A. General

1. Poles shall be wide flange sections as shown on the DB Entity's accepted Design Documents. All poles shall be anchor base (unless the DB Entity elects to use direct embedded poles) and located in optimal positions along the line. These poles shall have a hot dipped galvanized protective surface.

B. Direct Buried

1. Wide flange poles shall be placed into the pole hole with either a nylon sling or the attachment of a shackle to the hole in the top of the pole. When inserted into the hole, the pole bottom shall be in the middle of the inner pipe and then oriented as indicated on the DB Entity's accepted Design Documents. It shall be raked by an amount determined by the DB Entity and secured with steel angle as described herein. Concrete at the top of the outer pipe shall be poured level. The concrete at the top of the inner pipe shall be poured and then mounded for water runoff.

C. Anchor Base

1. The pole shall be placed onto the foundation anchor bolts by using a nylon sling wrapped around the pole for lifting or with the lifting eye as previously described. When placed onto the foundation, the pole bottom shall be placed onto four bottom nuts. The four bottom anchor bolt nuts and washers shall be placed on the bolts first and then the pole set onto the bolts. The second set of nuts and washers shall then be put onto the anchor bolts and the pole raked by an amount determined by the DB Entity by adjusting the eight anchor bolt nuts. Once the pole has been properly raked and secured, the nuts shall be tightened and then jam nuts placed onto the anchor bolts and tightened against the top nut. All nuts shall be properly torqued for the size and type of bolt and nut.

D. Foundations shall be used for pole installations and back guy anchor installations where indicated on the DB Entity's accepted Design Documents.

1. Foundations shall be for anchor base poles or for back guy anchors. Size of foundation and method of construction shall be determined by the DB Entity. Direct embedded pole foundations, if used, shall consist of an outer pipe (removed after installation) and an inner pipe. Back guy anchor foundations shall consist of a concrete reinforced cylindrical foundation, a reinforcing bar cage, and protruding anchor bolts for attaching a back guy connection plate. Overall sizes and depths shall be determined by the DB Entity.
2. Pole foundations shall be drilled with a pipe or cylindrical drill which will remain in the ground during the excavation and concrete pouring process. All soil will be excavated from it by any practical means including vacuum, hand digging, auger, shovel or other method as accepted by the MBTA. Upon excavation of soil, an interior pipe will be inserted into the hole and pushed into the soil by a minimum of 12 inches. The inner pipe shall rise above the outer pipe so that the top of foundation is level with proposed top-of-rail. Both the outer and inner pipe shall be parallel and plumb.
3. Concrete shall be poured and vibrated between the inner and outer pipes to the top of the outer pipe and into the inner pipe to a depth of 24 inches. Upon completion of the concrete pour between the inner and outer pipes, the outer pipe will be carefully removed leaving the inner pipe in place. The inner pipe shall have only a 24 inch concrete pad placed into it at this point. The concrete at the top of the outer pipe shall be poured level.

4. Poles shall not be inserted into the hole or attached to the anchor bolts for 7 days minimum to allow the concrete to set up properly. Upon initial concrete setup, the pole shall be inserted into the hole, oriented to the proper position and raked. When in position, a steel angle will be welded to the pole and the inner pipe to hold the pole in position. This will also electrically connect the pole to the inner pipe which is embedded into the earth so that it will act as an electrical ground. The galvanized coating shall be removed through grinding. The securing angle iron shall be placed 6 inches below the top of the inner pipe. No span wires, cantilevers, feeder cables or other hardware shall be attached to the pole for 28 days after the inner pipe concrete pour.
6. Concrete shall then be poured and vibrated between the inner pipe and the pole and mounded up at the inner pipe to the pole to permit water runoff.
7. Excavation of a back guy anchor foundation shall be the same as for direct embedded poles except that after the outer drill pipe is in place and the soil inside of it excavated, the reinforcing cage shall then be inserted into the hole. The cage shall not sit on bare soil or touch the sides of the pole hole. Concrete block spacers shall be placed in the bottom of the hole for the cage to sit on. Concrete block spacers may be placed onto the sides of the cage to keep it from touching the sides of the outer pipe. The anchor bolts shall then be placed into the hole and the reinforcing cage and secured to the correct positions and height above the top of foundation. Reinforcing cage dimensions and size of rods shall be determined by the DB Entity.

Once the cage and anchor bolts are in place, concrete shall be poured into the hole with vibration to ensure there are no voids in the concrete. When the pour is level with the top of the foundation outer pipe, the pipe drill shall be pulled out of the hole for reuse. Great care shall be exercised so as not to disturb the cage and the anchor bolts during the outer can removal. Should they be disturbed, the DB Entity shall reset them immediately to the correct position. The top of the foundation shall have a slight slope for water runoff as shown.

Where the top of the foundation is above grade, a shorter cylindrical form shall be placed on top of the existing pour and then additional concrete placed into this form immediately after removal of the outer pipe drill. The top of the foundation shall have a slight slope for water runoff.

3.2 INSTALLATION OF INSULATORS AND HARDWARE

A. General

1. The sections following are suggested methods of installation. The DB Entity shall determine the best methods for their work.
2. Deadends with insulators shall be attached to structures and poles prior to stringing operations to prevent overstress or damage.
3. All braces, brackets, and supports shall be attached, complete to receive the OCS hardware and devices to support the conductors in their final position.
4. Care shall be exercised in joining individual hardware components to form complete assemblies.
5. Clamped and bolted connections shall be made as to prevent damage and distortion of the joined pieces.
6. Hardware pieces joined to provide flexibility of movement shall be installed to prevent excessive bonding or chafing of surfaces when movement does occur.
7. Insulators shall be cleaned before installation according to the manufacturer's recommendations. Protective coverings shall be removed and properly disposed of after the unit is installed. Only clean rags, free from abrasive material, shall be used for cleaning insulators. Wire brushes shall not be used for cleaning parts, metal or non-metal. After installation, insulator assemblies and

hardware shall be clean, bright and free from nicks or blemishes. Touch-ups to insulator surfaces shall be done in a manner accepted by the MBTA.

B. Hardware:

1. Hardware shall be inspected for quality of construction and damage. Any item that does not fit, is damaged during installation, or is found defective shall be rejected.
2. All hardware shall be installed as indicated in the DB Entity's accepted Design Documents or supplied by the DB Entity using tools and methods as recommended by the manufacturer of those components. Bolts and nuts shall be properly tightened and torqued in accordance with the manufacturer's recommendations. All bolts, excluding foundation bolts, shall be of sufficient length to protrude at least two full threads, but not more than 1/2 inch beyond the nut. Bolt ends shall not be cut off. Standard split lockwashers shall be provided.
3. All cotter pins should have each leg-opened 45° after installation unless they are humped back type in which they shall be completely inserted through the clevis pin so that the hump prevents it from backing out.

C. Connectors:

1. Current-carrying connectors shall be as shown on the DB Entity's accepted Design Documents and shall be installed in accordance with the manufacturer's recommendations. Connectors for copper or bronze wire shall be bronze and utilize silicon bronze bolts, nuts and lockwashers.
2. Bolts in bolt-type connectors shall be lubricated as recommended by the manufacturer and torqued to the manufacturer's recommendation using a calibrated torque wrench.
3. The connectors where possible, shall be factory-loaded with a corrosion inhibitor, which is made for the specific purpose.
4. Wire surfaces which are in contact with conducting surfaces of the connector shall be thoroughly wire brushed or chemically cleaned to bright metal prior to makeup and shall have an inhibitor applied. Where connectors are not factory-loaded, the same inhibitor shall be applied in the field to the connector.
5. Corrosion inhibitors shall be stable over a wide temperature range, able to adhere to cold or hot metal surfaces, water-repellent, weather resistant, and inert to copper, aluminum, zinc, tin, cadmium, steel, and neoprene rubber. Silver-bearing inhibitors shall be used except for flat lugs, sliding surfaces or where the connector manufacturer recommends omission. Silver bearing inhibitors shall be compatible with the connector and wire metal. Inhibitor for copper and bronze shall be T&B "Kopr Shield", Fargo "Fargolene", Penn-Union "Cual-Aid", Burndy "Penetrox A", or approved equivalent.

3.3 INSTALLATION OF TROLLEY AND MESSENGER WIRES

A. General

1. The method of erecting the wires shall be submitted to and accepted by the MBTA prior to erecting the wire.
2. Care shall be taken to prevent kinks in the wires. The MBTA reserves the right to reject any wire in its entirety if it is judged that any kink is non-removable and will prejudice current-collection performance.
3. Splices shall not be permitted at any location except as accepted by the MBTA.
4. Any damage to the wires shall be reported to the MBTA. Remedial action shall be indicated and recorded.

5. Stringing of the wires will start from the location shown on the DB Entity's accepted Design Documents at Land Boulevard along the new right of way. The DB Entity shall determine the starting locations and methods employed in the stringing of wires. As the wires are pulled from the reel and lifted into position on the suspension supports, sufficient tension must be maintained in each wire during stringing to ensure that under no circumstances do the wires touch the ground between support points or sag excessively.
 6. When the termination location is reached, each wire shall be tensioned above the specified final tension by 15%. This tension can be slackened to the specified erection tension right after pre-stressing the wire. Tension measuring devices shall be installed at both ends of the wire during installation and tensioning.
 7. Erection tensions shall be in accordance with tables furnished for the purpose, based on the span and temperature of the wire, as determined by the DB Entity.
 8. Wire temperatures shall be measured by digital thermometer. The probe of the thermometer shall be in intimate contact with the wire when read.
 9. A record of temperature and tension measured at both ends of the tension lengths shall be submitted to the MBTA.
 10. The contact wire and the messenger cable shall be re-tensioned, if necessary after initial installation to achieve required tension.
 11. Wire runs shall be complete from termination to termination without splicing. Where it is necessary to splice either trolley wire or messenger wire, it shall be done as described herein and at the recommendation of the manufacturer of the splice. Any wires that are to be spliced must have the expressed acceptance of the MBTA.
- B. Installation of the messenger and contact wires may be undertaken so that each wire run is installed as a variable tensioned system. Temporary hangers can be used to support the contact wire to the messenger wire. The wires shall be pre-stressed and then let off to the tensions shown on the stringing tension charts to be developed by the DB Entity. All cantilever assemblies and steady arms can then be placed perpendicular to the wires and locked in place. After all wires have been installed and when the catenary is attached to the balance weights and the weights set to the design temperature location, the pins can then be pulled from the cantilevers so that they swing into the correct position according to their along-track movement position for temperature. The cantilever position relative to the track can be checked against the tables developed by the DB Entity.
- C. Cross contact wire clamps shall be positioned on the under running wire and the center of it located in relation to the along-track movement position so that they do not bind up with the wire they are fixed with.
- D. Trolley/Messenger Wire Reels
1. The DB Entity shall dispose of the wire reels after use.
 2. The wire shall not be ordered with several lengths of wires on one reel to satisfy several runs. Wire runs shall be from a continuous length of wire on the reel. As each length is cut and removed, the length remaining on the reel may be recomputed and properly recorded both on the reel and on substantiating documentation.
 3. Care must be taken with reels so as not to disrupt the stringing operation. Damaged reels shall be set aside for repair or replacement before use.
- E. Precautions in Handling Trolley Wires
1. The wire shall be handled in such a manner that it shall not be scratched, cut, or nicked with tools or clamps.
 2. The wire shall not lie upon or be dragged across, sharp or rough surfaces.

3. Wire shall not be annealed.
4. Sharp bends shall not be put in the wires.
5. The wire shall not be marred with temporary wire or hook hangers.
6. Only approved parallel jaw clamps shall be used in tensioning all wire. The grooves of the clamps must be free from burrs, fins or roughness and the ends of the grooves must be flared (bell-shaped). Acceptable trolley wire pulling grips are MAC Products part number E0205-04, Brecknell-Willis Come-Along Clamp Number D7068 or other approved equal. Upon removal of the grip from the contact wire after pulling, there shall be no kinks, gouges, scrapes or other damage to the contact wire.
7. Vertical and lateral kinks in the wire shall be removed. Kinks shall be removed with a specific tool designed to remove kinks such as Arthur Flury Kink Remover Type XDH41, Brecknell-Willis trolley Wire Straightener Number D7252 or other approved device. In the event the device cannot completely remove the kink or wave, a rubber hammer shall be used, beating against an 18 inches long steel block with a smooth semi-circular groove, ½” radius milled out for the length of the bar. The bar shall be held to underside of the contact wire and the top shall be beaten with the hammer until the wire is straight. The deviation from the straight bottom of the contact wire over the length of the bar shall not exceed 1/32”.

F. Splicing of Trolley Wires

1. Trolley wire splices shall be MBTA standard style, ImpulseNC Bulldog Splicer as supplied by ImpulseNC, Mac Products or Phoenix or approved equal.
2. Joining and splicing of two separate pieces of contact wire may be done as follows:
 - a. Cut the wire with a bolt cutter or special cutting device designed for cutting contact wire.
 - b. Cut approximately ½” of the end of the wire off using a hack saw.
 - c. File the ends smooth so that no burrs or sharp edges are present.
 - d. Straighten ends of the wires a distance of 8” from the end.
 - e. Slide the splice over one contact wire a distance where there is approximately 1/4” of groove extending beyond the wire.
 - f. Insert the other contact wire into the splice and push down on the splice until the wires slide into the splice and butts up against the other contact wire.
 - g. Push the splice or strike the end with a hammer until the center of the splice coincides with the ends of the two contact wires.
 - h. Apply “blue Loctite” to the set screw threads and then tighten the set screws until they bottom out.

G. Splicing of Messenger Wires

1. Joining and splicing of two separate pieces of messenger wire may be done as follows:
 - a. Cut the wire with a bolt cutter or special cutting device designed for cutting Copperweld type wire. Remove any burrs or sharp edges with a file.
 - b. Full Tension Compression Splice: lay the splice against the wire and place the center of the splice at the wire end. Mark the wire at the splice end and then insert the splice over the wire and stop at the mark. Secure the splice against the wire and then insert the other wire into the splice until it butts up against the other wire inside the splice. Place hydraulic crimping device on the splice to one side of the center and make a crimp. Do the same to the other side

of center. Each crimp position shall be 180 degrees to the previous on each side of center to prevent a “banana” shape from occurring. After the first two crimps are installed, start crimping one side of the splice and then the other and follow instructions for installation of the splice by the manufacturer.

3.5 TENSION EQUIPMENT INSTALLATION

A. Balance Weights

1. Balance weights shall be used on the main line with catenary and yard leads. The weight set for the main line shall have a total weight of 2,333 lbs +/- 100 lbs for a messenger tension of 4,000 lbs and a contact wire tension of 3,000 lbs and have a pulley ratio of 3:1.

2. Mainline balance weights may be installed as follows:

They may be installed on poles at heights determined by the length from the cross contact wire clamp to the deadend pole using a slope of 1:100. The pulley assembly clamp may be adjusted higher to clear pole obstructions or gain sufficient height for pantograph clearance. Where balance weights are used on the new Lechmere Viaduct, sufficient travel distance may not be realized due to pole base parapet height. The maximum tension length under this condition may have to be shortened to compensate for reduced weight travel.

3.6 EQUIPMENT AND HARDWARE INSTALLATION

- A. As far as practical, bolts shall be installed in the various clips so that the nuts are on the same side giving uniform appearance. On curves, the nuts shall be placed on the outside of the curve to provide the best clearance to the pantograph. Lock washers shall be used and shall be completely flat after installation.
- B. All clamp ears and feed tap clamp ears and other clamps on the trolley wire shall utilize hollow hex screws to allow the passage of a trolley pole current collector shoe. Contact wire clamps shall be placed on the contact wire so that both sides of the clamp fit completely into the groove of the wire. Hollow hex screws shall be tightened with a torque wrench using torques recommended by the manufacturer of the clamp.
- C. Clamps used for pulloffs shall have the clamp body bearing against the wire so that it is on the inside of the curve pull. The clamp portion shall be on the outside of the curve.

3.7 SUPPORT, REGISTRATION AND FEEDER ASSEMBLIES

- A. All support, registration and feeder assemblies, unless specifically stated to be a certain configuration or manufacturer may be determined by the DB Entity. All components and assemblies shall be compatible with the OCS system installed by the DB Entity and interchangeable with the MBTA’s standard OCS equipment.
- B. **Stitch Support Assemblies**
 1. New Stitch Support assemblies are to be manufactured in accordance to the parts, dimensions, materials and working loads as shown on the DB Entity’s accepted Design Documents.
 2. New Stitch Support assemblies shall be installed to support and register the trolley wires at the positions and heights as shown on the DB Entity’s accepted Design Documents. If no stagger at the assembly location is stated on the DB Entity’s accepted Design Documents, the stitch shall be slightly staggered to provide an inclination. Adjacent stitch assemblies shall be staggered in opposite directions on tangent track and shall be installed according to the manufacturer’s recommendations.
- C. **Feeder and Crossarm Assemblies**

1. New feeder and crossarm assemblies shall be manufactured in accordance to the dimensions, materials and working loads as shown on the DB Entity's accepted Design Documents.
2. Feeder tap cables will be supported from span wires or cantilever pipes. Feeder taps on span wires shall have an insulated tie wrap attaching them to the span wire. On cantilevers, they shall have a clamp insulator supporting them, both conforming to MBTA standards.
3. Feeder taps for electric track switch heaters will be attached to either span wires or cantilever pipes and run out to the messenger wire and shall be attached to the wire with a Fargo vise type connector separately from the feeder tap. The conduits and cables for the switch heaters will be installed by the signal DB Entity and sufficient slack will be left hanging out of the riser conduit for messenger wire attachment. The DB Entity shall attach and support the heater cable in the same manner and with the same hardware as the feeder taps.
4. Crossarms shall be wood with steel braces. All arms on poles shall be double arms whether on tangent or curve alignment. Mounting holes, brace holes and double arm bolt holes shall be pre-drilled for the type of pole to which they will be mounted. If holes are incorrectly drilled for the mounting pole, new arms shall be used and then field drilled. The DB Entity shall have on hand, spare undrilled crossarms to be used if pre-drilled arms do not fit. Where insufficient strength is encountered, the individual arms shall be doubled with another arm bolted directly to it.

D. Steady Arm Assemblies

1. New steady arm assemblies shall be manufactured in accordance to the dimensions, materials and working loads as determined.
2. Steady arms shall be adjustable with a rod with dimples inserted into a pipe held in place with a set screw. The arm shall be connected to an articulated swivel that will allow the arm to rotate 360° horizontally and 90° vertically. It shall be placed on the contact wire directly under the cantilever pipe at the neutral position of the cantilever at 60°F. If adjustment by extending or retracting the arm is done, the set screw shall be sufficiently tightened and then the jam nut shall be tightened. The clamp ear attached to the arm shall have a liberal coating of grease in the boss and shall be screwed on so that it can rotate and that the body of the clamp bears against the wire on the outside of the curve pull.

E. Pulloff Assemblies

1. New pulloff assemblies for contact wire and messenger cable shall be manufactured in accordance to the dimensions, materials and required working loads as DB Entity's accepted Design Documents.
2. Pulloff assemblies shall consist of a pullover rod, insulator, and clamp ear. The boss of the ear shall have a liberal coating of cup grease applied to it for corrosion prevention. The ear shall be screwed onto the insulator so that it can rotate for along-track movement in contact tension zones. Both boss and stud shall be 5/8-11 thread. The ear shall be secured onto the pullover so that the ear body is pulling the contact wire over and the clamp portion is on the outside of the curve and shall be able to rotate.
3. Contact wire may be strung on curves with a stringing hook attached to the line insulator if the pullover is attached to a cantilever or span wire. If the pullover is a flying pullover, use the pullover itself to hold the wire. After contact wire is strung and tensioned, relieve tension from the stringing hook and remove it. Then attach the pullovers to the contact wire and relieve tension so that the pullovers take all of the curve pull. Make adjustments to alignment and height as needed. Double pullover rods are to be spaced 24 inches at the contact wire.

F. Messenger Cable Support Assemblies

1. New Messenger Cable Support assemblies shall be manufactured in accordance to the dimensions, materials and working loads as shown on the DB Entity's accepted Design Documents.
2. New Messenger Cable assemblies shall be installed to support and register the messenger cable and trolley wires at the positions and heights as described in the DB Entity's accepted Design Documents.
3. Where messenger cables cross each other or overlaps or crossovers, the turnout wire shall be over the mainline wire. Distance between messengers shall be 3-6 inches and is to be developed through the assembly components. Adjustments are to be made in the field to keep the messenger wires from chafing against each other.
4. Messenger cables shall be suspended under the top cantilever pipe with insulation between the clamp and the pipe

G. Catenary Hangers

1. New Messenger Catenary Hanger assemblies shall be manufactured in accordance to the dimensions, materials and working loads as shown on the DB Entity's accepted Design Documents.
2. Adjustable Flexible Catenary Hangers required are current carrying and shall be used to support the trolley wire from the messenger wire where catenary suspension is utilized as shown on the DB Entity's accepted Design Documents. They may be either prefabricated or field cut, and lengths are based on the catenary hanger tabulation table shown on the DB Entity's accepted Design Documents. It is recommended that the DB Entity make up one side of the hanger assembly and keep the other side loose for adjustment after all stringing and adjustment operations have been made. The hanger heights can then be finalized. Along track positioning of each hanger shall be plus or minus 3 inches of intended position. Hangers shall be furnished and installed in accordance with MBTA Standard Specification P-160, as modified herein, and as shown on the DB Entity's accepted Design Documents.
3. Adjustable rigid insulated Catenary hangers and shall be used to support the trolley wire from the messenger wire where catenary suspension is utilized as shown on the DB Entity's Accepted Shop Drawings. They are to be used in locations where vertical distance between the messenger and trolley wires is less than 12 inches. When all adjustments have been completed and the correct contact wire height has been achieved, the rods of the hangers shall be bent inward 90 degrees and cut off so that they do not protrude beyond the sides of the hanger.

H. Section Insulators-Main Line

1. New section insulator assemblies shall be manufactured in accordance to the parts, dimensions, materials and working loads as shown on the DB Entity's accepted Design Documents.
2. Section Insulators for main line operation shall be the standard MBTA Double Beam Cut Out type, non-bridging and shall be suspended by either messenger wire or span wire. In main line catenary with a messenger wire, the section insulator shall be installed directly under the center of the messenger wire insulator and such that the length that the insulated portion extends beyond the double eyes of the sectionner. Split insulated messenger protector spools shall be fixed to the insulator for attaching the hanger wires. The messenger wire on each side of the sectionner shall terminate in automatic deadends fixed to the messenger insulator. The messenger wire shall be directly over the contact wire perpendicular to the track plane.
3. The sectionner shall be cut into the tensioned contact wire without the runners attached. Lay the unit on the contact wire directly under the messenger insulator. Mark the contact wire where it corresponds to inside end of the anchor tip. Remove tension from the contact wire and cut it in the middle. Saw cut the wire at the marks and file any burrs or rough edges. Cuts shall be square.

Slide one end of the unit onto one wire and tighten the set screws until they bottom out on the tip. Release tension in the contact wire and then put the end into the other tip and jack up the wire hitting the top of the tip to get the wire in. When completely inserted, tighten the set screws, release the tension on the contact wire and remove any kinks in the wires.

4. The plane of the sectionner runners shall lie parallel with the track. Make adjustments by either shortening one hanger wire or physically twisting the contact wire on each side of the unit so that it lays parallel to the track. The unit should then be lifted by the hanger wires so that it is slightly "hogged" so that hanger wires have the weight of the sectionner on them.

I. Section Insulators-Yard

1. Section insulators for yard operations shall be the standard MBTA NO-BO style section insulator or approved equal and shall be suspended by either span wire or without suspension close to a span wire or other support. It shall be installed according to the manufacturer's recommendations and shall stand vertically when installed with no tipping. The underrun shall be completely smooth with no burrs, gaps or other obtrusions to chip pantograph carbons. Length of insulated underrun shall be 14 inches.

3.8 OTHER SUPPORT SYSTEMS AND FITTINGS

A. Installation of Jumper Assemblies

1. New jumper assemblies shall be manufactured in accordance to the parts, dimensions, materials and working loads as shown on the DB Entity's accepted Design Documents.
2. All jumpers shall be installed at locations denoted on the DB Entity's accepted Design Documents. In-span jumpers between messenger and contact wire shall be shaped as shown on the DB Entity's accepted Design Documents. Overlap jumpers shall have sufficient slack to allow for along-track movement.
3. Before making up the jumper clamps, the conductor shall be wire brushed for good electrical connection.
4. The DB Entity shall install the jumpers in accordance with the normal direction of travel and all jumpers shall be installed in a similar manner.
5. In span jumpers for the catenary equalizers shall be shaped as shown on the DB Entity's accepted Design Documents.

B. Installation of Trolley Wire and Messenger Wire Deadends

1. The DB Entity shall install the trolley wire and messenger wire deadends in accordance with the manufacturer's recommendations.
2. Trolley Wire Deadends shall be placed in the deadend wire at a distance from the gage of the nearest running rail at no less than 18 inches. The messenger wire deadend shall be placed directly over the contact wire deadend and both shall be no less than 18" to the gage of the closest running rail.
3. The contact wire and messenger wire shall be placed into the deadend device and the end of it bent back 180 degrees for additional security against pulling out.
4. The deadends shall not droop below the main line contact wire. If this occurs, raise the deadend clamp on the pole for single wire or shorten the catenary hangers to pull it up.

3.9 FINAL ADJUSTMENTS

- A. After support registration, and termination assemblies have been installed, a final check of the construction and adjustment to final position shall be made.
 - 1. Height and lateral position of wire shall be checked, adjusted where necessary.
 - 2. The wire heights shall be finalized after tensioning and proper registration.
 - 3. Cantilever along-track movement shall be checked for each tension length to determine proper location. Tolerance of cantilever position is +/-1 inch
 - 4. The stagger of the trolley wire is relative to the centerline of the track. The stagger is measured in inches to left or right of this centerline. Tolerances shall be as follows:
 - a. Stagger of trolley wire: +/- 1/2 inch.
 - b. Height trolley wire: +/- one inch.

3.10 TROLLEY WIRE MEASUREMENTS AT SUPPORTS AND MIDSPAN

- A. The following measurements shall be made and recorded with the wire in its final position:
 - 1. Wire height above the plane of the track at each support point.
 - 2. Wire temperature and air temperature including time of day at the balance weight or deadend of each wire run.
 - 3. Trolley wire stagger and offset relative to centerline of the pantograph travel at each registration point and at midspan.
- B. The pantograph does not travel over the track center line on curves but is offset by an amount varying according to the track radius. The center of the pantograph from the center of the track on a curve will correspond approximately to mid-ordinate of a 20.11 foot chord set on the outer rail head edge of the inner curve rail. The DB Entity shall verify the offsets and staggers shown on the DB Entity's accepted Design Documents and make modifications to meet the criteria of a +/- six inches pantograph stagger.
- C. The DB Entity shall devise a measuring gage that locates the contact wire and allows adjustment so that the offset/stagger corresponds to the location of the pantograph on tangents and curves.
- D. After all wires, cables, and other OCS components have been installed; all systems tested, approved and energized, the DB Entity shall test the operation of the overhead system with a light rail vehicle in conjunction with MBTA forces. Any deviations to stagger/offset and adverse pantograph operation shall be adjusted or remedied so that the pantographs can travel along the overhead system at full rated allowable speed with no pantograph bounce, shimmy or arcing (except at section insulators) and with safe stagger.
- E. A complete set of the final height and stagger dimensions as accepted shall be submitted to the MBTA by the DB Entity before the final inspection and shall be incorporated into the final as-built drawings.

3.11 TROLLEY WIRE ELECTRICAL TESTING

- A. All measurements and tests to the catenary system shall be made in the presence of the MBTA unless the MBTA assigns another person to witness the tests.
- B. Catenary, trolley wire testing
 - 1. When all catenary is completely installed and ready to be energized, the DB Entity shall check the positions of all wayside disconnect switches for correct position, i.e. open or closed.

2. All surge arrestors shall be disconnected at their positive wire lead stud and the end of the wire shall be temporarily taped during OCS testing.
3. Each power section of contact wire (messenger/contact wire for catenary) shall be checked for insulation resistance using a constant voltage sourced 2,000 volt Meggar instrument. The positive lead will be attached to the contact wire and the negative lead wire attached to the running rails. The voltage shall be brought up to 2,000 volts and left in place for one minute and the readings recorded. Minimum reading shall be no less than 2 megohms.
4. Perform an acceptance test on the OCS including all contact wire insulators and feeder cables in accordance with NETA Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems, Section 7.3.3. Switch box cable lugs should be disconnected and covered with a rubber boot prior to the test and then reattached after the test. Any insulator or cable that fails shall be either replaced or repaired to the satisfaction of the MBTA.

C. Surge Arrestor Testing

1. Each surge arrestor shall be tested in place prior to testing and energizing the OCS to ensure the viability of the unit. The positive and negative wire leads shall be disconnected and the device prepared for test. Test instruments and test procedure shall be as recommended by ANSI/NETA ATS-2009 Section 7.19.2 and the manufacturer.
2. Test results and leakage values shall be noted and a report of the test results provided to the MBTA. Any arrestor that fails the test shall be replaced at no cost to the MBTA with a new unit which shall then be tested as described herein.
3. Upon successful (or unsuccessful) completion of the test, the unit shall have a ground placed on the negative lead to drain any residual voltage. The positive and negative wire leads will then be re-attached and the unit readied for operation.

END OF SECTION

SECTION 16124

GALVANIZED STEEL WIRE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing and delivery of stranded steel guy wire, Class C zinc-coated as described in MBTA Specification P-108B or approved equal for use in the OCS construction.
- B. All span wire for OCS suspension shall be 3/8" guy wire. Back guys, head guys and down guys shall be sized by the DB Entity.

1.2 REFERENCES

- A. Pertinent provisions of ASTM Standard A475 Zinc-Coated Steel Wire Strand shall apply to the work of this Section, except as it may be modified herein, and is hereby made a part of this Section to the extent required. One copy of the ASTM A475 Standard shall be furnished to the MBTA for their use and permanent record.
- B. Pertinent provisions of the MBTA "Specifications for the Purchase of Zinc-Coated Steel Wire Strand", Specification P-108B or approved equal, shall apply to the work of this Section, except as it may be modified herein and in Volume 2 Technical Provisions Sections 11.2 and 11.3.

1.3 SUBMITTALS

- A. The following information shall be submitted in accordance with Volume 2 Technical Provisions Subsection 2.8.
 - 1. The DB Entity shall submit shop drawings prior to steel wire delivery or manufacture, which shall include, but not be limited to, the following:
 - a. Physical Characteristics, chemical content and parameters
 - b. Size
 - c. Type
 - d. Material
 - e. Dimensions of wire
 - f. Overall diameter
 - g. Cross sectional area
 - h. Weight per foot
 - i. Rated breaking strength
- B. The DB Entity shall submit a certification to the MBTA verifying that the galvanized steel wire has been designed, manufactured, inspected and tested in accordance with the applicable portions of the referenced standards and these Mandatory Specifications.

1.4 DELIVERY, STORAGE AND HANDLING

- A. The wires shall be shipped on reels suitable for the weight of the wires.

- B. Materials shall be protected against damage in ordinary handling and shipping. Each reel shall have a strong, weatherproof tag securely fastened to it showing the physical and mechanical properties as well as the steel type designation, ASTM designation and the name and mark of the manufacturer, the length and weight of the wire.
- C. Reels shall be tagged with material description, contract number, and item number.

PART 2 – PRODUCTS

2.1 MATERIALS

- A. Components: The zinc-coated stranded wire shall be manufactured and tested in accordance with ASTM A475.
- B. Performance: Physical properties of the zinc-coated stranded wire shall conform to Table 1 of ASTM A475.
- C. Zinc Coating: The weight of coating for zinc-coated steel wire shall not be less than that specified in Table 4, under Class C of ASTM A475.
- D. Size of the wire shall range from 5/16” to 3/4” diameter, 7 strand guy wire.
- E. The grade of wire shall be determined by the DB Entity.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Galvanized steel wire shall be installed as part of one or more assemblies in accordance with these Mandatory Specifications, as indicated in Volume 2 Technical Provisions Sections 11.2 and 11.3, and shall be installed in accordance with Section 16123 – OVERHEAD CONTACT SYSTEM INSTALLATION.

END OF SECTION

SECTION 16125
CATENARY POLES
PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

A. This section specifies the following:

1. Furnishing of catenary poles and foundations which will include new poles on the new Lechmere Viaduct and along the right of way and in the yard area.
2. Poles comprised of wide flange beams with base plates for the new Lechmere Viaduct, and wide flange beams with base plates along the right of way and the yard. Anchor base poles will be mounted onto anchor bolts provided integrated into the viaduct or supplied by the DB Entity.
3. Foundations for anchor base poles (or embedded if used by DB Entity).
4. Foundations consisting of drilled holes with steel pipe liners and cast-in-place concrete.
5. Furnishing structural steel components as related to poles and supporting structural hardware.
6. Testing of pole to earth ground resistance.
7. Reference is made to SECTION 03300 "CAST IN PLACE CONCRETE" for concrete material requirements, and to SECTION 16124 GALVANIZED STEEL WIRE for guy wire requirements. Related section is SECTION 16123 OVERHEAD CONTACT SYSTEM INSTALLATION.

1.2 SUBMITTALS

A. Provide submittals in accordance with Volume 2 Technical Provisions Subsection 2.8.

B. Welding Records and Data

1. Submit certified copies of qualification test records for each welder, welding operator and tacker who will be performing work for material supplied to the Project. All said qualification test records shall be accepted by the MBTA in writing prior to any work being undertaken. Comply with the requirements of ANSI/AWS D1.1, Section 5, Parts A, C, D, and E.
2. Submit certifications that magnetic particle and dye penetrant inspections have been satisfactorily completed.
3. Submit records of ultrasonic testing.
4. Mill Certificates: Submit mill certificates and certified copy of reports for all analyses and tests required by referenced ASTM and AWS specifications.

C. Erection and Detail Drawings

1. Submit drawings of erection and detail of steel structures for review and acceptance before material is ordered or fabrication begins. Upon acceptance, the required number of sets of all prints shall be furnished before delivery of steel to the job site.
2. All details shall be completely dimensioned.

D. Submit the following for poles and hardware.

1. Shop drawings, catalog cuts, and descriptive data.
 2. Special storage instructions
 3. Certificates of Compliance.
- E. Submit the following for poles.
1. Listing of pole types, lengths and sizes (section type)
 2. Data sheets noting the deflection of poles
 3. Certificates of compliance to these Mandatory Specifications and testing criteria
- F. Submit factory test reports in accordance with Volume 2 Technical Provisions Subsection 2.8.

1.3 REFERENCES

- A. Pertinent latest edition provisions of the following listed standards shall apply to all work of this Section, except as modified herein, and are hereby made part of these Mandatory Specifications to the extent required.
1. American Society for Testing and Materials (ASTM)
 - a. A6 Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
 - b. A82 Steel Wire Plain, for Concrete Reinforcement
 - c. A123 Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
 - d. A143 Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
 - e. A242 High Strength-Low Alloy Structural Steel
 - f. A276 Stainless and Heat-Resisting Steel Bars and Shapes
 - g. A325 High-Strength Bolts for Structural Steel Joints
 - h. A354 Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
 - i. A370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products
 - j. A384 Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
 - k. A416 Steel Strand, Uncoated 7-wire for Prestressed Concrete
 - l. A421 Uncoated Stressed Relieved Steel for Prestressed Concrete
 - m. A435 Straight-Beam Ultrasonic Examination of Steel Plates
 - n. A490 Heat-Treated, Steel Structural Bolts, 150 ksi (1035 MPa) Tensile Strength
 - o. A496 Steel Wire, Deformed for Concrete Reinforcement
 - p. A500 Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
 - q. A501 Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
 - r. A588 High-Strength Low-Alloy Structural Steel

- s. A615/A615M Deformed and Plain-Billet Steel Bars for Concrete Reinforcement
 - t. A617/A617M Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
 - u. A641 Zinc Coated (Galvanized) Carbon Steel Wire (Metric)
 - v. A673 Sampling Procedure for Impact Testing of Structural Steel
 - w. A706A/A706M Low Alloy Steel Deformed Bars for Concrete Reinforcement
 - x. A871 High-Strength Low-Alloy Structural Steel Plate w/Atmospheric Corrosion Resistance
 - y. E376 Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Examination Methods
2. American Society of Civil MBTAs (ASCE):
 - a. No. 72 Design of Steel Transmission Pole Structures
 3. American Concrete Institute (ACI)
 - a. ACI 318, Building Code Requirements for Reinforced Concrete
 4. Industrial Fasteners Institute (IFI)
 - a. Fastener Standards
 5. American National Standards Institute (ANSI) C2
 - a. National Electrical Safety Code
 6. American Welding Society (AWS)
 - a. ANSI/AWS A2.4 Symbols for Welding and Nondestructive Testing
 - b. ANSI/AWS A3.0 Standard Welding Terms and Definitions
 - c. ANSI/AWS Welding Rods, Electrodes, and Filler Metals
 - d. ANSI/AWS B1.10 Guide for the Nondestructive Inspection of Welds
 - e. ANSI/AWS D1.1 Structural Welding Code – Steel
 - f. ANSI/AWS D1.3 Structural Welding Code - Sheet Steel
 - g. AWS QCI Standard and Guide for Qualification and Certification of Welding Inspectors
 7. Institute of Electrical and Electronics Engineers (IEEE) Standard P1630
 8. Steel Structures Painting Council (SSPC)
 9. Conflicts
 - a. When a conflict exists between two referenced industry standards, the more stringent requirement shall govern.
 - b. When a conflict exists between a referenced standard and this specification, the more stringent requirements shall govern unless stated otherwise.

1.4 DELIVERY AND STORAGE

- A. Ship poles suitably covered to protect them from damage during shipment. The poles shall be handled and stored in accordance with the manufacturer's instructions to protect them from damage. Protect poles during storage from collisions with vehicles, falling equipment, and rolling off of the storage pile. Each pole shall be laid above the ground so that they are not in contact with soil or other debris and each successive layer shall have wood dunnage of sufficient strength to prevent it from being crushed.
- B. Poles damaged during delivery or during storage shall be inspected by the DB Entity for extent of damage. Those poles deemed non-useable for the project shall be rejected and replaced by the DB Entity at the DB Entity's expense. Poles that are deemed repairable by the DB Entity shall have those repairs needed to put them in a state of good condition completed by the DB Entity and at the DB Entity's expense. Repaired poles shall be inspected by the MBTA and shall receive the MBTA's acceptance for re-use on the project.

1.5 QUALITY CONTROL

- A. Conduct factory testing in accordance with Section 01400.
- B. Welders: Certified by the MBTA and experienced in making steel welds for pole construction (minimum five years proven experience).
- C. The Project may request the welder to make test welds in the presence of the MBTA before certification is granted.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All new pole structures shall be steel, hot dipped galvanized except for those poles requiring a painted finish coat. Poles requiring a painted finish shall not be galvanized.

2.2 WIDE FLANGE BEAMS

- A. Wide flange beams and cross beams for portal structures shall be wide flange sections conforming to ASTM A992 with minimum yield strength of 50,000 psi. They shall be either anchor base type or direct embedment type. Where wide flange beams require an anchor plate at the base of the pole, it shall be comprised of steel per ASTM A572 grade 50 with minimum yield strength of 50,000 psi.
- B. Poles having anchor plates shall have the pole welded to the plate with full depth penetration welds as described herein. All welds shall be inspected for integrity of workmanship.
- C. Poles shall be one piece up to 45' long. Where excessive lengths are required, the pole shall be extended in length by splicing another wide flange section to it of the same type. Splices shall consist of steel splice plates to which the two sections of pole shall be attached. All holes drilled in the pole sections shall be done in the fabrication shop and prior to hot dip galvanizing. Splice plates shall be located on the spliced pole where the splice plate would be on the section of the pole that is inserted into the pole foundation hole.
- D. Poles and connecting hardware shall be hot dipped galvanized after fabrication according to ASTM A123 and A153.

2.3 FOUNDATIONS

- A. Foundations shall be classified as anchor base (unless DB Entity chooses embedded poles). Anchor base type poles which are mounted on the viaduct structure, on walls will not utilize drilled caisson foundations but will be mounted and secured to anchor bolts installed separately from the pole installation. For anchor base poles requiring an earth foundation, the foundation shall consist of a drilled caisson to the depth and diameter indicated in Volume 2 Technical Provisions Sections 11.2 and 11.3. Foundations shall be cast in place. The method of installing these foundations is further described in SECTION 16123 – OVERHEAD CONTACT SYSTEM Installation.
- B. Steel Casing
 - 1. Steel casing shall be carbon steel, free of cracks and other signs of distress, conforming to ASTM A36, or ASTM A252, seamless or welded. Surface shall be free of loose scale or rust, grease and other foreign matter.
 - 2. Inner diameter of casing shall be large enough to construct pole foundations as described herein and elsewhere within the Construction Documents. All casings shall extend the full length of the embedded pier. Splicing of casings by full penetration butt welds will be acceptable. Welding shall conform to AWS Structural Welding Code D1.1.
 - 3. Steel casing thickness shall be no less than 3/8". The steel liner may remain in place or be removed and the inner casing shall remain in place after installation.
- C. Concrete
 - 1. Concrete shall have 28 day strength (fc) of 4,000 psi.
 - 2. Aggregate shall be no greater than 3/8".
- D. Steel Reinforcement
 - 1. Steel reinforcement shall conform to ASTM A615, Grade 60 and shall be bare steel without coating.

2.4 FACTORY TESTS

- A. Conduct tests in accordance with ASCE standards for fabricated structures.
 - 1. Poles: deflection tests

PART 3 - EXECUTION

3.1 INSTALLATION

- A. General
 - 1. The DB Entity shall inform the MBTA about any field conditions encountered which are not covered or are substantially different from those specified in this Specification and perform the work in question in accordance with the MBTA's instructions and direction.
 - 2. The DB Entity shall coordinate this work with the installation of the overhead contact system, other systems, structural and civil work. All pole installations shall be complete and accepted by the MBTA.
 - 3. The DB Entity shall conform to safety features and requirements specified herein and to those required by the MBTA.

4. Any pole that is damaged during installation shall be assessed by the MBTA. Poles which cannot be repaired shall be replaced with an in-kind new pole at no cost to the MBTA. Finishes damaged during installation shall be restored in a manner consistent with manufacturer's instructions for finish restoration and shall be accepted by the MBTA.
5. Poles may be moved laterally along track or back from the track by up to 12" for clearance of obstructions. Poles may not be moved closer to the track unless the DB Entity is directed to do so by the MBTA. The DB Entity shall inform the MBTA of any pole location changes.

B. Foundation Excavation-Suggested

1. Foundation holes shall be drilled using a steel pipe casing with a minimum thickness of 3/8 inch and with a diameter specified in the Volume 2 Technical Provisions Sections 11.2 and 11.3. Each foundation shall be staked in advance of drilling and receive acceptance of the MBTA prior to excavation. The steel pipe drill shall remain in place when drilling is complete.
2. Soil shall be excavated after the drill has reached the proper depth.
3. Excavated soil shall be considered contaminated due to the nature of the railroad environment and shall be properly disposed of as indicated in other sections of the Contract Documents.
4. Where complete depth penetration cannot be achieved due to encountering bedrock or hard ledge, the remainder of the hole shall be drilled in rock to a diameter 6" greater than the pole width. The depth in rock shall be no less than 4 feet.
5. Where any unforeseen obstruction is encountered that prevents the hole from being drilled, the DB Entity shall inform the MBTA and take direction.

C. Foundation Steel Reinforcement Placement

1. Upon completion of drilling to the desired depth, the soil shall be removed from the interior of the pipe and reinforcing and anchor bolts shall be installed. The reinforcing shall not be placed directly to earth contact but be spaced 6 inches from any soil.
2. Concrete shall be poured into the hole with care so as to not unseat the anchor bolts. A pencil vibrator shall be placed into the hole to ensure that all concrete is properly distributed and that no voids are created.
3. Upon completion of the concrete pour, the steel liner may remain in place or be removed. If removed, care shall be exercised to prevent disturbance of the anchor bolt arrangement. If disturbed, the DB Entity shall reposition the anchor bolts as required.
4. The foundation shall remain in place until the concrete is set up (7 days minimum) at which time, the pole can be inserted into the anchor bolts.

D. Direct Embedment

1. Direct embedded poles may be used but at the discretion of the DB Entity.
2. Direct embedded poles shall be set into the pole foundation interior pipe when the concrete has set up sufficiently to support the pole weight and wind load.
3. The pole shall be set in the center of the hole so that its axis coincides with the center axis of the pipe and it shall remain supported until supports are attached.
4. Upon insertion of the pole into the foundation hole and orienting the web to the proper direction, it shall be raked by an amount determined by the DB Entity.
5. When the pole is properly raked, the DB Entity shall insert steel angles into the interior pipe on two sides of the pole and weld them, the angles, to the pole and the pipe so that the angles hold the pole in place and electrically connect the pole and the interior pipe together. The angles shall be

placed 6 inches from the top of the pipe and all galvanized surfaces to which the angles are being welded shall have grinding applied to remove the zinc coating. All welding shall be done on a bare steel surface. Upon completion of welding and when sufficiently cool, the exposed surfaces shall be coated with a zinc rich paint type coating.

E. Concrete Pouring

1. Concrete shall be mixed, placed, finished and cured. Concrete may be placed by a tremie pipe or hose when free drop is not practical. If a tremie is used, fabricate the tremie in sections with joints that allow the upper sections to be removed as the placement progresses. Sections may be jointed by flange, bolted connections (with gaskets) or be screwed together. Whatever joint technique is selected, joints between tremie sections must be watertight. The joint system selected shall be tested for water-tightness before beginning placement. The tremie pipe shall be marked to allow quick determination of the distance from the mouth of the tremie. Provide the tremie with a suitably sized funnel or hopper to facilitate transfer of sufficient concrete from the delivery device to the tremie. Provide a stable platform to support the tremie during the placement. The platform shall be capable of supporting the tremie while sections are being removed from the upper end of the tremie.
2. Concrete shall be vibrated during the entire course of the pour to ensure complete compactness and prevention of voids. Each foundation shall be completely poured and no partial pours will be accepted. Excess concrete shall be removed and disposed of by the DB Entity off the construction site. Any spilled concrete shall be immediately cleaned up and disposed of. Care shall be exercised during the pour to prevent concrete spillage and any staining of OCS poles with concrete shall be cleaned off the pole completely.
3. Concrete shall be certified as to strength and aggregate size and the DB Entity shall provide documentation of such for each batch delivered.
4. The DB Entity shall inform the MBTA of all scheduled concrete pours 24 hours prior to the pour.

F. Attachment to Retaining Walls

1. Poles attached to retaining walls shall be considered anchor base type and shall be set onto anchor bolts protruding from the wall.
2. Installation shall be as described herein and on the Contract Documents.

G. Control of Excavated Material from Pole Foundations

1. All excavated material shall be considered contaminated and shall be disposed of in a manner consistent with the Contract Documents and the MBTA's requirements for disposal of contaminated materials.
2. Safety to personnel from excavated pole holes shall be of primary concern and the DB Entity shall cover all open excavations with heavy steel plates so that they cannot be inadvertently moved or removed. They shall be installed over the pole hole in such a way that it shall be impossible for personnel to fall into the hole.

H. Installation of New Viaduct Poles

1. All poles on the new viaduct shall be anchor base type and shall be mounted onto anchor bolts protruding from the viaduct pole haunches.
2. Anchor bolts will be provided and installed by the constructor of the new viaduct.
3. DB Entity shall verify the height of the pole base parapet above the top of rail and determine the required height of the pole. New viaduct poles shall have a nominal height above top of high rail of 24'-0" unless DB Entity determines otherwise.

I. Installation of Portal structures

1. Portal structures shall be installed on wide flange beams if required.
2. Design of portal structures shall be according to the DB Entity. They shall be installed to the heights above top of rail providing safe clearance. They shall be no less than 3' above the messenger wire for catenary construction or 3' above the contact wire for single wire construction.

3.2 TESTS

A. General

1. The DB Entity shall provide all instruments, materials, and labor required for tests specified herein on all poles and related structural steel furnished and installed by him.
2. The DB Entity shall formulate an overall test program for the installation, which shall include, but not be limited to, the tests specified in this Section to ensure equipment and material compliance with the relevant standards, this Specification and satisfactory and reliable performance in actual intended operation.
3. The DB Entity shall perform field tests of pole to earth resistance ground tests.

B. Conditions for Tests

1. Prior to testing of any pole prior to the installation, the following conditions shall be fulfilled by the DB Entity:
 - a. The DB Entity shall have in his possession, all the shop drawings duly accepted by the MBTA.
 - b. The DB Entity shall have submitted testing procedures for the MBTA's acceptance at least 45 days in advance of the testing.

C. Witnessing Tests

It is the discretion of the MBTA, to witness all testing of poles. Should the MBTA not witness testing, the DB Entity shall document all tests for submission to the MBTA. All tests, whether or not in the presence of the MBTA, shall be certified.

D. Responsibility

The DB Entity shall assume full responsibility during installation of all poles and structural steel provided by them. Should there be any loss due to theft or damage to such material or installation as a result of these installations, the DB Entity shall be fully responsible for replacing the damaged poles and materials. Replacement of damaged poles and materials shall include all costs, including, but not limited to, removal of damaged material, furnishing of, transportation of, and installation of replacement material.

E. Rejection

1. The MBTA reserves the right to reject any pole or installation that is in non-conformance to the Contract Documents.
2. Any rejected pole, foundation, cross beam or other associated pole installation shall be replaced in total to the complete satisfaction of the MBTA.
3. Replacement of rejected installations and hardware shall be undertaken at the expense of the DB Entity and at no cost to the MBTA.

F. Costs of Tests

The price for conducting all factory, field tests and checkouts in the presence of the MBTA, including entire cost of rectification, retesting, and/or supplying of new items shall be deemed to be included in the Contract Price.

G. Field Tests

1. All tests required herein shall be undertaken and performed by the DB Entity.

H. Defective Poles and Material

1. Any DB Entity furnished pole or material found defective before installation shall be replaced by the DB Entity. Cable found defective after installation shall be repaired or replaced at the DB Entity's expense.
2. Any pole or material installed under this Contract found defective during the testing shall be replaced with a new material. Rectification of defects of any pole or related material shall be done only with the specific acceptance of the MBTA.
3. Anchor base poles shall have a pole ground installed and that shall be tested after the pole, ground wire, and ground rod has been installed. If the resistance test indicates a resistance greater than 25 ohms, the DB Entity shall drive additional ground rods until the required resistance can be met. If resistance cannot be met, take direction from the MBTA.
4. Testing of pole grounds shall be performed on the pole after it is installed. If the resistance to earth is 25 ohms or less, taking into account temperature, the test shall be considered successful. If the earth resistance is greater than 25 ohms, additional 4/0 AWG ground wires shall be welded to the pole and passed through foundation ground wire conduit and run to a separate ground rod. The test shall then be redone and the resistance noted. If still greater than 25 ohms, the DB Entity shall take direction from the MBTA.
5. If the drilling caisson remains in place, it may be used as a ground electrode and the ground wire may be welded to it.

I. Test Reports

1. The DB Entity shall submit five copies of certified test reports of all factory and field tests for the MBTA's review and acceptance. Test reports of field tests shall be submitted no later than seven days after testing. Test reports shall be self-explanatory, noting the personnel involved, and shall show the instruments used for testing and the date(s) of their last calibration. Test reports shall contain identification of each pole tested in a manner that can be referenced to the Contract Documents.

3.3 POLE IDENTIFICATION TAGS

- A. Install standard pole tags on all poles, two pole tags to each location, one cable tag on the front of the pole facing the track and one cable tag on the pole facing the direction of traffic. The pole cable tag will be the standard MBTA type embossed aluminum tag as described herein and as indicated on the Contract Documents.
- B. Pole tags shall be placed 10' above the top of rail unless stated otherwise.
- C. Numbers shall be black on yellow background. Letter/number height shall be 2".
- D. Each pole tag shall consist of two holders placed so that they butt up against each other providing route number and pole number as shown on the Contract Documents. The route number shall be on top of the pole number. Each holder shall be fixed to the pole surface with 1/4-20 stainless steel machine screws.

Each hole shall coincide with the hole on the holder and shall be drilled and tapped into the pole. The hole threads shall have Loctite 242 (“Blue Loctite”) applied. Tags shall be horizontal to the pole sides.

- E. Poles on the right of way shall have numbers facing the track. Where the pole is between two tracks, the numbers shall be on two sides of the pole facing each track.

END OF SECTION

SECTION 16126

DIRECT CURRENT POWER CABLE AND DIRECT CURRENT POWER FEEDER DISCONNECT SWITCHES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following:
1. Furnishing, installing, testing, terminating and splicing EPR/XLPO insulated DC power cables and installing and testing, 2000/4000 Amp feeder disconnect switches.
 2. Furnishing, installing, terminating, splicing, and testing new aerial 1,000 kcmil ethylene propylene rubber (EPR) insulated cross-linked polyolefin (XLPO) jacketed cable rated for 2,000 Volts for 600 Volt DC positive supplementary feeders.
 3. Furnishing, installing, terminating, splicing, and testing new 1,000kcmil and 2,000kcmil ethylene propylene rubber (EPR) insulated cross-linked polyolefin (XLPO) jacketed cable for 650VDC positive feeders.
 4. Furnishing, installing, terminating, splicing, and testing, new 1,000,000 and 2,000,000 circular mil cross-linked polyolefin (XLPO) insulated cable for 600 VDC negative return circuits.
 5. Furnishing, installing, connecting and testing of manual DC traction power disconnect switches at locations as described in Volume 2 Technical Provision Section 11 Railroad Systems and Exhibit 2A.1 Mandatory Specifications.
 6. Furnishing and installing of galvanized and stainless steel channel supports, miscellaneous cable clamps, exterior grade FRE conduit, cable terminations, pole supports and cable insulators for DC cables as described in Technical Provision Section 11 Railroad Systems and Exhibit 2A.1 Mandatory Specifications.
 7. Furnishing and installing aerial feeder taps of 4/0 AWG extra flexible cable as described herein.
 8. Furnishing and installing aerial 500 kcmil insulated, ethylene propylene rubber (EPR) insulated cross-linked polyolefin (XLPO) jacketed cable for 600 Volt DC positive feeders as described herein.
 9. Installation of new cable tags of the same type as the pole tag and switch box identification plates of vitreous porcelain enamel.

1.2 REFERENCES

- A. Pertinent latest edition provisions of the following listed standards shall apply to all work of this Section, except as modified herein, and are hereby made part of these specifications to the extent required.
1. American Society for Testing and Materials (ASTM)
 - a. B8 - Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard or Soft.
 - b. B33 - Standard Specification for tin coated Soft or Annealed Copper Wire for Electrical Purposes.
 - c. B172 - Standard Specification for Rope-Lay-Stranded Copper having Bunch-Stranded members for electrical conductors.

1.3 SUBMITTALS

- A. Submit the following for each type of cable in accordance with Volume 2 Technical Provision Subsections 2.7 and 2.8.
 - 1. Shop drawings, catalog cuts, and descriptive data
 - 2. Special storage instructions.
 - 3. Installation, termination, splicing and repair materials and procedures recommended by the cable manufacturer.
 - 4. Certificates of Compliance in accordance with these Mandatory Specifications.
- B. Submit the following for DC traction power disconnect switches in accordance with Volume 2 Technical Provision Subsections 2.7 and 2.8.
 - 1. Detail drawings of the disconnect switch and enclosure, including composite of switch in enclosure.
 - 2. Bill of materials.
 - 3. Data sheets noting the electrical and thermal ratings of the switch.
 - 4. Switch assembly drawings, outline and detail drawings of switch enclosure, showing materials, methods of assembly, anchorage to other work and other significant data for cable racks, cable clamps and cable splicing components.
 - 5. Certificates of Compliance to these Mandatory Specifications and testing criteria.
 - 6. Design test reports as specified in MBTA Standard Specifications.
- C. Submit factory test reports in accordance with Volume 2 Technical Provision Section 2, Volume 1 Section 4.
- D. Prior to making splices, submit the name and qualifications of each individual who will perform cable splicing including experience on similar previous projects.
- E. Submit materials list and assembly details of cable support arrangements, cable clamps and aerial termination details.

1.4 DELIVERY AND STORAGE

Ship cable on reels suitably covered to protect the cable from damage during shipment. Seal, secure, and protect cable ends from damage. Make both ends available for testing, unless prevented by cable size or reel construction. The cables shall be stored in accordance with the manufacturer's instructions to protect them from damage.

1.5 QUALITY CONTROL

- A. Conduct factory and field testing in accordance with Volume 2 Technical Provision Section 2, Volume 1 Section 4.
- B. Cable splicers: certified by the MBTA and experienced in making or breaking splices of similar cables for similar application (minimum five years proven experience).
- C. The MBTA may request the splicer to make test splices in the presence of the MBTA before certification is granted.

PART 2 - PRODUCTS

2.1 GENERAL

All insulators, connectors and support hardware for installation of new traction power feeder cable shall be new, having the physical dimensions, electrical ratings and mechanical strength required for the intended service as shown on the Contract Documents and as specified herein.

2.2 DC POSITIVE FEEDER CABLE AND NEGATIVE CABLE

- A. Cables covered in this section are intended for use in DC traction power service operated at a nominal 600 Volts, subjected to additional Voltage stresses resulting from the operations of light rail vehicles with regeneration and substation rectifier equipment. Cables shall be suitable for installation in dry or wet locations, in exposed or underground conduits, trays, cable racks, directly buried or run exposed.
- B. Furnish positive/negative 1,000 kcmil, single conductor, EPR insulated, XLPO jacketed cable in accordance with MBTA Specification P-118F.
- C. Furnish positive/negative 2,000 kcmil, single conductor, EPR insulated, XLPO jacketed cable in accordance with MBTA Specification P-120F.
- D. Furnish positive 500 kcmil, single conductor, EPR/XLPO insulated cable in accordance with MBTA Specification P-129C.
- E. Furnish 4/0 AWG, single conductor, EPR insulated, XLPO jacketed cable in accordance with MBTA Specification P-179.

2.3 MISCELLANEOUS INSULATED CABLE

- A. No. 4/0 AWG Extra-Flexible Cable for Jumpers
 - 1. Cable shall be extra flexible containing 259 strands of copper wire with rope-lay-stranding, without insulation. The cable shall be tin coated copper in accordance with ASTM-B33 with Class H stranding as specified in ASTM-B173.
- B. Feeder Cable Tie Wire
 - 1. The tie wire used with pin-type insulators shall be No. 2 AWG annealed solid copper, with black XLPO jacket.

2.4 TRACTION POWER DISCONNECT SWITCHES

- A. Furnish open knife blade type, unfused, no load break, single throw, front-connected, front operated disconnect switches mounted on an insulated base. The switch shall be arranged so that feeder cables can be disconnected easily and reattached easily for cable testing. Cable configurations shall be as shown on the Contract Documents or as required by MBTA.
- B. Furnish new traction power 2,000 amp or 4000 amp disconnect switches with enclosures in accordance with the Contract Documents and MBTA Specifications P-150F.

2.5 AERIAL AND NON-AERIAL CABLE SUPPORT

- A. Aerial feeder cables shall be self-supporting and shall not use a messenger cable. They shall be attached to insulators mounted on wood crossarms or attached to cable cleat insulators where attached to walls or bridge ceilings. Where the feeder cable deadends on a pole or crossarm, strain insulators with deadend clamps shall be utilized to take the tension of the cable. Strain insulators shall be constructed with 3/4-inch diameter epoxy-fiberglass rods with end fittings of the strain insulator of ductile iron or stainless steel with clevis end and eye end in the same plane. Ends shall be crimped over the fiberglass rod. The rod portion of the strain insulator shall have a heat shrink Teflon® tube shrunk completely over it and to

protect the rod from UV radiation. Nominal insulation length shall be 12 inches and maximum design tension shall be 35,000 pounds. The heat shrink Teflon® tube shall pass under the crimped end fitting.

- B. Strain clamps for traction feeder cable may contain two mating pieces connected with U-bolts. One end shall contain an offset clevis fitting for attaching to eye of insulator, the other end a pulling eye. Strain clamps must withstand breaking strength of the cable.
- C. Ferrous hardware, including bolts, nuts, and washers, shall be hot-dip galvanized as indicated on the Contract Documents.
- D. Non-Aerial feeder cables, positive and negative shall be mounted on Porce-A-Clamp or approved equal, which will be attached to 1-5/8" x 1-5/8" double side stainless steel unistrut channel at 3ft intervals, secured to the building structure.
- E. Cable clamps of the G10 fiberglass for supporting the cable risers to the switchgear and all power switches shall be provided. G10 blocks shall be attached to 1-5/8" x 1-5/8" double side stainless steel unistrut channel secured to the building structure.

2.6 CABLE CONNECTORS, CLAMPS, CONDUIT AND HARDWARE

- A. Connectors for connections to new aerial DC feeder cables shall be mechanical, vise type of high strength, high conductivity bronze alloy. The connector opening shall be sized to accommodate the size cables being connected and as noted on Contract Documents. All connectors shall be new.
- B. Connectors for splicing DC aerial cable shall be full tension compression type as recommended by the cable manufacturer.
- C. Beam clamps, cable supports and dead-ending hardware shall be furnished in accordance with details on the Contract Documents.
- D. Cable riser clamps shall be of two-piece grade G10 fiberglass blocks for supporting riser cables or tap cables on beams and poles and shall be furnished either separately or as part of an assembly as shown on the Contract Documents.
- E. Connectors for connections to switchgear and power switches shall be mechanical, high conductivity copper alloy. The connector opening shall be sized to accommodate the size cables being connected and as noted on Contract Documents. All connectors shall be new.
- F. Temporary connectors for splicing supplementary cable shall be full tension compression type as recommended by the cable manufacturer.
- G. All feeder cables, positive and negative, with the exception of the aerial cables, shall be installed in FRE conduit. FRE conduit shall be suitable for outdoor exposure and shall be in accordance with MBTA Specification P-175. FRE conduit shall be located and installed in accordance with the details on the Contract Documents.

2.7 FACTORY TESTS

- A. Conduct tests in accordance Volume 2 Technical Provision Section 2, Volume 1 Section 4 and the following.
 - 1. Cable: standard manufacturers' tests and in accordance with the following standards: NEMA WC8; ANSI/IEEE-48; ANSI/IEEE-400; ANSI/IEEE-532; and ANSI/UL-1072.
 - 2. Disconnect Switches:
 - a. Allowable maximum temperature rise of the switch parts during continuous operation at rated current as specified in ANSI C37-3 when the ambient temperature outside switch in its enclosure is 40°C.

- b. Allowable maximum temperature rise when operating at overload capacity as specified for 15 seconds every 90 seconds over a two-hour period.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General

1. The cable installation shall be in accordance with the manufacturer's recommended installation procedures and SECTION 16127 - AC AND DC AERIAL CABLE INSTALLATION and the Contract Documents.
2. The cable installation for non-aerial DC power cable shall be per this Section.
3. The DB Entity shall inform the MBTA about any field conditions encountered which are not covered or are substantially different from those shown on Contract Documents or specified in this Section and perform the work in question in accordance with the MBTA's instructions.
4. The DB Entity shall coordinate this work with the installation of the substation and overhead contact system per the Design Documents and other sections of the Mandatory Specifications. All riser and tap connections to the switchgear and power switches shall be completed prior to turning over to the MBTA.
5. The DB Entity shall conform to safety features and requirements specified.

B. Splicing and Terminating – Non-Aerial Cables

1. The DB Entity shall splice the cables only where permitted in Article 3.1 of this Section.
2. In order to obtain optimum electrical contact and adequate insulation at the points of connection of each cable, only the most highly skilled cable splicers shall be employed. Cable splicers shall have experience in making splices of similar cables for similar applications. The DB Entity shall submit the name of the individual, with the number of years and type of experience on similar projects. The DB Entity shall obtain prior approval of all individuals who will be making splices.
3. Each splicer shall be accepted for the job by the MBTA prior to any splicing activities. The MBTA may request the splicer to make test splices in the presence of the MBTA before the acceptance is granted.
4. All faulty, imperfect, or damaged splices found during or after installation, shall be removed and replaced. New splices shall be subject to the same tests as are required for the cables after initial installation.

C. Other Cables

1. The DB Entity shall install other overhead cables and cable assemblies as shown on the Design Documents, such as feeder taps and equalizer jumpers.
2. Riser cables shall be supported using new split G10 fiberglass as shown on the Contract Documents, or approved equal. Tap cables shall be supported on support brackets or span wires using new clamps.

3. The DB Entity shall cut new riser and tap cables to final length, install lugs and clamps, and connect these cables to disconnect switches and trolley wires, respectively.
4. The DB Entity shall reinsulate the cable at locations where tap connections are removed from new supplementary cable and thermo-seal the exposed ends of all new cables after cutting if final connection will be delayed.
5. Current-carrying connectors shall be installed in accordance with the following:
 - a. Wire surfaces, which are in contact with conducting surfaces of the connector, shall be thoroughly wire brushed and shall have an inhibitor applied. Where connectors are not factory-loaded, the same inhibitor shall be applied in the field to the connector.
 - b. Corrosion inhibitors shall be stable over a wide temperature range, able to adhere to cold metal surfaces, water-repellent, weather resistant, and inert to copper, aluminum, zinc, tin, cadmium, steel, and neoprene rubber. Grit-bearing inhibitors shall be used except for flat lugs, sliding surfaces or where omission is recommended by the connector manufacturer. Grit shall be compatible with the connector and wire metal. Inhibitor for copper and bronze shall be T&B "Kopr Shield", Fargo "Fargolene", Penn-Union "Cual-Aid", Burndy "Penetrox A", or approved equivalent.
 - c. Bolts in bolt-type connectors shall be lubricated as recommended by the manufacturer and torqued to the manufacturer's recommendation using a calibrated torque wrench.

D. Control of Scrap

1. Scrap components including any abandoned ac and dc cable shall be collected, removed daily from the job site and delivered to the DB Entity at a site designated by the DB Entity.
2. All cable, wire, OCS components, balance weights, pullovers, insulators, poles and other associated OCS material removed from the old viaduct and Lechmere Station shall be returned to the DB Entity at a site designated by the DB Entity.

E. Installation of Traction Power Disconnect Switches and Supports

1. Install traction power disconnect switches assembled in boxes including cable clamp supports. Install a cable tag on each cable entering the box.
2. Install switch enclosures plumb and level and in alignment with adjoining work or structure.

3.2 TESTS

A. General

1. The DB Entity shall provide all instruments, materials, and labor required for tests specified herein on the dc traction feeder cable furnished and installed by him.
2. The DB Entity shall formulate an overall test program for the installation, which shall include, but not be limited to, the tests specified in this Section to ensure equipment and material compliance with the relevant standards, this Specification and satisfactory and reliable performance in actual intended operation.

B. Conditions for Tests

1. Prior to testing of any cable and the installation, the following conditions shall be fulfilled by the DB Entity:
 - a. The DB Entity shall have in his possession, all the shop drawings duly accepted by the MBTA.
 - b. The DB Entity shall have submitted testing procedures for the MBTA's acceptance at least 45 days in advance of the testing.

C. Witnessing Tests

The MBTA will witness complete field-testing on all the cable installation.

D. Responsibility

The DB Entity shall assume full responsibility during field-testing of all cable installation provided by him. Should there be any loss or damage to such cable or installation as a result of these tests, the DB Entity shall be fully responsible for replacing the damaged cable. Replacement of damaged cable shall include all costs, including, but not limited to, removal of damaged cable, furnishing of, transportation of, and installation of replacement cable.

E. Rejection and Retesting

1. Failure of cable or splice to withstand tests or to meet ratings shall be sufficient grounds for rejection of the item tested.
2. Any cable or splice rejected shall be retested in the presence of the MBTA after renewal.
3. If it is not possible to rectify rejected cable to the satisfaction of the MBTA, new cable shall be installed.

F. Costs of Tests

The price for conducting all field tests and checkouts in the presence of the MBTA, including entire cost of rectification, retesting, and/or supplying of new items shall be deemed to be included in the Contract Price.

G. Field Tests

1. All DB Entity installed DC positive traction feeder cables and DC traction power switches shall be tested to ascertain that the dielectric strength of the insulation has not been impaired during installation, that the splices and terminations are properly made and to confirm the integrity of the cable system prior to energization. Tests shall include continuity tests, insulation resistance tests and high potential direct current tests. High potential direct current tests specified herein shall be applicable only to dc positive cables. Rectification of defects of any cable shall be done only with the specific acceptance of the MBTA.
2. Acceptance Tests: After installation of any length of a cable and completing all connections to risers, jumpers, and taps, the DB Entity shall perform the below listed tests on each cable circuit. To preclude damage to equipment and devices the tests shall be conducted before the cable is connected to the disconnect switches and trolley wires.
 - a. Continuity Test: This test shall be performed to prove the continuity of cable circuits.
 - b. Insulation Resistance Test

- 1) This test shall be performed to determine the cable insulation resistance to ground.
 - 2) Tests shall be conducted with a 2,000-volt motor operated megger. Test voltage shall be applied between the conductor and ground and shall be held until the reading reaches a constant value for five minutes. Insulation resistance values obtained by the megger tests shall not be less than two megohms. The DB Entity shall bring to the attention of the MBTA, the results of similar tests having unequal ratings with the variations of 25% or more.
 - 3) For each test, the DB Entity shall record the temperature, humidity, duration of the test and the voltage of the megger used.
- c. High Potential Test, DC positive cables: This test shall be performed only after the insulation resistance test has been successfully completed and shall be performed on each cable circuit installed under this Contract. Before conducting the high potential direct current tests, the DB Entity shall comply with the following requirements:
- 1) Nearby equipment, the conductors of nearby insulated cables not under test, except those in service, and the ground stick shall be all securely tied to the grounding system.
 - 2) The insulated conductor under test shall have a safe clearance from adjacent conductors and surrounding metal objects. For every 1,000 volts of dc test voltage, 1/4-inch clearance is regarded as a safe distance.
 - 3) High voltage tested gloves shall be worn by each participant.
 - 4) The test voltages shall meet the recommendations of the cable manufacturer.
 - 5) Danger signs and sentries shall be posted at all critical points along the entire cable route under test.
 - 6) The operator's manual for the particular test set being used shall be read and understood.
 - 7) All safety precautions shall be observed at the testing end and at the far end of the cable.
- d. Each cable circuit shall be tested separately while grounding test equipment and all cables not under test, except those in service.
- 1) The test equipment shall be supplied from a stable, constant voltage source having a maximum variation of the voltage of plus or minus five percent. Preferably, a motor-driven generator shall be used for the supply. The output voltage of the test set must be filtered, regulated, and spike free.
 - 2) The direct current test voltage shall be applied between conductor and ground slowly in equal steps (in steps of five to seven percent of full test voltage) until the designated test voltage is reached. The rate of voltage acceleration shall be consistent under each step.
 - 3) Sufficient time shall be allowed after each step for the leakage current to stabilize.
 - 4) Total leakage current shall be recorded in micro-amperes after each step. The same length of time shall be allowed after each step for the total current to stabilize before taking the readings.
 - 5) The test voltage shall be 80% of the original factory test voltage. The test voltage shall be maintained for five minutes after it has reached the specified value.
 - 6) Total current values shall be recorded in micro-amperes at one minute intervals for the duration of the test.
 - 7) The test set voltage control shall be set at zero at the end of each test. The residual voltage on the circuit shall be allowed to decay to approximately 1.0 kV before applying the

manual grounds.

- 8) The insulated conductor under test shall be grounded with ground stick after each test. The conductor should remain grounded for at least 30 minutes after completion of the test.
- e. Failure of the initial leakage current to decrease, or any increase in the leakage current at any time during the test shall be presumed to be indicative of a cable defect and the test shall be continued until cable failure occurs.

H. Defective Cables

1. Any DB Entity furnished cable found defective before installation shall be replaced by the DB Entity. Cable found defective after installation shall be repaired or replaced at DB Entity's expense.
2. Any cable section installed under this Contract found defective during the testing shall be replaced with a new cable section. Rectification of defects of any cable shall be done only with the specific acceptance of the MBTA.

I. Test Reports

The DB Entity shall submit five copies of certified test reports of all field tests for the MBTA's review and acceptance. Test reports of field tests shall be submitted no later than seven days after testing. Test reports shall be self-explanatory, noting the personnel involved, and shall show the instruments used for testing and the date(s) of their last calibration. Test reports shall contain identification of each conductor tested in a manner that can be referenced to the Design Documents.

3.3 CABLE IDENTIFICATION TAGS

Install MBTA standard cable tags on new cables, two cable tags to each box, one cable tag on the cable in the box and one cable tag on the cable below (or above) the box. The aerial cable tag will be the standard MBTA embossed aluminum tag.

END OF SECTION

SECTION 16127

AC AND DC AERIAL CABLE INSTALLATION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing, installing and testing of AC and DC power cable at voltages of 13.8 kV and 600 volts.
 - 1. AC voltage power cable includes the following:
 - a. Three-conductor ethylene-propylene rubber insulated cable (EPR cable) rated 15 kV for use on Authority 13.8 kV system – refer to Section 16120 for requirements.
 - 2. DC voltage power cable includes the following: Refer to SECTION 16126 DC POWER CABLE AND DC POWER FEEDER DISCONNECT SWITCHES for requirements.
 - a. Insulated 4/0 feeder tap cable.
 - b. Insulated 500 kcmil feeder cable
 - c. Insulated 1000 kcmil feeder cable
- B. Related works are included in, but not limited to, the following Sections:
 - 1. SECTION 16201 BASIC MATERIALS AND METHODS FOR TRACTION POWER ELECTRICAL WORK.

1.2 REFERENCES

- A. MBTA Standard Specification
 - 1. P-179A 4/0 AWG Flexible Feed Tap Cable
 - 2. P-129C – 500 kcmil Ethylene-Propylene Rubber Insulated Cross-Linked Polyolefin Jacketed Cable
 - 3. P-118F 1,000 kcmil Ethylene-propylene Rubber Insulated Cross Linked Polyolefin Jacketed Cable
- B. Insulated Cable MBTAs Association (ICEA) S-68-516 standards

1.3 SUBMITTALS

- A. Submittals shall be in accordance with Volume 2 Technical Provision Subsections 2.7 and 2.8, except as modified herein.
- B. Product Data/Catalog Cuts
 - 1. Cable

- a. Include data on manufacturer's cold weather temperature limitations.
 2. Stress cones
 3. Fire proofing tape
 4. Splicing materials
- C. Cable Test Reports
1. Manufacturer's standard physical and electrical test reports.
 - a. Submit test reports prior to shipment of cable from manufacturer.
- D. Certificates of Compliance
1. Cable
 - a. Submit certificates of compliance prior to shipment of cable from manufacturer.
- E. Manufacturer's Instructions
1. Cable terminating procedures.
 2. Cold weather installation procedures for cable.
 3. Cable splicing procedures.

1.3 DELIVERY, HANDLING, TRANSPORTATION, STORAGE AND PROTECTION

- A. Delivery, handling, transportation, storage and protection shall be in accordance with the contract documents, except as modified herein.
1. Cable shall be unloaded in a manner such that the unloading equipment used does not come into contact with the cable surface and protective wrap.
 2. Cable reels shall be stored on a hard surface so that the flanges do not sink into the soil and allow the weight of the reel and cable to rest on the cable surface.
 3. Cable reels shall be stored in an area where construction equipment, falling or flying objects or other material will not come into contact with the cable, and where chemicals, and petroleum products will not be spilled or sprayed on the cable.
 4. Cable shall be stored in an area away from open fires and sources of high heat.
 5. When a reel of cable is to be rolled from one point to another, the surface over which the reel of cable is to be rolled shall be examined for objects which could contact and damage the cable surface or protective wrap.

- a. Remove objects prior to moving the reel of cable.
- 6. If a length of cable has been cut from the reel, the cable end shall be immediately resealed to prevent the entrance of moisture.

1.4 QUALITY ASSURANCE

A. Environmental Requirements

- 1. When cables are to be installed in cold weather, the cables shall be stored in a heated area for a minimum of 24 hours prior to installation.
- 2. Cold weather temperature installations shall be in accordance with the manufacturer's recommendations. Submit manufacturer's cold weather temperature limitation data, including, but not limited to, data on temperature ranges.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. The cable shall be suitable for use in outdoor environments, wet and dry locations in conduit and underground duct systems.
- B. The cable shall be rated for 90°C normal, 130°C emergency and 250°C short circuit operating conditions.

2.3 AC AERIAL CABLE

- A. AC aerial cable shall be either 4/0 or 500 kcmil, ethylene-propylene rubber insulated cable in accordance with SECTION 16120 MEDIUM VOLTAGE POWER CABLE FOR THE TRACTION POWER SYSTEM, assembled with a 9/16" copperweld messenger. Size of cable installed shall be as indicated in the Contract Documents.

2.4 STRESS CONES

- A. Stress relief cones shall be manufactured by G & W Electric Specialty Co., Thomas & Betts, Raychem, or approved equal.
- B. Connectors shall be long barrel compression type.
- C. Cable terminations shall be rated at 15 kV phase to phase.

2.5 FIRE PROOFING TAPE

- A. Fire proofing tape shall be manufactured by 3M Company, Scotch Brand 77; Plymouth Brand Ply-Are; Elastimold, fire and arc proofing tape, or approved equal.

2.6 SOURCE QUALITY CONTROL

- A. Cable Testing

1. Cable shall receive the manufacturer's standard physical and electrical tests prior to shipment from the factory. Testing shall be in accordance with ICEA S-68-516.
 - a. Conductor resistance: In accordance with AEIC, paragraph 1.2
 - b. AC withstand (5 minutes): 15 kV - 44 kV
 - c. IR constant (at 15.6°C), minimum: 50,000 megohms/MFT
 - d. DC withstand (15 minutes): 15 kV - 80 kV

PART 3 - EXECUTION

3.1 INSTALLATION: AC CABLE

- A. The cable installation shall be in accordance with the manufacturer's recommended installation procedures and SECTION 16120 MEDIUM VOLTAGE POWER CABLE FOR THE TRACTION POWER SYSTEM, and the Contract Documents.

3.2 INSTALLATION: DC CABLE

A. General

1. The DB Entity shall inform the MBTA of any field conditions which prevents construction and perform the work in question in accordance with the MBTA's instructions.
2. The DB Entity shall coordinate this work with the installation of the overhead contact system and other disciplines. All riser and tap connections in the overhead system work area shall be completed prior to turning over the overhead system to revenue service.
3. The DB Entity shall conform to safety features and requirements specified, especially the requirements related to safety vests and flagmen when required.

B. Insulators and Hardware

1. Insulators and hardware shall be assembled and installed as indicated in Contract Documents. Nuts shall be tightened with lockwashers and cotter pins properly installed. Nuts and cotter pins shall be oriented toward the pole or downward as applicable.
2. Hardware shall be inspected for missing parts and visual defects prior to installation. All metal shall be free of dirt, corrosion or damage to the galvanizing.
3. Insulators shall be bright and clean when installed. Abrasive materials shall not be used for cleaning of insulators. Chipped or cracked insulators shall not be reused.

C. Feeder Cable Stringing

1. Cables shall be handled with care. Cables shall not be run over by vehicles or any other object that could damage the insulation or conductors. The cable on each reel shall be examined for cuts, kinks, or other damage. Damaged portions shall be removed and replaced or repaired as directed by the MBTA.
2. Temporary guard structures shall be installed as required to maintain adequate clearance over roads and other lines.
3. Scrap materials such as timbers or other supports, shall be gathered up and disposed of in a manner satisfactory to the MBTA. The scrap cable pieces shall be salvaged and disposed of by the DB Entity.
4. The cable shall be inspected continuously as it leaves the reel. If severe cuts are detected, the stringing operation shall be stopped until the damage is repaired. Repair sleeves may be used only with permission of the MBTA. Damaged cable shall not be installed without repair. All repairs shall be accepted by the MBTA.
5. No splices shall be permitted in spans over road crossings. In other spans, only one splice per span will be permitted in each wire and the splice shall not be within 10' of any structure. Splices shall not be pulled through stringing sheaves or sagging blocks.
6. Stringing tension shall be adjusted to correspond to the conductor temperature as indicated in Contract Documents but all stringing tensions shall be developed by the DB Entity. The conductor temperature shall be measured after taping an electronic type thermometer in contact with the bare conductor and shading the thermometer from direct sunlight. The DB Entity shall record conductor temperature and tension at each end of the cable length and any temperature variations during sagging operation. These records shall be retained and copies submitted daily to the MBTA. All supplementary cables in the same span, whether existing or new, shall be sagged evenly. The DB Entity shall correct any cable length installed at incorrect tension.
7. All equipment such as sheaves, clamps, pulling devices, and tension stringing equipment shall be in good condition. Any such equipment that, in the opinion of the MBTA could result in damage to the cables shall be removed from the work site.
8. Stringing blocks shall be properly mounted on the pole or crossarm in such a manner that no binding shall occur while stringing. Stringing blocks that are not properly maintained shall not be used and shall be removed from the job site.

D. Aerial Cable Splicing and Terminating

1. The DB Entity shall splice the aerial cables only where permitted in Section 3.2 of this section.
2. In order to obtain optimum electrical contact and adequate insulation at the points of connection of each cable, only the most highly skilled cable splicers shall be employed. Cable splicers shall have experience in making splices of similar cables for similar applications. The DB Entity shall submit the name of the individual, with the number of years and type of experience on similar projects. The DB Entity shall obtain prior approval of all individuals who will be making splices.

3. Each splicer shall be approved for the job by the MBTA prior to any splicing activities. The MBTA may request the splicer to make test splices in the presence of the MBTA before the acceptance is granted.
4. All faulty, imperfect, or damaged splices found during or after installation, shall be removed and replaced. New splices shall be subject to the same tests as are required for the cables after initial installation.
5. The DB Entity shall splice the aerial cables using a full tension compression type connector recommended by the cable manufacturer for the conductor size and expected service conditions and shall cover the joint and seal the cable insulation using heat shrinkable insulating tubing. Tubing shall be rated for 2,000 volts and for outdoor use.
6. Full tension cable splices shall be installed with the cable laid out in a straight line for approximately 10' on each side of the connection.
7. Ends of the aerial cable shall be sealed or terminated at pole mounted disconnect switches, if required or at other location.

E. Other Cables

1. The DB Entity shall install other overhead cables and cable assemblies as indicated in the Contract Documents, such as feeder taps and equalizer jumpers.
2. Riser cables shall be supported using new split Glastic G10 clamps as shown on the Project Standard Plans. Tap cables shall be supported on support brackets or span wires using new clamps or tie wire.
3. The DB Entity shall cut new riser and tap cables to final length, install lugs and clamps, and connect these cables to disconnect switches and conductors, respectively.
4. Current-carrying connectors shall be installed in accordance with the following:
 - a. Wire surfaces, which are in contact with conducting surfaces of the connector, shall be thoroughly wire brushed and shall have an inhibitor applied. Where connectors are not factory-loaded, the same inhibitor shall be applied in the field to the connector.
 - b. Corrosion inhibitors shall be stable over a wide temperature range, able to adhere to cold metal surfaces, water-repellent, weather resistant, and inert to copper, aluminum, zinc, tin, cadmium, steel, and rubber. Grit-bearing inhibitors shall be used except for flat lugs, sliding surfaces or where omission is recommended by the connector manufacturer. Grit shall be compatible with the connector and wire metal. Inhibitor for copper and bronze shall be T&B "Kopr Shield", Fargo "Fargolene", Penn-Union "Cual-Aid", Burndy "Penetrox A", or approved equivalent.
 - c. Bolts in bolt-type connectors shall be lubricated as recommended by the manufacturer and torqued to the manufacturer's recommendation using a calibrated torque wrench.
5. Install and connect the feeder tap cable used to provide 600-volt power to the messenger cable from the manual disconnect switch.

F. Control of Scrap

1. Scrap and debris shall be collected, removed daily from the job site and disposed of by the DB Entity.

G. Installation of Traction Power Disconnect Switches and Supports

1. Install traction power disconnect switches assembled in enclosures including cable clamp supports, as indicated in the Contract Documents. Install a cable tag on each cable in the switch box as indicated in the Contract Documents.
2. Install switch enclosures plumb and level and in alignment with adjoining work or structure in accordance with the Contract Documents.

H. Cable Identification

1. Install a cable tag indicating the power section on the cable at all feeder tap locations as described herein.

3.3 TESTS

A. General

1. The DB Entity shall provide all instruments, materials, and labor required for tests specified herein on the DC traction feeder cable furnished and installed by the DB Entity.
2. The DB Entity shall formulate an overall test program for the installation, which shall include, but not be limited to, the tests specified in this Section to ensure equipment and material compliance with the relevant standards, this Specification and satisfactory and reliable performance in actual intended operation.

B. Conditions for Tests

1. Prior to testing of any cable and the installation, the following conditions shall be fulfilled by the DB Entity:
 - a. The DB Entity shall have in his possession, all the shop drawings duly accepted by the MBTA.
 - b. The DB Entity shall have submitted testing procedures for the MBTA's acceptance at least 45 days in advance of the testing.

C. Witnessing Tests

1. The MBTA will witness complete field-testing on all the cable installation.

D. Responsibility

1. The DB Entity shall assume full responsibility during field-testing of all cable installation provided by them. Should there be any loss or damage to such cable or installation as a result of these tests, the DB Entity shall be fully responsible for replacing the damaged cable. Replacement of damaged cable shall include all costs, including, but not limited to, removal of damaged cable, furnishing of, transportation of, and installation of replacement cable.

E. Rejection and Retesting

1. Failure of cable or splice to withstand tests or to meet ratings shall be sufficient grounds for rejection of the item tested.
2. Any cable or splice rejected shall be retested in the presence of the MBTA after rectification.
3. If it is not possible to rectify rejected cable to the satisfaction of the MBTA, new cable shall be installed.

F. Costs of Tests

The price for conducting all field tests and checkouts in the presence of the MBTA, including entire cost of rectification, retesting, and/or supplying of new items shall be deemed to be included in the Contract Price.

G. Field Tests

1. All DB Entity-installed DC positive traction feeder cables shall be tested to ascertain that the dielectric strength of the cable insulation has not been impaired during installation, that the splices and terminations are properly made and to confirm the integrity of the cable system prior to energization. Tests shall include continuity tests, insulation resistance tests and high potential direct current tests. High potential direct current tests specified herein shall be applicable only to DC positive cables. Rectification of defects of any cable shall be done only with the specific acceptance of the MBTA.
2. Acceptance Tests: After installation of any length of a cable and completing all connections to risers, jumpers, and taps, the DB Entity shall perform the below listed tests on each cable circuit. To preclude damage to equipment and devices the tests shall be conducted before the cable is connected to the disconnect switches and trolley wires.
 - a. Continuity Test: This test shall be performed to prove the continuity of cable circuits.
 - b. Insulation Resistance Test
 - 1) This test shall be performed to determine the cable insulation resistance to ground.
 - 2) Tests shall be conducted with a 1,000-volt motor operated megger. Test voltage shall be applied between the conductor and ground and shall be held until the reading reaches a constant value for five minutes. Insulation resistance values obtained by the megger tests shall not be less than two megohms. The DB Entity shall bring to the attention of the MBTA, the results of similar tests having unequal ratings with the variations of 25% or more.

- 3) For each test, the DB Entity shall record the temperature, humidity, duration of the test and the voltage of the megger used.
- c. High Potential Test, DC positive cables: This test shall be performed only after the insulation resistance test has been successfully completed and shall be performed on each cable circuit installed under this Contract. Before conducting the high potential direct current tests, the DB Entity shall comply with the following requirements:
- 1) Nearby equipment, the conductors of nearby insulated cables not under test, except those in service, and the ground stick shall be securely tied to the grounding system.
 - 2) The insulated conductor under test shall have a safe clearance from adjacent conductors and surrounding metal objects. For every 1,000 volts of DC test voltage, 1/4-inch clearance is regarded as a safe distance.
 - 3) High voltage gloves, tested for insulation integrity, shall be worn by each participant.
 - 4) The test voltages shall meet the recommendations of the cable manufacturer.
 - 5) Danger signs and sentries shall be posted at all critical points along the entire cable route under test.
 - 6) The operator's manual for the particular test set being used shall be read and understood.
 - 7) All safety precautions shall be observed at the testing end and at the far end of the cable.
- d. Each cable circuit shall be tested separately while grounding test equipment and all cables not under test, except the one being tested. The following test procedure shall be followed:
- 1) The test equipment shall be supplied from a stable, constant voltage source having a maximum variation of the voltage of plus or minus five percent. Preferably, a motor-driven generator shall be used for the supply. The output voltage of the test set must be filtered, regulated, and spike free.
 - 2) The direct current test voltage shall be applied between conductor and ground slowly in equal steps (in steps of five to seven percent of full test voltage) until the designated test voltage is reached. The rate of voltage acceleration shall be consistent under each step.
 - 3) Sufficient time shall be allowed after each step for the leakage current to stabilize.
 - 4) Total leakage current shall be recorded in micro-amperes after each step. The same length of time shall be allowed after each step for the total current to stabilize before taking the readings.
 - 5) The test voltage shall be 80% of the original factory test voltage. The test voltage shall be maintained for five minutes after it has reached the specified value.

- 6) Total current values shall be recorded in micro-amperes at one minute intervals for the duration of the test.
 - 7) The test set voltage control shall be set at zero at the end of each test. The residual voltage on the circuit shall be allowed to decay to approximately 1.0 kV before applying the manual grounds.
 - 8) The insulated conductor under test shall be grounded with ground stick after each test. The conductor should remain grounded for at least 30 minutes after completion of the test.
- e. Failure of the initial leakage current to decrease, or any increase in the leakage current at any time during the test shall be presumed to be indicative of a cable defect and the test shall be continued until cable failure occurs.

H. Defective Cables

1. Any DB Entity furnished cable found defective before installation shall be replaced by the DB Entity. Cable found defective after installation shall be repaired or replaced at DB Entity's expense at the direction of the MBTA.
2. Any cable section installed under this Contract found defective during the testing shall be replaced with a new cable section. Rectification of defects of any cable shall be done only with the specific acceptance of the MBTA.

I. Test Reports

The DB Entity shall submit five copies of certified test reports of all field tests for the MBTA's review and acceptance. Test reports of field tests shall be submitted no later than seven days after testing. Test reports shall be self-explanatory, noting the personnel involved, and shall show the instruments used for testing and the date(s) of their last calibration. Test reports shall contain identification of each conductor tested in a manner that can be referenced to the Contract Documents.

3.4 CABLE IDENTIFICATION TAGS

- A. Install standard cable tags on all cables, one cable tag on the cable in the enclosure below the switch and one cable tag on the cable above the switch. Where cables are common to a power section and do not have an identifying number, install a cable tag with the power section number on the riser cable. Tag to read: "SECTION XX" with XX being the associated power section number. The aerial cable tag will be the standard MBTA embossed aluminum tag and held onto the cable with double tie wraps that are UV stable.

END OF SECTION

SECTION 16128

OVERHEAD CATENARY SYSTEM SURGE ARRESTOR PROTECTION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing and installation of surge arrestor devices for protection of the overhead contact system from lightning strikes and overvoltage surges.

1.2 REFERENCES

- A. The installation shall conform to the requirements of the National Electrical Safety Code (NESC), National Electric Code (NEC), Rural Electric Association (REA), National Fire Protection Association (NFPA), applicable MBTA standards and the Contract Documents.
- B. Components shall conform to the latest editions of the following national standards and codes:
 - 1. ICEA
 - 2. ANSI/IEEE C62.11
 - 3. ANSI C29, EEI TD-17
 - 4. NEMA
 - 5. IEEE 80

1.3 SUBMITTALS

- A. Submittals shall be in accordance with the Contract Documents.
- B. The DB Entity shall submit a certification to the MBTA verifying that the surge arrestor has been designed, manufactured, inspected and tested in accordance with the applicable portions of the referenced standards.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Arrestors shall be inspected for damage upon receipt of delivery and handled with care. They shall be stored in a clean, dry environment.
- B. Materials shall be protected against damage in ordinary handling and shipping. Each arrestor shall have a strong, weatherproof tag securely fastened to it showing the operating properties as follows:
 - 1. Duty cycle voltage.
 - 2. Maximum continuous operating voltage (MCOV)
 - 3. Part number

PART 2 – PRODUCTS

2.1 MATERIALS

- A. Surge arrestors shall be inherently resistant to corrosion or properly protected against corrosion. No

materials shall be combined which form an electrolytic coupling that accelerates corrosion such as copper-aluminum couplings.

- B. Surge arrestors shall consist of a metal oxide varistor housed in polymer rubber rated for 3,000 volts. They shall be Ohio Brass PDV-65, the MBTA standard or approved equal.
- C. All metallic hardware used in the arrestor shall be stainless steel. Each arrestor shall have a protective insulating cap to insulate the positive terminal on the top of the arrestor. Arrestors shall have attachment hardware for attaching to cross-arms or pole clamps.
- D. The arrestor positive wire lead shall be copper wire supplied separately by the DB Entity. It shall be No. 2 AWG stranded insulated copper wire rated for 2,000 volts. Strands shall be tinned.
- E. All cable connectors where arrestor lead wires connect to feeder tap or feeder cables shall be of bronze and suitable for the application as indicated in the Contract Documents.
- F. Arrestor ground wires shall be AWG 4/0 stranded copper cable, tinned and jacketed/insulated for 2,000 volts. Markings on the cable jacket shall be consistent with other MBTA specifications.
- G. Ground wire shall be placed in a 1" FRE conduit as indicated in the Contract Documents. The conduit shall be bolted to either a pole or wall with a conduit.
- H. Ground rods shall be 3/4" x 10'-0" and be comprised of copper clad steel. If necessary, provide additional ground rods as required to achieve a resistance ground of 5 ohms or less.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Surge arrestors shall be installed as part of one or more assemblies in accordance with these Mandatory Specifications, and shall be installed in accordance with Section 16123 – OVERHEAD CONTACT SYSTEM INSTALLATION.
- B. Surge arrestors shall be installed at all locations where an underground cable rises up to tap into the OCS. They shall also be installed at feeder tap locations every 500' along the right of way, only when coming from an underground cable.
- C. They shall be installed on the OCS pole or cross arms at the height of the feeder tap but not below the feeder tap or cable to which they are connected. Arrestors shall not be located directly above disconnect switch enclosures but mounted on the same pole at the feeder tap or feeder cable height.
- D. Arrestor positive lead wire shall be no longer than 12 inches. Where this length cannot be achieved, the DB Entity shall take direction from the Engineer of Record and lead wire size may have to be increased to ensure the same resistance. Lead wires shall be attached directly to the feed tap or feeder cable. The connector shall be fully insulated to the level of the cable.
- E. Surge arrestors shall be installed on individual cables so that there is one arrestor for each feeder tap or feeder cable. The ground wire of multiple arrestors on a pole can be common so that all arrestor ground wire leads are connected and one ground wire is run down the pole. The ground wire shall be an insulated 4/0 AWG stranded copper cable. Where multiple ground wire leads are connected to a common ground wire, the wire leads from the negative terminals can be a No. 2 AWG insulated wire as used for the positive lead wire. These shall be connected to one 4/0 AWG insulated ground wire that will run down the pole.
- F. Ground wires shall run straight with as few bends as possible. Where the cable must be bent, it shall be

done with as large a radius as possible. Kink bends are not allowed. All connections of ground wires except at the top of the OCS pole shall be by exothermic weld.

- G. Where bolted connectors are used, the conductors shall be thoroughly cleaned of corrosion and a liberal coating of anti-oxidation paste applied to the cable, wire and connector prior to makeup of the connector. The connection shall be insulated by a combination of layering of rubber insulating tape with a covering of electrical tape to an insulation level consistent with the cable insulation.
- H. Acceptance testing of surge arrestors shall be as stated in SECTION 16123 OVERHEAD CONTACT SYSTEM INSTALLATION.

END OF SECTION

SECTION 16140

OVERHEAD CONTACT SYSTEM FITTINGS AND HARDWARE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies furnishing, delivery and installation of ferrous and non-ferrous metal material, hardware and fittings for a catenary system as shown in the Volume 2 Technical Provisions, including, but not limited to, the following:
1. Hangers
 2. Wire splices
 3. Clevis-clevis fittings
 4. Wire terminations
 5. Parallel wire clamps
 6. Nuts, bolts, washers and cotter pins
 7. Turnbuckles
 8. Double clevis end fittings
 9. Thimbles
 10. Wire sleeves
 11. Wire clips
 12. Registration fittings and components
 13. Feeder, suspension and supports
 14. Section insulators

1.2 REFERENCES

- A. Pertinent provisions of the MBTA reference drawings and standards contained in the appendices and the following listed codes and standards shall apply to the work of this Section, except as modified herein, and are hereby made a part of this Specification to the extent required:
1. Ferrous Metals: American Society for Testing and Materials (ASTM)
 - A27 - Mild to Medium-Strength Carbon-Steel Castings
 - A36 - Structural Steel
 - A47 - Malleable Iron Castings
 - A153 - Zinc coating (Hot-Dip) on Iron and Steel Hardware
 - A167 - Stainless and Heat-Resisting Steel
 - A501 - Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

A518 - Corrosion-Resistant High Silicon Cast Iron

A536 - Ductile Iron Castings

A668 - Steel Forgings, Carbon and Alloy for General Industrial Use

A711 - Carbon and Alloy Steel Blooms, Billets and Slabs for Forgings

A747 - Steel Castings, Stainless, Precipitation Hardening

2. Non-Ferrous Metal: American Society for Testing and Materials (ASTM)

B26 - Specification for Aluminum-Alloy Sand Castings

B140 - Copper-Zinc-Lead (Leaded Rod Brass or Hardware Bronze) Rod, Bar and Shapes

B148 - Aluminum-Bronze Sand Castings

B179 - Aluminum Alloys in Ingot Form for Sand Castings, Permanent Mold Castings and Die Castings

B248 - General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strips and Rolled Bar

B249 - General Requirements for Wrought Copper and Copper-Alloy Rod, Bar and Shapes

B315 - Specification for Seamless Copper Alloy Pipe and Tube

B557 - Methods of Tension Testing Wrought and Cast Iron Aluminum - and Magnesium - Alloy

B584 - Copper Alloy Sand Castings for General Applications

B686 - Specification for Aluminum Alloy Castings - High Strength

One copy of each of the standards for Ferrous and Non-Ferrous Metals shall be furnished to the MBTA for their use and permanent records.

1.3 SUBMITTALS

A. The following information shall be submitted in accordance with Section 01300:

1. Shop drawings: The DB Entity shall submit shop drawings for all components for approval prior to manufacture, showing details and dimensions, and giving designations of the materials comprising the various components together with technical, mechanical and electrical characteristics as appropriate.
2. Parts, materials, components and all other hardware shall not be accepted without the submittal and acceptance of shop drawings. The MBTA reserves the right to require the DB Entity to remove any and all materials and methods that have not been approved before installation.

1.4 DELIVERY, STORAGE AND HANDLING

- A. The identification mark of the manufacturer or foundry and the pattern numbers assigned by the supplier shall be cast or stamped into all castings and fabrications. Marks and numbers shall be readable size, and placed in such a position that they will not affect the electrical or mechanical performance.
- B. Fittings and hardware shall be packed adequately to ensure acceptance and safe delivery, in accordance with the best commercial practice.
- C. Overhead fittings and hardware shall be adequately packaged to allow stacking and outdoor storage until installation, with no harmful effects until installation.
- D. Each part shall be tagged with description, purchase order and line item numbers, as well as assembly and item number.

1.5 QUALITY CONTROL

- A. The DB Entity shall submit certification to the MBTA verifying that all hardware items are in conformance with either ASTM Standards referenced herein, other applicable standards and requirements, or Volume 2 Technical Provisions.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Material for hardware and fittings shall comply with the MBTA standard specifications for overhead components and Volume 2 Technical Provisions. Substitutions may only be submitted to the MBTA for consideration if the part is not manufacturer specific. The DB Entity shall be responsible for form and fit of all components and hardware. Maximum interchangeability of components shall be considered to reduce inventory.
- B. All OCS components and parts thereof shall be time proven and in use in other transit systems and railroads utilizing overhead catenary systems. Manufacturers providing equipment and parts shall have been doing business in the OCS industry for a minimum of 10 years.
- C. In order to ensure compatibility with MBTA requirements and the existing overhead contact system, certain specific components of the overhead system have been specified by manufacturer's part number or designated as approved equal on the Contract Documents. This provides continuity and interchangeability of hardware throughout the entire MBTA overhead network. DB Entity shall verify that indicated components function properly as indicated on the Contract Documents. Substitutions of "as equal" shall be per acceptance of the MBTA.

2.2 METAL CHARACTERISTICS

- A. Malleable Iron: Fittings or components made of malleable iron shall be Grade 32510 or better and shall conform to ASTM-A47. All components and fittings shall be galvanized in accordance with ASTM-A153.
- B. Forged Steel: Material for forged steel shall comply with ASTM-A711 or A668. All components and fittings shall be galvanized in accordance with ASTM-A153.
- C. Structural Steel Tubing: Structural steel tubing shall conform to ASTM-A501 and be galvanized in accordance with ASTM-A153.
- D. Ductile Iron: Fittings or components requiring high yield strength shall be of ductile iron, Grade 60.40.18 or better and shall conform to ASTM-A536. All fittings shall be galvanized in accordance with ASTM-A153.
- E. Stainless Steel: Stainless Steel hardware shall conform to ASTM-A747. Cotter pins shall be made of stainless steel.
- F. Non-Ferrous Metals: Copper alloys for fittings and components shall conform to ASTM-B584 and B148.
- G. Copper: All copper components shall conform to ASTM-B248 or B249.

2.3 FABRICATION AND CASTING

- A. Castings shall be of uniform quality and shall be made in such a manner that the material of the casting conforms to the chemical and mechanical properties prescribed in the referenced ASTM standards. Castings shall be tested for anomalies, inclusions, cold forming and other defects that could affect the performance of the component. The DB Entity shall provide an adequate supply of parts, equipment, materials and required tools available at the site for orderly installation and testing of equipment without delay.
- B. Material to be fabricated shall be performed in a manner consistent with best practices. Formed steel pieces shall be heated and bent while red hot. Cold bending of components for OCS is not allowed.

2.4 TECHNICAL SUPPORT EQUIPMENT

- A. General: The DB Entity shall provide an adequate supply of parts, equipment, materials and required tools available at the site for orderly installation and testing of equipment without delay.
- B. Requirements for Installation: An additional quantity of ten (10) percent or a minimum of two of each item of fittings and hardware, whichever is greater, shall be provided at no additional cost to the MBTA and shall be made available for use after the installation. These items shall be turned over to the MBTA's Power Division at 21 Arlington Avenue, Charlestown, Massachusetts.
- C. Special Tools: If any special tools are required for installation, the DB Entity shall furnish two sets of each, to be turned over to the MBTA upon Contract Substantial Completion.

2.5 SPARE PARTS

- A. The DB Entity shall provide supply of spare parts at the end of the contract. The quantity of spare parts shall be for all types of OCS components, wire and cable and it shall be 10% of the amount used on the project. Poles shall be an exception where a specific quantity of spare poles shall be required as indicated in the following list:

Description	Quantity
Pole, wide flange, 10 x 39, 40 ft	5
Pole, wide flange, 10 x 53, 40 ft	5
Pole, wide flange, 12 x 79, 40 ft	5
Pole, wide flange, 12 x 106, 40 ft	5

PART 3 – EXECUTION

3.1 INSTALLATION

Overhead fittings and hardware shall be installed as part of one or more assemblies shown on the Contract Documents in accordance with Section 16123 – OVERHEAD CONTACT SYSTEM INSTALLATION and per manufacturer’s recommendations.

END OF SECTION

SECTION 16201

BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK FOR THE TRACTION POWER SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies basic materials and methods for electrical work for providing a complete traction power system.
- B. Related Work: Refer to Section 16450 - Grounding for the Traction Power System, for proper installation of components identified in this section. The following items are not included in this Section and will be performed under Specification Sections 16100, 16203 and 16311:
 - 1. Determine interfaces and coordinate electrical work with utility company or the MBTA where power source is the MBTA's.
 - 2. Determine interfaces and coordinate with work completed, progressing, or to be performed under other sections of these Specifications. Make indicated connections to previously completed work. Where future connections to or extensions of the work are indicated, make safe and convenient provisions for such future connections and extensions.
 - 3. Where indicated, take possession of, maintain, and operate as required any electrical plant and equipment left in place by others. Where indicated, leave temporary and interim electrical work, plant and equipment in place for maintenance and operation by others.

1.2 REFERENCES

- A. Comply with applicable requirements of the following:
 - 1. National Electrical Code
 - 2. Massachusetts Electrical Code

1.3 SUBMITTALS

- A. Submit shop drawings for review showing fabricated work being furnished and installed under these Specifications. Submit such drawings prior to fabrication and within ample time to prevent delays in the work.
- B. Submit verified test results to the MBTA promptly upon completion of test.
- C. Before procurement of the wire and cable, submit the following information for each type and size of wire and cable:
 - 1. Manufacturer of the wire and cable.
 - 2. Number and size of strands composing each conductor.
 - 3. Conductor insulation composition and thickness in mils.
 - 4. Average overall diameter of finished wire and cable.
 - 5. Minimum insulation resistance in megohms per 1000 feet at 20°C ambient.
 - 6. Jacket composition (if any) and thickness in mils.
 - 7. Total number of conductors per cable.
 - 8. Shield material (if any) and thickness.
 - 9. Conductor resistance and reactance in ohms per 1000 feet at 20°C ambient.

10. Conductor ampacity at 20°C ambient.
- D. Conduit fill and cable pulling calculations shall be provided.
- E. Cable tray and raceway system design
1. Manufacturer
 2. Material
 3. Methods of support
 4. Fill calculations
 5. Grounding/bonding
 6. Loading calculations
 7. Layout of raceway systems and location of anchoring supports

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Furnish all items of the materials, design, sizes, and ratings shown on the Design Documents and herein specified.
- B. Furnish materials and equipment bearing evidence of UL listing where UL standards exist and such product listing is available.
- C. Methods of fabrication, assembly and installation shall be proposed by the DB Entity unless otherwise specifically indicated.
- D. Provide products that are free from defects impairing performance, durability, or appearance, and of the commercial quality best suited for the purpose shown on the Design Documents or specified herein.
- E. Steel conduit and accessories specified to be zinc coated: Hot-dipped galvanized after fabrication in accordance with ASTM A286.
- F. Conform to applicable requirements of Insulation Power Cable Owners' Association (IPCEA).

2.2 RIGID GALVANIZED STEEL CONDUIT AND ACCESSORIES

- A. Conduit, couplings, elbows, bends, and nipples: ANSI C80.1 and UL 6, with each length bearing manufacturer's stamp and UL label.
- B. Method used to determine the thickness of zinc coating: The Referee Test included in the appendix to ANSI C80.1.
- C. Fittings and Accessories:
 1. Galvanized steel or malleable iron, ANSI C80.4.
 2. Provide separable watertight hub fittings with a gasket, separate nylon insulated throat and a case hardened locknut.
 3. Bushings: Nylon insulated metallic and grounding type.
 4. Furnish conduit straps, clamps, and clamp backs made of galvanized malleable iron.
- D. PVC Coated Conduit

1. NEMA Standard No. RN1, Coating Type A-40.
 2. Thread protectors installed on both ends of conduit for shipment and handling, couplings packaged separately.
 3. Submit full technical parameters for review by the MBTA.
- E. Almost without exception, exposed conduit in any below grade structures, the MBTA requires the use of RGS conduit.
- F. All conduits penetrating floors and ceilings must have brass labels for ease of tracing circuits.
- G. Buried conduits cannot have buried pull boxes.

2.3 LIQUID-TIGHT FLEXIBLE METALLIC CONDUIT AND FITTINGS

- A. Furnish conduit consisting of a core of flexible galvanized steel with an extruded liquid-tight plastic or neoprene jacket overall. Jacket shall be moisture and oil-proof, capable of conforming to the minimum radius bends of flexible conduit without cracking.
- B. Furnish conduits with a continuous copper bonding conductor spiral wound between the convolutions, as required by NEC, and as indicated.
- C. Fittings: UL Standard 514, cadmium or zinc-coated.
- D. Liquid-tight conduit may not be used for High Voltage circuits.

2.4 PVC ELECTRICAL CONDUIT AND FITTINGS (ONLY FOR OUTDOOR USE IN CONCRETE ENCASED DUCTBANKS)

- A. Heavy wall, high impact strength, rigid PVC conforming to the requirements of EPC-40-PVC conduit of NEMA TC2 and fittings for EPC-40-PVC conduit of NEMA TC3.
- B. UL listed in accordance with Article 347 of the NEC for underground and exposed use.
- C. Flammability rated as self-extinguishing, and having the following minimum properties:
 1. Tensile strength, ASTM D638 at 78°F: 6,000 psi.
 2. Flexural strength, ASTM D790: 11,000 psi.
 3. Compressive strength, ASTM D695: 8,500 psi.
 4. Hardness (Durometer D), ASTM D2240: 77.
 5. Water absorption, percent maximum, in 24 hours at 72°F. ASTM D570: 0.03.
 6. Dielectric strength, volts per mil, ASTM D149: 1,100.
 7. Thermal conductivity: 1.3 BTU per square foot per degree F per inch.

2.5 NON-METALLIC CONDUIT

- A. Non-metallic conduits shall be used for conduits entering the DC switchgear and Rectifier equipment, including connections to DC surge arresters.
- B. Fiberglass conduits shall conform to MBTA Standard Specification P-138 "Specification for Fiberglass Reinforced Thermosetting Resin Conduit".

2.6 CONDUIT EXPANSION FITTINGS

- A. Fabricate from material similar to the type of conduit with which they are to be used.
- B. Include a factory installed packing ring, designed to prevent the entrance of moisture, and a pressure ring.
- C. Also include a grounding ring or a grounding conductor for metallic expansion couplings.

2.7 MULTIPLE PIPE HANGERS (TRAPEZE TYPE)

- A. Fabricate of two or more steel hanger rods, a steel horizontal member and all U-bolts, clamps, and other attachments necessary for securing hanger rods and conduits.
- B. Hanger Rod: Not smaller than 3/8" diameter, threaded either full length or for a sufficient distance at each end to permit at least 1-1/2" of adjustment.
- C. Horizontal Member
 - 1. Standard structural steel shapes such as angles or channels, 1-1/2" x 1-1/2" or 1-5/8" x 1-5/8", 12 gauge, cold-formed, lipped channel, and designed to accept special spring-held hardened steel nuts for securing hanger rods and other attachments.
 - 2. Two or more channels may be welded together to form horizontal members of greater strength than single channels.
 - 3. Galvanize after fabrication.
- D. Design
 - 1. Capable of supporting a load equal to the sum of the weights of the conduits and wires, the weight of the hanger itself, plus 200 pounds.
 - 2. The stress at the root of the thread of the hanger rods; not more than 9,475 psi at design load.
 - 3. Size the horizontal member such that the maximum stress will be not more than 12,650 psi at design load.

2.8 INSERTS

- A. Channel Inserts. Fabricate from not less than 12 gauge steel channel having an overall size of 1-1/2" x 1-1/2" or 1-5/8" x 1-5/8" inches with continuous 7/8" wide slot, in lengths as indicated. Galvanize after fabrication.
- B. Channel Inserts for Embedding in Concrete
 - 1. Fabricate from channels having a solid base.
 - 2. Weld concrete anchors to the channel during fabrication and before coating.
 - 3. Galvanize after fabrication
 - 4. Provide assemblies with a minimum pull-out load rating of 4,500 pounds per linear foot uniformly distributed.
 - 5. Furnish all channel inserts for installation embedded in concrete with the channel interior completely filled with styrofoam to prevent seepage of concrete into the channel during installation.
- C. Channel Inserts for Surface Mounting
 - 1. Fabricate from channel having 3/8" x 3" slots on 4" centers in the base.

2. Galvanize inserts for surface mounting on concrete surfaces or for installation in damp or wet areas.

D. Spot Inserts for Embedding in Concrete

1. Steel, galvanized after fabrication
2. Designed for a maximum loading of 800 pounds with safety factor of three.
3. Knockout openings to accommodate either square or rectangular nuts.

2.9 SURFACE METAL RACEWAYS AND FITTINGS

- A. ANSI/UL 5 and the NEC.

2.10 OUTLET, JUNCTION AND PULL BOXES

- A. Conform to NEC Article 370. Electrical boxes shall conform to UL-50, "Standard for Electrical Cabinets and Boxes", and UL-514, "Standard for Electrical Outlet Boxes and Fittings".
- B. Provide electrical boxes of the material, finish, type and size indicated and required for the location, kind of service, number of wires, and function. Boxes shall have mounting holes retapped for 10-24 machine screws.
- C. Provide boxes complete with accessible covers designed for quick removal and suitable for the purpose for which they will be used, except that boxes in which or on which no devices or fixtures are to be installed, shall be equipped with flat or raised blank covers as required. All ceiling fixture outlet boxes shall be equipped with 3/8" boltless fixture studs.
- D. Boxes less than 40 cubic inches in size shall be cast. Boxes over 40 cubic inches in size shall conform to the requirements for cabinets.
- E. Covers: Same thickness as boxes and secured in position by means of No. 10-24 stainless steel machine screws. Arrange covers to be readily and conveniently removed.
- F. Coat junction boxes inside and outside to prevent oxidation. Where outlet boxes are used as junction boxes they shall be cast aluminum and not be smaller than 4 inches square by 1-1/2" deep. Provide such boxes with flat blank covers.
- G. Outlet Boxes: Cast aluminum, not be smaller than 4 inches square by 2-1/8" deep.
- H. Concealed Switch Boxes: Cast aluminum, not less than 4 inches square by 1-1/2" deep for two devices unless otherwise indicated. Provide covers with rectangular openings of proper size and shape. Furnish and install special boxes required to suit the kind of service and location requirements, as indicated, and as may be directed by the MBTA.
- I. Cast metal boxes shall be of aluminum alloy, with compatible conduit fittings.
- J. Boxes for exposed switches and receptacles: Cast metal, FS and FD Types.
- K. Furnish brackets, supports, hangers, fittings, bonding jumpers and all other accessories required.
- L. Provide neoprene gaskets 1/8" thick with boxes subjected to weather, and as directed by the MBTA.

- M. Grounding. Provide each box to which a lighting fixture or receptacle is to be attached with a grounding terminal.
- N. Grounding Terminal: Either a green-colored washer-in-head machine screw not smaller than No. 10-32 in a drilled and tapped hole in the back of the box, or a grounding bushing with green-colored machine screw terminal attached to one of the conduits.
- O. Provide suitable grounding terminals in motor connection boxes.
- P. Install grounding jumpers as specified in Section 16450 – Grounding for the Traction Power System.
- Q. Junction and pull boxes must be surface mounted and not buried.

2.11 CABLE TRAYS

- A. General. Provide cable tray systems conforming to the requirements of NEMA VE1, except for modifications indicated. Cable tray system shall be designed to withstand Seismic Zone 2A earthquake.
- B. Cable tray within 6' of the DC switchgear and rectifiers shall be fiberglass to avoid the possibility of grounding the equipment.
- C. Cable Tray System Components: Hot-dipped, galvanized steel with PVC coating; or, stainless steel, unless as indicated in B above.
 - 1. Hot-dipped galvanized after fabrication in accordance with ASTM A 386. PVC coating of 20 mils minimum having Shore A durometer hardness of 75.
 - 2. Stainless steel as indicated.
- D. Dimensions
 - 1. Straight sections and fittings: Inside clear width as indicated, measured between the rails. Overall width not exceeding inside depth by more than 2-1/2". Inside nominal depth: 4". Overall tray depth not exceeding inside depth by more than 3/4".
 - 2. Rung spacing for ladder-type straight sections: 9" on centers maximum.
- E. Fabrication
 - 1. Straight sections and fittings consisting of stiffened channel rungs located between channel-shaped side rails having outward projecting flanges.
 - 2. Straight-section side rails shall have a top flange at least 1-1/4" wide and minimum 3/8" vertical stiffening lip.
 - 3. Rungs shall be positioned to provide a flat, cable support surface at least 1-1/8" wide, excluding corner radii, and shall be 0.060" thick. MIG-weld rungs to side rails and clean welds.
- F. Test Requirements
 - 1. Cable tray system shall be capable of supporting a total cable load of 55 pounds per linear foot on a maximum span of 8' with a safety factor of 2 based on the destructive load, regardless of the type of splice plates or type of span, when tested in accordance with load test procedure described in NEMA VE1.
 - 2. Straight sections and fittings shall not permanently deform under a 202 pound static concentrated load applied vertically along a 4" length for both of the following conditions:

- a. Load applied to one side rail of tray section having specified cable load and support spacing. Load shall be applied at midpoint between supports over a splice connection.
- b. Load applied to one rung of empty tray section having specified support spacing. Load shall be located at midpoint between side rails and supports. Cable tray support shall be capable of supporting 0.625 of the sum of the total load on both spans adjacent to support with safety factor of 2.

2.12 CABLE TRAY CHANNEL SUPPORTS

- A. Fabricate from minimum 12 gauge steel channel, 1-5/8" x 1-5/8" inches, with a continuous 7/8" wide slot. Hot-dipped galvanized.
- B. Hardware, Fittings, and Brackets: Zinc or cadmium coated.
- C. Design assembled supports, fittings, brackets, and hardware to carry the loads calculated for the tray with a factor of safety of three or greater.
- D. Supports shall provide at least 1-1/8" bearing length for each rail and shall have provision for tray hold-down clamps and fasteners.

2.13 UNDERFLOOR DUCTS, TRENCHES, AND FITTINGS

- A. Manufacture ducts and trenches from 14 gauge galvanized steel, furnished with a UL listed corrosion-resistant coating.
- B. Design fittings for use with the duct or trench to form a complete underfloor raceway system.
- C. Ducts for Power Service: 3-1/8" wide by a minimum 1-1/4" deep, or 6" wide by 1- 1/2" deep, as indicated, with threaded 2" IPS inserts spaced on 2' centers.
- D. Ducts for Low Voltage, Communication, or Signal Use; 6" wide by 1-1/2" deep with 2" IPS inserts spaced on 2" centers.
- E. Floor Trenches: 18" wide by 4" deep with 5/16" thick floor plate. Cover plates of maximum length, as indicated.
- F. Equip inserts with caps and countersunk-head floor marking screws.
- G. Size junction boxes for underfloor ducts to accommodate the ducts, and finish similar to the duct.
- H. Provide approximate tile holders of a depth as required for installation of the floor finish.
- I. Provide service fittings where required, complete with adapters and locking nipples suitable for use with the duct.

2.14 WIRE AND CABLE (600 VOLT)

- A. Conductors: Conform to the requirements of the NEC.
 1. Feeder and Branch Circuit Conductors: Soft-drawn copper.
 2. Control Circuits: Soft-drawn copper.

3. Conductor Sizes: Standard American Wire gauge sizes. Conductors No. 10 and smaller, solid copper; No. 8 and larger, stranded copper.
 4. Minimum AWG sizes unless otherwise indicated:
 - a. No. 12 for branch circuits.
 - b. No. 14 for control wire and fixture wire
 - c. No. 16 for low voltage circuit and indication wire.
- B. Wire and Cable 600 volts and Below Installed in Raceways: Single conductor, NEC type XHHW, conforming to requirements of NEMA WC 7, or THWN. Conductors shall be tray cable rated when used in cable trays.
- C. Fixture Wire: Type AF single conductor, rated for 150°C conductor temperature, 300 volts.
- D. Color Coding of Conductors
1. Color code supply cables and branch circuit conductors throughout the secondary alternating current wiring system as follows:

Conductor	208/120 Volts	480/277 Volts
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Off-White
Ground	Green	Green

2. Color code single-conductor wires as follows:
 - a. 480/277 volt circuits, blue with yellow tracer.
 - b. 120/208 volt circuits, yellow with blue tracer.
 3. Branch circuit phase conductors No. 10 and smaller and all neutral and equipment conductors: Solid color insulation or solid color coating.
 4. Solid color coatings and tracers: A strongly adherent paint or dye not injurious to the insulation and which will not be obliterated by pulling into a conduit or raceway.
 5. On-site coloring of ends of conductor may be permitted by the MBTA upon receipt of satisfactory evidence that the DB Entity is unable to order color-coded wire and cable as specified. Provide certification from the cable manufacturer that the paint or dye proposed for field application is non-injurious to the insulation. Colored tape may be used to mark the ends of conductors in lieu of paint or dye.
- E. Identification Tags
1. Provide waterproof identification tags of brass, aluminum, plastic, or pressure-sensitive moisture-resistant labels designed for fastening to cables, feeders, and power circuits in vaults, pull boxes, manholes, and switchboard rooms and at all terminations of cable or wire.
 2. Stamp or print tags or labels to correspond with markings on the Design Documents or accepted Shop Drawings, or mark so that feeder, cable or conductor may be readily identified. Tags on conductors at switches, receptacles, motor control panels, wireways, and junction boxes shall bear the circuit number of the conductor as it appears in the circuit directory. Mark conductors in motor control panels with the terminal number.
 3. If suspended type tags are provided, design tie tags with slip-free plastic cable lacing unit or design for attachment by nylon bundling straps.

F. Cable Supports and Fasteners: Design for use with channel inserts.

G. Conductor Bundling Straps

1. Formed from self-extinguishing nylon having a temperature range of minus 65°F to plus 250°F.
2. Equip each strap with a locking hub or head with a stainless steel locking barb on one end and a taper on the other end.
3. Make wire and cable ties for installation outdoors and in exposed locations of ultraviolet resistant nylon material.

H. Splice and Terminal Connectors

1. Design termination fittings for use with the cable furnished, NEMA Standard, and UL approved.
2. Termination and splice fittings for No. 10 and smaller conductors; Screw on, spring pressure-type copper connectors with nonflammable, self-extinguishing insulation of temperature rating equal to that of cable being connected. Terminals to provide a metal insulation grip on the conductor for stain relief.
3. Termination and splice fittings for No. 8 and larger conductors: Tool-applied compression connectors of material and design compatible with the conductors for which they are used.
4. Terminal connectors for conductors Size No. 4/0 and larger: Long-barrel, double compression type, and furnished with two bolting holes in the pad.

I. Insulating Material for Splices and Terminations

1. Of the type accepted by the MBTA for the particular use, location and voltage, 3/4 inch nominal width.
2. Plastic electrical insulating tape for general use: Vinyl plastic with rubber-based pressure-sensitive adhesive. Pliable at temperature of minus 18°C to 105°C. When tested in accordance with ASTM D 3005, the tape shall have the following minimum properties:
 - a. Thickness: 7 mils.
 - b. Breaking Strength: 15 pounds per inch.
 - c. Elongation: 200%.
 - d. Dielectric Strength: 10,000 volts/mil
 - e. Insulation Resistance (Direct method of electrolytic corrosion): 1,000,000 megohms.
3. Rubber electrical insulating tape for protective overwrapping: Silicone rubber with a silicone pressure-sensitive adhesive. When tested in accordance with ASTM D1000, the tape shall have the following minimum properties:
 - a. Thickness; 15 mils.
 - b. Tensile Strength: 11 pounds per inch.
 - c. Elongation: 525%.
 - d. Dielectric Strength: 13,000 volts
 - e. Insulation Resistance (Indirect Method of Electrolytic corrosion): 1,000,000 megohms.
4. Arcproof Tape: Flexible, conformable organic fabric, coated one side with a flame-retardant flexible elastomer-self-extinguishing, with the following minimum properties:
 - a. Thickness, ASTM D1000: 55 mils.
 - b. Tensile strength, ASTM D1682; 50 pounds per inch.
 - c. Thermal conductivity, ASTM D1518; 0.478 btu/hour/square foot/degrees F.
 - d. Electrical Arc Resistance: Withstand 200 ampere arc for 40 seconds.
5. Mark each tape package to indicate shelf-life expiration date.
6. Glass Cloth Electrical Insulating Tape (for use with arcproof tape): Woven glass fabric; when tested in accordance with ASTM D1000, the tape shall have the following minimum properties:
 - a. Thickness: 7 mils
 - b. Breaking Strength: 170 pounds per inch.
 - c. Elongation: 5%.
 - d. Dielectric Breakdown: 2,500 volts.

e. Insulation Resistance (Indirect Method of Electrolytic Corrosion): 5,000 megohms.

J. Wire Harnesses

1. Wire harnesses shall be supported with a bracket fastened to the enclosure via a tack welded stud or a machine screw utilizing a shake-proof washer. Welding and/or drilling and tapping for machine screws shall be accomplished before finish paint is applied. Nylon composite tie wraps may be used for securing the harness to the support. Wire support brackets attached to the enclosure with adhesives are not acceptable. Harnesses shall be arranged to ensure that one harness does not support another and each harness can be accessed without removal of another.

2.15 WIRING DEVICES

A. General. Wiring devices include switches, receptacles and special outlets installed in raceway or conduit boxes, complete with cover plates.

B. Switches

1. AC tumbler-toggle switches: Meeting minimum requirements of UL 20 and further requirements herein specified and of specification grade, heavy duty, of the type indicated.
2. Provide switches that operate in any position and are fully enclosed with entire body and cover of molded phenolic, urea or melamine. Do not use fiber, paper or similar insulating material for body or cover.
3. Equip switches with metal mounting yoke with plaster ears, insulated from the mechanism and fastened to the switch body by bolts, screws, rivets or other substantial means that meet test requirements.
4. Provide a green-colored equipment grounding screw on the yoke.
5. Provide the section of the yoke normally intended to bear on the surface outside the box with a minimum over-all dimension of 3/4", measured at right angles to the longitudinal axis of the yoke.
6. Make switch contacts between silver or silver alloys.
7. Switches shall be back and side wired with terminals of screw or combination screw-clamp type.
8. Terminal Screws: No. 8 or larger, captive or terminal type.
9. Provide access holes for back wiring.
10. Wiring terminals capable of receiving and holding proper wire sizes as shown below:

Switch Rating	Wire Size, AWG No.
20 amperes	12 and 14
30 amperes	10

C. Wall switches: Tumbler type, totally enclosed, heavy duty, in accordance with NEMA WD 1.

D. Switches for use on incandescent or fluorescent lighting circuits: Fully rated 20 amperes at 120 or 277 volts, as indicated. Actual connected lamp wattage not to exceed the following:

Switch Rating at 120- 277 Volts	Maximum Wattage Allowed	
	120 Volts	277 Volts

20 amperes	1,400	3,000
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- E. Switches controlling outlets other than lighting, such as motors less than 1/4 horsepower may be specification grade, flush type, AC - DC, T-rated 20 ampere, 125 volts. Switches controlling straight resistance loads may be snap switches as specified herein, of the proper rating up to 30 amperes at 120-277 volts.
- F. Provide ac 120-277 volt snap switches capable of withstanding tests as outlined in NEMA WD 1, Paragraphs WD 1-2.04, WD 1-2.05A, WD 1-2.05C, WD 1-2.05E2, WD 1-2.05F2, and WD 1-2.05G. If requested by the MBTA, submit satisfactory evidence that the types of switches proposed have satisfactorily withstood these tests.

2.16 RECEPTACLES AND PLUGS

- A. Configuration and requirements for connector and outlet receptacles; UL 498 and NEMA WD 1 for heavy duty general use type.
- B. Receptacles: Fire-resistant nonabsorptive, hotmolded phenolic composition or equal bodies and bases with metal plaster ears integral with supporting member.
- C. Type: Flush type, except where otherwise indicated.
 - 1. Wall receptacles; Single or duplex as shown on the Design Documents.
 - 2. Provide receptacles and plugs (caps) with light-colored terminal facilities for neutral connections, amber or brass colored for phase conductor connections, and green-colored hexagonal machine screws for the equipment grounding conductor or connections.
 - 3. All contracts of the receptacles, including the grounding contract: Double grip bronze type with spring steel backup clips so that both sides of each male prong of the plug will be in firm contact.
 - 4. Provide all receptacles with self-grounding clip or mounting strap screws.
 - 5. Ground fault circuit interrupter duplex receptacles shall be 120 volt, 60 Hz, 15 ampere with built-in test, reset buttons, and ground fault tripped indication. They shall interrupt the circuit within 1/30th of a second on a 5 milliampere earth leakage current. They shall be designed for end of run installation or with provisions for feeding through to protect other outlets on the circuit. Maximum circuit capacity for the latter shall be 20 amperes. The receptacles shall be furnished with necessary wire connectors, clips, mounting scores and instruction.
- D. Clock Receptacles
 - 1. Receptacles for clocks are not required for clocks operating on less than fifty volts, and flush-mounted clocks (inserted type).
 - 2. Provide receptacles for clocks conforming to NEMA 5-15R, recessed so that male cap will be flush with the wall to permit the clock to cover the outlet.
 - 3. Provide plates, including finishes, as specified for cover plates, adapted to the recessed receptacles and with substantial hooks to support the clocks.
 - 4. Receptacles for surface-mounted clocks connected to the building 120-volt electrical system: As indicated.
 - 5. Where clock receptacles are shown on the Design Documents or specified, furnish the grounded type and provide with a ground jumper.

2.17 COVER PLATES

- A. Provide cover plates for each switch, receptacle, and special purpose outlet.
- B. Use multi-gang plates for multi-gang boxes.
- C. Unless otherwise indicated, use cover plates conforming to FS W-P-455.
- D. Provide and install cover plates of brushed stainless steel in ancillary spaces, mechanical rooms, fan rooms, wire closets, AC switchboard rooms, traction substations, and all unfinished areas.
- E. In public areas provide cover plates fabricated of corrosion-resistant steel, 18% chromium, 8% nickel with baked porcelain enamel bronze finish.
- F. For special purpose outlets commercially produced using special material, configuration, and size, use plate of brushed stainless steel and of a design for the particular application.
- G. Where plates of material and finish herein specified are not available commercially for these special purpose outlets, plates commercially available and suitable for enameling to match adjacent surface will be acceptable.
- H. Use stainless steel cover plates of 0.040" thickness for flush devices.

2.18 DISCONNECTION DEVICES

- I. Safety Switch Type Disconnecting Devices: Enclosed, conforming to UL Standards and the following:
 - 1. Motor Circuit Switches (600 Volts AC):
 - a. Furnish motor circuits with a separately mounted disconnect switch where required within sight of the motor.
 - b. Switch: HP rated, UL listed, quick make quick break, full cover interlock and indicator handle, conforming to FS W-S-865 for heavy duty switches.
 - c. Enclosure Type: As indicated.
 - d. Furnished handle mechanism with continuous engagement of the switch handle whether the door is open or closed, and is pad-lockable in the OFF and ON position.
 - 2. Heavy Duty Safety Switches (240 Volts AC):
 - a. Furnish heavy-duty safety switches having electrical characteristics, ratings, and modifications indicated.
 - b. Furnish switches with NEMA 12 General Purpose Enclosures, unless otherwise indicated, and with metal nameplates, front cover mounted, containing a permanent record of switch type, catalog number, and HP ratings.
 - c. Furnish handle with visible blades; reinforced fuse clips; nontearable, positive, quick make-quick break mechanism, and which is pad-lockable in the OFF and ON position.
 - d. Furnish switches meeting NEMA KS 1 requirements.
 - 3. Heavy Duty Safety Switches (600 Volts AC):
 - a. Furnish heavy-duty safety switches having electrical characteristics, ratings, and modifications shown on the Design Documents.
 - b. Furnish all switches with NEMA 12 General Purpose Enclosures, unless otherwise indicated, meeting NEMA KS 1 requirements.

2.19 INSULATED WALL COVERING

- A. As required by reduced clearances install insulated wall covering adjacent to DC switchgear and Rectifier equipment. Reduced clearance shall be a clearance less than 6'.

- B. The wall covering shall extend from floor to ceiling in the area required. The insulation shall be located to ensure that personnel cannot bridge the gap between the DC equipment and a grounded component.
- C. The insulated wall covering shall be fabricated from fiberglass and as a minimum meet the requirements for NEMA Grade GPO-1. The material shall be fire-resistant and have a high di-electric strength.
- D. The wall insulation shall be mounted to provide a flush level finish. Measures shall be provided to avoiding warping of the insulation. All securing fasteners or anchors shall be non-metallic or covered to prevent personnel contact.
- E. The wall mountings shall be provided for acceptance by the MBTA. The mountings shall be moisture resistant and not subject to warping.

PART 3 - EXECUTION

3.1 GENERAL

- A. Install all items in their proper locations as required, rigid and secure, plumb and level, and in true alignment with related and adjoining work. Do not weld electrical materials for attachment or support.
- B. Furnish anchor bolts and anchorage items as required, and field check to ensure proper alignment and location. Provide templates, layout drawings, and supervision at the job site to ensure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.
- C. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts and angles as required to set and connect rigidly the work.
- D. Control erection tolerance requirements to not impair the strength, safety, serviceability, or appearance of the installations, as accepted by the MBTA. Determine exact location of conduit. Route all conduit parallel to building lines.
- E. The trade size, type and general routing and location of conduits, raceways, and boxes shall be as indicated.
- F. Install exposed conduit so as to avoid conflicts with other work. Install horizontal raceway close to the ceiling or ceiling beams, and above water or other piping whenever possible.
- G. Install individual conductors in conduits, raceways, cable trays, ducts, and trenches and multiple-conductor sheathed cables as shown on the Design Documents to complete the wiring systems.
- H. Install switches, receptacles, special purpose outlets, and cover plates complete in a neat manner in accordance with the NEC and local electrical codes.

3.2 CONDUIT AND FITTINGS

- A. Metallic Electrical Conduit
 1. Install metallic conduit in accordance with the NEC and as indicated. Prevent concrete and other materials from obstructing the conduit. Pack all outlet, pull and junction boxes with paper

- prior to pouring concrete ends of embedded conduit. Do not use conduit smaller than 3/4" diameter.
2. Make all conduit bends in accordance with the NEC, with not more than 3 bends or 270 degrees of bends per run.
Where more than 3 bends totaling more than 270 degrees are required in a particular run, install pull boxes as required to facilitate pulling conductors.
 3. Unless otherwise indicated, terminate metallic conduit installed for future extension with flush couplings set to finished floor level.
 4. Provide metallic numbering tags indicating the conduit number on the end of conduit. Identify train control and communication conduit as indicated.
 5. Conduit shall be routed to minimize the use of embedded runs. Properly support conduit to be embedded to maintain correct location and spacing during concreting operations. If necessary, provide suitable metal supports for this purpose.
 6. Install conduit so that any moisture collecting in the conduit will be drained to the nearest outlet or pull box.
 7. Whenever exposed or buried conduit passes through an expansion or contraction joint in the structure, install the conduit at right angles to the joint, and provide an approved conduit expansion joint at the joint. Paint the conduit with an approved bituminous compound for one foot on each side of the expansion couplings.
 8. Provide expansion joints in conduit runs where required to compensate for thermal expansion.
 9. Rod and swab embedded conduit after installation to remove foreign matter, which may have worked in at the joints. If obstructions are encountered which cannot be removed, or if any conditions exist which may result in damage to wires and cables pulled through the conduit, install new conduit at no additional expense to the MBTA.
 10. After the conduit has been rodded and swabbed, repack boxes and protect conduit ends to prevent any foreign material from entering the conduit.
 11. Where metallic conduit is exposed to different temperatures, seal the conduit to prevent condensation and passage of air from one area to the other.
 12. Use only conduits that are electrically and mechanically continuous and connect to the structure ground system. Secure continuous ground by bonding where required.
 13. Apply conductive anti-seize compound to the threads of threaded rigid conduit joints. Do not use compounds containing lead. Terminate the conduit in appropriate boxes at all motors, switches, outlets, and junction points.
 14. When field cutting of conduit is required, thread and ream the conduit to remove any rough edges. Where a conduit enters a box or other fitting, provide a bushing to protect the wire from abrasion. Provide insulation type bushings and double locknuts on ends of rigid conduits terminating at steel boxes, panelboards, cabinets, motor starting equipment, and similar enclosures.
 15. Support individual horizontal conduits not larger than 1-1/2" diameter by means of one-hole pipe straps with back spacers or individual pipe hangers.
 16. Space conduits installed against concrete surfaces away from the surface by clamp backs or other approved means.
 17. Support individual horizontal conduits larger than 1-1/2" diameter by individual pipe hangers.
 18. In dry locations, spring steel fasteners, clips, or clamps specifically designed for supporting exposed single conduits may be used in lieu of pipe straps or pipe hangers.
 19. Hanger rods used in connection with spring steel fasteners, clips, and clamps shall be either 1/4" diameter galvanized steel rods or, if concealed above a suspended ceiling, galvanized perforated steel strapping. Do not use wire for support of conduit.
 20. Support parallel conduits at the same elevation on multiple conduit hangers or channel inserts. Secure each conduit to the pipe hanger or channel insert member by a U-bolt, one-hole strap, or other specially designed and approved fastener suitable for use with the pipe hangers or

channel inserts.

21. Space supports not over 10' on centers for vertical conduits spanning open areas. Securely anchor conduit at each end and run so as not to interfere with the installation and operation of equipment at the location.
22. Support conduits and raceways above suspended ceilings from either the floor construction above or from the main ceiling support members, using the applicable method specified herein.
23. Install liquid-tight flexible metal conduit so that liquids tend to run off the surface and not drain toward fittings. Provide sufficient slack to reduce the effects of vibration. Running threads are not acceptable. Where necessary for connecting conduits, use right and left hand couplings.

B. Non-Metallic Electrical Conduit

1. Non-metallic electrical conduit includes polyvinyl chloride (PVC) and asbestos cement conduit.
2. Cap or plug the ends of embedded conduit to prevent concrete and other materials from obstructing the conduit.
3. Sandpaper joints in PVC conduit to remove all burrs, clean and dry the joints, and brush with a solvent cement acceptable to the manufacturer before installing.
4. Properly support conduits to maintain the correct location and spacing during concreting operations and, if necessary, provide suitable plastic supports and spacers for this purpose.
5. Wherever buried non-metallic conduit passes through an expansion or contraction joint, or where required to compensate for thermal expansion and contraction, provide a conduit expansion joint. Install the conduit to cross the joint at right angles. In areas of floating slabs, install horizontal runs of conduit beneath the floating slab. Conduit shall pass through the floating slab only where required to terminate in a vertical direction as shown on the Design Documents.

C. Pull Wires

1. Use nylon pull wires of tensile strength not less than 240 pounds in each conduit and duct, leave pull wires in ducts and conduit after cleaning.
2. No splices in pull wire will be allowed.
3. Leave ample slack length at each end of pull wire.

D. Filling of Openings: Wherever slots, sleeves, or other openings are provided in floors or walls for the passage of raceways, including bus ducts, fill such openings as follows:

1. Use fire-resistive filling material for openings similar to the material of the floor, wall or ceiling being penetrated, and finish to prevent passage of water, smoke, and fumes.
2. Where conduits passing through openings are exposed in finished rooms, use filling material that matches, and is flush with, the adjoining finished floor, ceiling or wall.

3.3 INSERTS

A. Channel Inserts. Install embedded channel inserts with the slotted face flush with the finished concrete surface.

B. Spot Inserts

1. Install with the insert face flush with the finished concrete surface, firmly embedded, with no evidence of movement.

2. Test selected inserts, as required by the MBTA, by suspension of 800 pounds of weight from the insert. If there is evidence of failure, replace the inserts in a manner satisfactory to the MBTA.

3.4 SURFACE METAL RACEWAYS

- A. Securely ground surface metal raceways to outlet boxes or to backplates and fixtures by means of bolts, screws or other approved means and as specified in Section 16450 GROUNDING.
- B. Install surface metal raceways where indicated, in accordance with the NEC. Use fittings and accessories designed for the raceway.

3.5 OUTLET, JUNCTION AND PULL BOXES

- A. Outlet Boxes
 1. Unless otherwise indicated, flush mount outlet boxes with the front edges of the boxes or plaster covers attached thereto flush with the finished wall or ceiling.
 2. Mount boxes so that the long axis of the devices will be vertical, unless otherwise indicated.
 3. Locate conduit boxes and conduit box knockouts so as not to interfere with the reinforcing steel.
 4. Unless otherwise specified, provide boxes in plastered walls and ceilings with plaster covers.
 5. Do not install these covers until the finish plaster line is determined for the particular location.
 6. The mounting height indicated for a wall-mounted outlet box shall be construed to mean the height from the finished floor to the horizontal centerline of the cover plate.
 7. Mount outlet boxes for switches and receptacles located on columns and pilasters so as not to interfere with installation of partitions.
 8. Install boxes located near doors on the lock sides, even where the symbols appear on the hinge sides on the Design Documents, unless other locations are accepted by the MBTA.
- B. Junction and Pull Boxes
 1. Install so that covers are readily accessible after completion of the installation.
 2. Do not install boxes above suspended ceilings, except where the ceiling is of the removable type or where definite provisions are made for access to each box.
- C. Boxes Set in Concrete
 1. Adequately support boxes to prevent movement during placement of concrete.
 2. Unused nailing holes or other holes in the side or bottom of the boxes will not be permitted.
 3. After installation, clean boxes placed in concrete.

3.6 CABLE TRAYS

- A. Install as required and in accordance with NEC Article 318 using approved fittings and adequately supporting the complete system.
- B. Provide anti-sway brackets on all horizontal tray assemblies where necessary as determined by calculation, field installation review or MBTA request.
- C. Connect each isolated cable tray system or the entire tray system to the building equipment grounding system with a green insulated conductor in accordance with the NEC.
- D. Base size determination on the largest power conductor in the rack.

1. Minimum size: No. 6
2. Maximum size: 4/0 copper

3.7 UNDERFLOOR DUCTS AND FITTINGS

- A. Install as required.
- B. Accurately align and level the ducts with the top of inserts 1/8" below the finished concrete floor.
- C. Hold ducts in place during pouring of concrete by use of duct support fitting designed for the duct used, spaced at five-foot intervals. Carefully level all boxes, with the tops flush with the finish floor.
- D. Install appropriate insert markers in the last insert at all dead ends, on each side of partitions, and first insert adjacent to junction box to indicate high and low voltage services.
- E. Seal duct installation watertight with an approved sealing compound.

3.8 WIRING

- A. General
 1. Furnish wires and cables to the site in unbroken standard coils or reels, to which shall be attached a tag bearing the manufacturer's name, trade name of the wire, and the UL label for 600 volt wire and cable.
 2. Provide all wiring complete as indicted. Provide ample slack wire for motor loops, service connections and extensions. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.
 3. Do not bend cables during installation, either permanently or temporarily, to radii less than 12 times the outer diameters, except where conditions make the specified radius impracticable, and shorter radii are permitted by the NEC and NEMA Standard WC 7, Appendix N.
 4. Neatly and securely bundle cable conductors located in branch circuit panelboards, cabinets, control boards, switchboards and motor control centers and pull boxes. Use nylon bundling straps.
- B. Wire Pulling
 1. Install wire and cable in conduit as indicated. Do not pull wiring into any conduit until conduits and outlets have been thoroughly cleaned and swabbed to remove water and debris. Do not use block or tackle or other mechanical means in pulling conductors smaller than No. 2 AWG in raceways.
 2. Provide suitable installation equipment to prevent cutting and abrasion of conduits and wire during the pulling of feeders. Use lubricant and installation procedure as recommended by the cable manufacturer, and as accepted by the MBTA.
 3. Use masking or other means to prevent obliteration of cable identifications when solid color coating or colored tracers are used.
 4. Pull together all cables to be installed in a single conduit.
- C. Cable Supports. Install cable supports for vertical feeders in accordance with the NEC.
- D. Splices and Terminations
 1. Make wire and cable splices only in outlet, junction or pull boxes, or in equipment cabinets.
 2. Splices in conduit or raceway will not be permitted. Make splices by means of compression type connectors, and cover with tape to an insulation level equal to that of the cable.

3. Use positive type connector installation tools as recommended by the manufacturer.
4. Mechanical hand tools, with dies for each conductor size, recommended by the manufacturer, may be used on conductor sizes through No. 4/0.
5. For conductor sizes larger than No. 4/0, use hydraulic tools with hexagonal or circumferential installing dies for each conductor size, as recommended by the manufacturer.
6. For inspection purposes, clearly mark die numbers on the installed connectors.
7. Before installation, apply anti-corrosion electrical joint compound to conductors and terminal bolting pads.

3.9 WIRING DEVICES

- A. Locate switches four feet above finished floor, except as otherwise indicated.
- B. Attach receptacles rigidly to outlet box by means of two screws.
- C. Wire duplex receptacles, where so indicated, so that one unit of the duplex may be controlled by a wall switch and the other unit remain continuously energized.
- D. For exterior locations, mount receptacles in watertight cast type outlet boxes with threaded hubs or bosses and equipped with gasketed cover and captive cap of the screw or twist type.
- E. Provide equipment permanently connected to exterior receptacles, or in areas subject to spray or hose cleaning, with watertight male plugs to suit. Such receptacles shall be of the ground fault circuit interrupter type, as specified herein.
- F. Furnish one matching plug with each receptacle, as indicated, installed in the work.

END OF SECTION

SECTION 16203

TRACTION POWER EQUIPMENT GENERAL REQUIREMENTS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the general requirements for the supply and delivery of new traction power substation equipment including AC switchgear units, transformer/rectifier unit, DC switchgear units, interconnecting bus duct, and DC disconnect switch assemblies. Specific requirements for each substation equipment item are included in subsequent sections of these Mandatory Specifications.
- B. Additionally, this Section identifies the expected documentation required for Traction Power under the design phases of the project.

1.2 MAJOR ELECTRICAL EQUIPMENT

- A. Major electrical equipment includes the following:
 - 1. 15 kV AC switchgear assembly
 - 2. Rectifier transformer(s)
 - 3. Rectifier(s)
 - 4. 750 Volt DC switchgear assembly
 - 5. Anode (AC) bus and Cathode (DC) bus
 - 6. Negative bus and Drainage Board
 - 7. DC Feeder Disconnect Switches
 - 8. 15 kV circuit breaker control and indication panel
 - 9. DC circuit breaker test cabinet
 - 10. 15 kV ground and test devices
 - 11. AC circuit breaker test cabinet
 - 12. Station battery, charger and accessories
 - 13. Technical Support Equipment
 - 14. Supervisory Equipment (SCADA) System
 - 15. 125 VDC Control Voltage Distribution System
 - 16. Substation Automation System (SAS)

1.3 REFERENCES

- A. The DB Entity shall comply with all applicable regulatory requirements, national codes and technical references and publications listed in Section 16201.
- B. All major electrical equipment furnished under this Contract shall be in accordance with the latest applicable standards of NEMA, IEEE, ANSI, NFPA, ICEA, OSHA, UL, National Electrical Code and Massachusetts Electrical Code with regard to material, design, construction and testing, except for variations as specified in the Specification. The standards applicable shall include, but not be limited to the following:

1. IEEE 1584 Guide for Performing Arc Flash Hazard Calculations
2. IEEE 1653.2 Uncontrolled Traction Power Rectifiers for Substation Applications
3. ANSI C37.06 AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis Preferred Ratings & Related Required Capabilities
4. IEEE C37.09 Test Procedure for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
5. IEEE C37.1 IEEE Standard Definition, Specification, and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control
6. ANSI C37.2 IEEE Standard Electrical Power System Device Function Numbers
7. IEEE C37.11 Requirements for Electrical Control for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
8. IEEE C37.13 Low Voltage AC Power Circuit Breakers Used in Enclosures
9. IEEE C37.14 Low Voltage DC Power Circuit Breakers Used in Enclosures
10. ANSI C37.16 Low Voltage Power Circuit Breakers and AC Power Circuit Protectors Preferred Ratings, Related Requirements, and Application Recommendations
11. ANSI C37.17 Trip Devices for AC and General Purpose DC Low Voltage Power Circuit Breakers
12. IEEE C37.20.1 Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear
13. IEEE C37.20.2 Metal-Clad and Station-Type Cubicle Switchgear
14. IEEE C37.20.7 IEEE Guide for testing medium voltage metal enclosed switchgear for internal arcing faults
15. ANSI C37.32 High Voltage Air Switches, Bus Supports, and Switch Accessories Schedules of Preferred Ratings, Manufacturing Specifications, and Application Guide

16. IEEE C37.34 Standard Test Code for High-Voltage Air Switches
17. IEEE C37.40 Service Conditions and Definitions for High Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories
18. ANSI C37.90 Relays and Relay Systems Associated with Electric Power Apparatus
19. ANSI C39.1 Requirements for Electrical Analog Indicating Instruments
20. ANSI/UL 1561 Standard for Safety for Dry-Type General Purpose and Power Transformers
21. ANSI C57.12.01 General Requirements for Dry-Type Distribution and Power Transformers
22. ANSI C57.12.10 Transformers 230 kV and Below – Safety Requirements
23. ANSI C57.12.50 Ventilated Dry-Type Distribution Transformers 1 to 500 kVA Single-Phase and 15 to 500 kVA Three-Phase,
24. ANSI C57.12.51 Ventilated Dry-Type Power Transformers, Three-Phase, 501 kVA and Larger
25. ANSI C57.12.91 Test Code for Dry-Type Distribution and Power Transformers
26. ANSI C57.13 IEEE Standard Requirements for Instrument Transformers
27. ANSI C57.13.2 Conformance Test Procedures for Instrument Transformers
28. ANSI C57.18.10 IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers
29. ANSI C57.110 IEEE Recommended Practice for Establishing Transformer Capability When Supplying Non-sinusoidal Load Currents
30. ANSI B1.1 Unified Inch Screw Threads
31. ANSI B1.10-58 Unified Miniature Screw Threads
32. ANSI Z55.1.61 Gray Finishes, Light Gray Color Chip No. 61
33. ANSI 634 Cable Penetration Fire Stop Qualification Test
34. IEEE 4 Standard Techniques for High Voltage Testing
35. IEEE 48 Standard Test Procedures and Requirements for Alternating Current Cable Terminations 2.5 kV Through 765 kV
36. IEEE C62.11 IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1 kV)

37. IEEE 82	IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors
38. ICEA S-73-532 (NEMA WC 57)	Standard for Control Cables
39. ICEA S-95-658 (NEMA WC70)	Standard for Nonshielded Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy
40. ICEA S-96-659 (NEMA WC71)	Standard for Nonshielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electrical Energy
41. ICEA S-93-639 (NEMA WC 74)	Nonshielded Power Cables Rated 5000-46000 Volts for the Distribution of Electrical Energy
42. NEMA AB 3	Molded Case Circuit Breakers and Their Application
43. NEMA FU-1	Low Voltage Cartridge Fuses
44. NEMA ICS 1	Industrial Control and Systems: General Requirements
45. NEMA ICS 4	Industrial Control and Systems: Terminal Blocks
46. NEMA KS 1	Enclosed and Miscellaneous Distribution Equipment Switches
47. NEMA LA 1	Surge Arresters
48. NEMA LS 1	Low Voltage Surge Protection Devices
49. NEMA PE 5	Utility Type Battery Chargers
50. NEMA SG 4	Alternating Current High Voltage Circuit Breaker
51. NEMA SG 6	Power Switching Equipment
52. NEMA FG-1	Fiberglass Cable Tray Systems
53. NFPA 70	National Electric Code
54. NFPA 70E	Standard for Electrical Safety Requirements for Employee Work Places
55. NEMA ST 20	Dry-Type Transformers for General Applications
56. NEMA TR 1	Transformers, Regulators, and Reactors
57. NEMA 250	Enclosures for Electrical Equipment (1000V Max.)

58. NFPA262	Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air Handling Spaces.
59. UL-44	Thermoset-Insulated Wires and Cables
60. UL-224	Extruded Insulating Tubing
61. UL-508	Industrial Control Equipment
62. UL-1581	Standard for Safety Electrical Wires, Cables and Flexible Chords
63. EIA 232-F	Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Interchange
64. EIA 455-11-177A	Standards for Test measurements and Inspection for Fiber optic Cables, Connectors and/or Other Fiber Optic devices.
65. IEEE C37.90.1	Standard Electrostatic Discharge Tests for Protective Relays
66. IEEE 802.3	Carrier Sense Multiple Access with Collision Detection.
67. UL 1581	Standard for Safety Electrical Wires, Cables and Flexible Cords
68. NETA ETT-2000	Standard for Certification of Electrical Technicians
69. NETA ATS	Standard for Acceptance testing Specifications for Electrical Power Equipment and Systems.
70. IEC 61850	Communication Protocol for Network Automation in Substations
71. IEEE 730-2014	Standard for Software Quality Assurance
72. IEEE C37.90	Standard for Relays associated with Electric Power Apparatus
73. OSHA- 29 CFR Part 1910 Sub Part S	-

- C. Where any requirements specified herein or shown on the Design Documents exceed those of the above listed standards, the DB Entity shall adhere to the higher standard. In case of conflict in requirements between two or more standards, the decision of the MBTA shall be final.
- D. In cases where equipment from U.S. suppliers is not available, equivalent British, European, Japanese or IEC standards are acceptable, provided a tabulation is furnished citing the comparison between the applicable U.S. and the equivalent non-U.S. standards. In addition, the non-U.S. suppliers shall note where U.S. standards are not met, for evaluation and acceptance by the MBTA. Factory testing shall be performed whenever possible. If factory testing must occur outside of the USA, then the DB Entity shall bear the costs associated with the witness testing by the MBTA and one additional MBTA representative.
- E. All equipment and materials furnished under Division 16 of Exhibit 2A.1 shall conform to all Federal, State or Municipal laws or ordinances, and if any requirement shown or specified conflicts with such laws or ordinances, the DB Entity shall make such changes as are necessary to meet said requirements. The

cost of such changes shall be borne by the DB Entity and shall be included in the DB Entity's original bid. Where any standards shown on Design Documents or specified herein exceed the minimum standard set by law, the DB Entity shall adhere to the higher standard.

- F. Where materials or equipment are specified to conform to the standards of the Underwriters Laboratories, Inc., or to be constructed or tested in accordance with the standards of the National Electrical Manufacturers' Association or American National Standards Institute, the DB Entity shall submit proof that the item furnished conforms to such requirements. The label of, or listing by the Underwriters' Laboratories, Inc. will be acceptable as sufficient evidence that the item is in accordance with the Underwriters' Laboratories standard. A company listed as a member company of NEMA for an item under consideration will be acceptable as sufficient evidence that the item conforms to the requirements of the National Electrical Manufacturers Association. In lieu of such stamp or certification label listing, the DB Entity may submit a written certificate from any nationally recognized testing agency adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the requirements listed herein including methods of testing by the specified agencies. Conformance with the agency requirement does not relieve the item from complying with any other requirements of the Mandatory Specifications.
- G. The DB Entity shall clearly state compliance / non-compliance with the traction power specifications however small, on a clause-by-clause basis. The list shall identify all specification clauses in the Traction Power Specifications and adjacent to each listed clause a category of 'compliant', or 'non-compliant'. Each non-compliance shall be provided with a description or explanation and the DB Entity's proposed alternative or solution.

1.4 GENERAL

A. DESIGN SUBMITTAL REQUIREMENTS

1. Refer to the Sections 2.7 and 2.8 for the overall requirements related to design and construction submittals.
2. Also refer to Specification 16311 for detailed of the product and installation design submittals required including meetings and design conferences.
3. As detailed in the Contract Documents, there are four design submittals required. Phase I: Preliminary, Phase II: Intermediate, Phase III: RFC (Readiness for Construction) and Phase IV: Final
4. Phase I: Preliminary
 - a. The deliverable should be similar to a 30% level design submittal. The following deliverables shall apply to the traction power documentation to be provided. The submittal shall include but not be limited to:
 - AC and DC System Sectionalizing and Feeding Diagrams
 - Preliminary Systemwide ductbank layout
 - TPS relay and metering diagrams / Single Line Diagrams
 - TPS substation building and equipment layout drawings
 - TPS substation elevations views and sections.
 - Main equipment arrangement drawings.
 - Ground grid design and calculations
 - Overall dimensional drawings showing clearances and access
 - Typical equipment operating schematic drawings

- Foundation plan
- SCADA system points list
- SAS block diagram and system definition report
- Concept and definition of Utility interfaces
- Building electrical, mechanical, plumbing, structural and architectural details as required by the respective discipline deliverables.
- Specifications
- Design basis report or narrative

5. Phase II: Intermediate

- a. The deliverable should be similar to a 75% level design submittal. The following deliverables shall apply to the traction power documentation to be provided. In addition to the documentation listed in the previous phase, the submittal shall include but not be limited to:

- Equipment details including mounting arrangements and all equipment locations
- Equipment functional schematics
- Equipment interconnection details and terminal charts
- Grounding and bonding details
- Systemwide Grounding Schematic
- Details of Utility Interfaces
- Cable block diagram
- Conduit and Cable routing (Systemwide and TPS)
- Cable schedules
- Systemwide Ductbank layouts and profiles
- Typical Manhole details
- Cable pulling calculations and conduit fill calculations
- AC and DC distribution systems
- Traction power negative return system schematic diagram
- Traction power negative connection diagrams
- SCADA points address list
- SAS equipment details and functional report showing screens, hierarchy and operational intent
- Details of any stray current system connections to the TPSS
- Building electrical, mechanical, plumbing, structural and architectural details as required by the respective discipline deliverables.
- Technical Specifications
- Calculations
- Design basis report or narrative

6. Phase III: RFC (Release for Construction)

- a. The deliverable should be similar to a 100% level design submittal and include all details required for procuring equipment and installing the equipment. The following deliverables shall apply to the traction power documentation to be provided. In addition to the documentation listed in the previous phase, the submittal shall include but not be limited to:

- Cable schedules
- Conduit schedules and allocation charts
- Installation details
- Interconnection/interface drawings

- Manhole / pullbox development drawings
- Building electrical, mechanical, plumbing, structural and architectural details as required by the respective discipline deliverables.
- Technical Specifications
- Final calculations

7. Phase IV: Final

- a. Stamped and sealed plans for construction.

B. EQUIPMENT

1. The design of the equipment shall provide features for the safety of personnel during operation, maintenance, and repair.
2. All equipment and materials supplied by the DB Entity shall be new, of recent manufacture and of highest grade as specified. They shall be resistant to moisture and corrosion to withstand their environment and operational conditions with minimum maintenance and long life.
3. Wherever practicable, all major electrical equipment and materials furnished under this Contract shall be the product of a single manufacturer. In the case of major items, the manufacturer shall maintain a service organization within a reasonable distance from the project which is properly staffed and equipped to make repairs as required.
4. Materials and equipment shall be essentially the products of a manufacturer regularly engaged in the manufacturing of the product and the manufacturer shall have such products of comparable capacity and function to that specified in satisfactory use on a rapid transit system.

1.5 MANUFACTURER'S DRAWINGS

- A. All units of measurement of length-weight-time shall be in the United States system of feet-pounds and seconds. Unit of measurement of temperature shall be in degrees Celsius, denoted by degrees C. Design Documents may use metric dimensions and tolerances provided the equivalent United States units are clearly shown in parenthesis on all drawings defining general arrangements and interfaces, and on all drawings used for installation, repair, maintenance or disassembly. Design Documents shall be prepared using terms and units standard to U.S. industry.
- B. Unit of measurement for wire and cables shall be American Wire Gauge (AWG) up to size 4/0 and circular mils for larger sizes. Conductor stranding shall be as per ASTM.
- C. All Design Documents shall be in English language only, irrespective of country of origin.
- D. All Design Documents shall have a blank 3” x 4” space on the top right hand corner, clear of all markings, for acceptance stamping by the MBTA. If the DB Entity's standard drawing does not provide this space, the drawing shall be prepared on the next larger sheet, or the 3” x 4” space may be provided elsewhere on the Design Documents.
- E. The submittal requirements identified in Section 16311 shall be observed by the DB Entity. The process of highlighting drawing changes for progress submittals shall be complied with.

1.6 BUS AND BUS CONNECTIONS AND JOINTS

- A. The buses within equipment supplied by the DB Entity shall be fabricated of high conductivity rectangular copper bars as specified herein. Aluminum may be used for rectifier heat sinks. Buses shall be designed to carry rated currents without exceeding the maximum allowable temperature rise as specified in ANSI, NEMA and IEEE standards when operating at specified overloads. Bus connections and joints shall have an ampacity equal to that of the bus ampacity, and be fabricated so that there will be no loss of conductivity during the life of the equipment.
- B. The entire contact area of all bolted current carrying connections in copper buses shall be factory silver-plated. Ring-plated method of silver plate and tin-plated contact surfaces will not be acceptable. Silicon bronze bolts, nuts and lockwashers, or approved equal, shall be used. Connections shall be made with a minimum of two ½" - 13 bolts at each end of the joint.
- C. All bolted current carrying connections in aluminum heat sink assemblies of rectifiers, where accepted by the MBTA, shall be first copper plated, then nickel plated and provided with proper spring tensioning devices to maintain proper joint pressure under load (heat) cycle. Stainless steel bolts, nuts and lockwashers shall be used.
- D. The DB Entity shall coordinate all connections to mate with adjacent equipment terminals and enclosures. Provisions shall be made for access to permit assembly of these connections and inspection after installation or removal without displacing the major components within the enclosure.

1.7 POWER AND GROUNDING CONNECTORS

- A. All terminal lugs furnished for power and grounding cables shall be heavy duty, bolted type, of high copper content alloy, complete with silicon bronze bolts, nuts and lockwashers. Lugs shall have tongues with either two or four ½" - 13 bolts, as specified, spaced per standard NEMA drillings, and four-bolt cable clamps. All contact surfaces shall be machined smooth and silver-plated.

1.8 NAMEPLATES

- A. Each major component of equipment shall have, as a minimum, the manufacturer's name, address, and catalog number, model, style or type on a nameplate securely attached to the item in an area easily accessible to normal visual demands by maintenance and service personnel. Nameplates for electrical apparatus shall conform to the referenced standards and as specified elsewhere in this specification.
- B. Each rectifier and transformer, switchgear assembly unit, circuit breaker and auxiliary unit, auxiliary transformer, bus ducts, battery charger, panel board, terminal box, and all panel mounted and individually mounted equipment and devices shall be provided with nameplates for proper identification. Panel and door mounted devices shall also be identified in the rear with the designations indicated on manufacturer's connection diagrams. Internally mounted devices shall be similarly identified with nameplates and manufacturer's connection diagram designations.
- C. Nameplates identifying major equipment shall be provided in duplicate: one on front and the second on the rear of the equipment, when not located against a wall. The major equipment labels shall have 2" black lettering on white background. Lettering shall not be closer than 1/4" from the edge of the nameplate and if more than one line of text is required each line shall be separated by 1/4".
- D. Nameplates identifying AC and DC circuit breaker and auxiliary units shall have inscription including

circuit breaker number and service. One nameplate shall be provided on front, the second on the rear of each unit. DC circuit breaker nameplates shall include the breaker name/number, cable designation, and associated track section designations. When applicable, AC circuit breakers shall include the breaker name/number, cable designations, and associated equipment designations.

- E. Nameplates for panel boards, terminal boxes and similar equipments shall have lettering in accordance with MBTA standards.
- F. Nameplates for panel and door mounted relays, meters, control and instrument switches, fuses and auxiliary devices and individually mounted circuit breakers, disconnect switches and all other components, shall have 1/4", minimum, lettering. For protective and auxiliary relays, the nameplate inscription shall include device number and function. Nameplates for fuses shall note the type and rating of fuse, polarity and identify the circuit.
- G. All nameplates shall be laminated plastic with dull white surface and black core unless otherwise specified. Letters shall be engraved through outer layer to expose black core. All exposed edges shall be beveled. Nameplates shall be fastened with machine screws. Use of self-tapping screws or adhesives will not be permitted.
- H. The legends of all nameplates shall be submitted to the MBTA for acceptance.

1.9 WIRING AND TERMINAL BLOCKS

A. Wiring

1. All secondary and control wiring in equipment, including wiring on removable elements of circuit breakers, shall be ICEA/NEC type SIS, or approved equal, stranded tinned copper switchboard wire, rated for a minimum conductor temperature of 90 degrees C. Wire shall be insulated for 600 volts unless otherwise specified. Wire shall comply with UL-44 for flame retardant properties for thermo-plastic insulated wire. Wire crossing hinged joints shall be similar except extra flexible, suitably protected against abrasion.
2. Wiring to and from the rectifier and DC switchgear (including 15kV AC control panel if integral) shall have minimum insulation rating of 1000V DC.
3. Current and potential transformer secondary wiring shall be No. 12 AWG copper or larger, unless otherwise specified.
4. All elements of control wiring operated at 600V DC shall be connected with red colored wire rated for 2000V.
5. Control wiring, including internal wiring and wiring between equipment in separate enclosures, shall be No. 12 AWG copper or larger, unless otherwise specified.
6. Analog indication wiring to SCADA shall be No. 16 AWG or larger, unless otherwise specified.
7. Wiring shall be provided with ring-type compression terminals with insulated sleeves at each termination. Locking fork-type compression terminals are acceptable except for current transformer wiring. All wiring shall be identified at each termination by printing on wire jacket or on an insulating sleeve. Adhesive wire markers are not acceptable.
8. Wiring installed through openings in metal barriers or structural members shall be protected against abrasion by approved grommets.

9. Wire harnesses shall be supported with a bracket fastened to the enclosure via a tack-welded stud or a machine screw utilizing a "shake-proof" washer. Welding and/or drilling and tapping for machine screws shall be accomplished before finish paint is applied. Nylon composite tie wraps shall be used for securing harness to the support. Wire support brackets attached to the enclosure with adhesives are not acceptable.
10. All fiber optic or Ethernet cable shall be run independently within orange colored innerduct when installed on cable tray and within equipment. The length of the inner duct shall run the entire length of the circuit, equipment to equipment. For Cat 5E Ethernet cables, the requirement for 1kV insulation level at the rectifier and DC switchgear shall be maintained, through combination of the innerduct and insulation properties of the cable.

B. Terminal Blocks

1. Circuits requiring external connections shall be factory-wired to terminal blocks, readily accessible for field wiring entering from top or bottom as specified for the equipment involved. Sufficient number of terminals to satisfy all external connection requirements and 20 percent additional unassigned terminals shall be provided.
2. Terminal blocks shall be heavy-duty, washer-head screw type with insulating barriers between circuits, 1000V dc rated for DC switchgear and rectifier equipment and 600 Volts for miscellaneous lighting and control circuits, unless otherwise specified, complete with marking strips and plastic covers. Similar terminal blocks, complete with properly tagged jumper wires, shall be provided at each shipping split to facilitate field assembly.
3. Current and potential transformer secondary leads shall be wired directly to terminal blocks before being wired to relaying, metering or control devices. Terminal blocks for current transformer leads shall be short-circuiting type. For multi-tap or multi-ratio devices all taps shall be wired to adjacent terminal blocks.

1.10 RELAYS, SWITCHES AND DEVICES

A. General

1. The type of relays, switches and devices used in the control and supervision of the supplied equipment shall have proven record of successful operation in similar application to the satisfaction of the MBTA.
2. All externally mounted relay, switches, and devices mounted to the DC switchgear shall be insulated from the enclosure by mounting on glastic sheeting. Minimum clearance from the electrical components to enclosure shall be 2".

B. Relays and Meters

1. All single-function protective relays shall be of draw-out construction, provided with semi-flush mounting cases. Relays shall be connected to external wiring through built-in test switches or connection blocks arranged to allow in case testing of the relay. Single-function and multi-function protective relays shall be microprocessor based with resettable targets (flags), and 125 VDC control. Current versions of the relay software shall be provided with each relay. The relays shall have facility or communication to a laptop PC and interface to the substation automation system.
3. All control and auxiliary relays shall be front connected, surface mounting type, with cover, suitable for use in switchgear equipment in accordance with ANSI C37.90. Operating coils of direct current

relays shall be suitable for continuous operation between 80 percent and 110 percent of rated voltage and for alternating current relays between 85 percent and 110 percent of rated voltage.

4. The coils of interposing relays, Devices 201C and 201T (if required depending on integration within the SAS), for interfacing with supervisory system equipment shall be rated for operation on 125 volts DC and shall have a burden of not more than 12.5 watts. Coils shall be provided with surge limiting diodes to suppress noise during operation which may cause momentary false indication. Contacts shall be rated 30 amperes DC, minimum.
5. Auxiliary relays shall be rated for 750 volts DC service, minimum. Relays shall be isolated from equipment enclosures for 1,000 volts DC, minimum.
6. If not integral to the DC switchgear protection relay, the pickup of relays for cable energized indication, Device 197X, of DC traction feeder circuits shall be adjustable for a minimum range of 50 volts to 750 volts.
7. All indicating instruments shall be switchboard type, one percent accuracy, semi-flush mounted having metal scales with black figures on white background. They shall be approximately 4-1/2" square with a minimum of 240-degree scale, furnished with anti-glare glass, unless otherwise specified. Digital meters may be used on the AC control panel as shown on the Design Documents.
8. Ammeters for space heater circuits shall be panel type, two percent accuracy, semi-flush mounting, approximately 2-1/2 inch square. A red mark shall indicate the normally expected current reading.
9. All meters shall be provided with insulating covers on exposed terminals.

C. Switches

1. All control, selector and instrument switches shall be rotary type, provided with properly designated black escutcheon plates, clearly marked with white letters to show operating position. General Electric type SBM, Shallco Series 26, Electroswitch Series 24 or Type W2 or approved equal.
2. Breaker control switches shall be spring-return to normal with escutcheon engraved TRIP-CLOSE, trip counter-clockwise, close clockwise, furnished with target and red pistol grip handle.
3. Breaker control mode selector switches, Devices 43 and 143, shall be four -position, maintained contact type with escutcheon engraved LOCAL-HMI-OFF-SUPV off position at 12 o'clock, with black oval handle.
4. Instrument switches shall be maintained contact type, shall have an OFF position and black knurled round handle.
5. Load measuring circuit bypass switch shall be key-operated, two position, with escutcheon engraved "NORMAL-OPERATED", maintained contact type. Key shall be held captive at "OPERATED" position. All switches shall be set to operate with the same key. Information related to lock setting and number of keys to be supplied will be furnished by the MBTA.
6. At least one of each type of switch shall be provided as spare parts along with the equipment, unless otherwise identified.

D. Test Switches

1. Test switches shall be provided for in-service testing and calibration of indicating instruments,

transducers and other devices not furnished with built-in test devices, for removal of these devices from potential and current circuits without disturbing switchgear wiring. Test switches are not required for devices on DC switchgear.

2. Each test switch shall be provided with a minimum of three poles for potential circuits and six poles for current circuits. Current switches shall be provided with features for short-circuiting current transformer secondaries prior to disconnecting the instruments and devices from current circuits. The individual switch units shall be assembled on an insulated base provided with insulated barriers between each pole. Test switches shall be arranged for semi-flush mounting in front of the switchgear. The DB Entity shall furnish a set of necessary test plugs and jumper cables with the switchgear assembly.

E. Indicating Lamps

1. All indicating lights shall be of the light emitting diode (LED) type, mounted in assemblies which include an appropriate series resistor, hardware for panel mounting, and colored lenses. LED element(s) shall be mounted on a socket to facilitate replacement and shall have a rated life of 100,000 hours, minimum.
2. Internal surfaces of the lenses shall be Fresnel-cut to produce a brilliance comparable to that of a low-burden incandescent light unit, and a wide viewing angle. The DB Entity shall forward one assembled light unit of each color proposed to be supplied with the equipment to the MBTA for acceptance.
3. Indicating lamps shall be red for circuit on or breaker closed, green for breaker open or de-energized, white for circuit breaker spring charging, blue for heater circuits on.
4. Breaker closed red lamp and open green lamp shall be located above the associated circuit breaker control switch. Red to the right, green to the left.

F. Fuses and Fuse Holders

1. All fuses for control, auxiliary, and metering circuits shall be located in such a position that they are easily and safely accessible. Fuses shall be of the non-renewable, cartridge type, with "finger-safe" holders where available.
2. Fuse holders and fuses installed in solidly grounded equipment assemblies shall be rated for 250 volts AC service. Fuses shall have a minimum interrupting rating of 20,000 amperes rms, symmetrical, at 250 volts AC and DC.
3. Fuse holders and fuses installed in rectifier units and in DC switchgear for control and auxiliary circuits shall be rated for 1,000 volts DC service. Fuses shall have a minimum interrupting rating of 20,000 amperes, rms, symmetrical, at 600 volts AC or DC.
4. Fuse holders and fuses for metering circuit taps to 600-volt nominal DC power buses at rectifier DC switchgear shall be rated for application on systems capable of delivering DC short circuit current of 200,000 amperes. Fuse holder shall be designed to reject fuses of lower interrupting ratings. Fuses shall be either pull-out mounted or the bolted-on type. Disconnect means shall be provided with bolted-on fuses, for safe disconnection of the fuse holder from the energized bus.

G. Protection and Control Equipment Voltage Ratings

1. Auxiliary relays, control and selector switches, fuse holders and fuses, terminal blocks and other

devices which are located in the rectifier unit and DC switchgear and which operate on 125 VDC may be rated for 600 volts AC or DC insulation only under the following conditions:

- a. Similar 1000VDC rated devices are not available; and
- b. Such devices are insulated for 1,000 volt, minimum, from equipment enclosure.

1.11 TRANSDUCERS AND ISOLATION AMPLIFIERS FOR TELEMETERING AND LOCAL INSTRUMENTATION

A. Transducers

1. General

- a. Transducers for converting the measured AC and DC quantities into DC milli-ampere signal for telemetering via Authority's SCADA system shall be of the solid state design, suitable for installation in switchgear equipment. The transducers shall integrate the signals into the substation automation system either directly or via a local digital input/output device.
 - b. The transducers shall be of the 0.2 percent accuracy class, having a DC output signal linearly proportional to the measured quantity. Devices shall have an operating temperature range from minus 20°C to plus 60°C, minimum, and shall perform satisfactorily in an atmosphere containing up to 95 percent humidity (noncondensing). Transducers shall withstand for one minute a hi-pot test of 1,500 Volts, rms, 60 Hz applied between the input and output circuits and from input and output circuits to ground. Output shall be adjustable within plus-minus 10 percent of the full output range.
 - c. Potential circuits of transducers shall be designed for continuous operation at 20 percent higher than the rated voltage. Current circuits shall be capable of continuous operation at twice the rated current and shall withstand a fault current of 250 amperes for one second.
 - d. The surge withstand capability of all transducers shall be in accordance with IEEE Standard C37.90.1.
 - e. Transducers with dc current and voltage inputs shall be isolation amplifier type, providing electrical isolation of the input signal from the output signal.
2. Ratings: Transducers shall have the electrical ratings and characteristics specified below:
- a. For measuring average ac voltage and current:

	<u>Voltage Transducers</u>	<u>Current Transducers</u>
Input, 60 Hz	0-150 V	0-5 A
Output - dc into 10k ohm load	4-20 mA	4-20 mA
Output ripple - peak, max.	< 0.2 percent	< 0.2 percent
Response time for 0-99 percent output, max.	< 250 msec.	< 250 msec.
Accuracy - percent of rated output	0.2 percent	0.2 percent

60 Hz dielectric withstand (one minute)	2500 Volts rms	2500 Volts rms
Auxiliary Power	125V, DC $\pm 20\%$ < 3W With reverse surge protection	125V, DC $\pm 20\%$ < 3W With reverse surge protection

Voltage
Transducers

- b. For measuring average dc bus voltage:
- | | |
|--|---|
| Input, DC | 0 -750 V |
| Output - DC into 10k ohm load | 4-20 mA |
| Response time for 0-99 percent output, max. | < 250 msec. |
| Accuracy - percent of rated output | +/- 0.2 percent |
| 60 Hz dielectric withstand (one minute), output/power/case | 2500 Volts rms |
| Auxiliary Power | 125V, DC $\pm 20\%$ < 3W
With reverse surge protection |
- c. For measuring average dc voltage from a 50 mV current shunt:
- | | |
|--|---|
| Input, DC | 0 to ± 50 mVdc |
| Output - DC into 10k ohm load | 4-20 mA |
| Response time for 0-99 percent output, max. | < 250 msec. |
| Accuracy - percent of rated output | +/- 0.2 percent |
| 60 Hz dielectric withstand (one minute), output/power/case | 2500 Volts rms |
| Auxiliary Power | 125V, DC $\pm 20\%$ < 3W
With reverse surge protection |
- d. For measuring average dc power (Watts):
- | | |
|---|------------------------|
| Input, DC: | |
| Voltage | 0-750 V |
| Current shunt | 0 to ± 50 mV, from |
| Output - DC into 10k ohm load | 4-20 mA |
| Response time for 0-99 percent output, max. | < 250 msec. |

Accuracy - percent of reading	+/- 0.2 percent
60 Hz dielectric withstand (one minute), output/power/case	2500 Volts rms
Auxiliary Power	125V, DC \pm 20% < 3W With reverse surge protection

B. Isolation Amplifiers and Power Supply

1. For telemetering rectifier DC current, DC traction feeder currents and DC drainage currents via Authority's SCADA system, the millivolt signal, obtained from shunts at the circuit breakers, shall be insulated from the supervisory equipment at the substations by use of isolation amplifiers. An isolation amplifier, suitable for installation in the DC switchgear assembly, shall be furnished for each rectifier and traction feeder circuit.

2. Isolation Amplifier

- a. The isolation amplifiers shall be of high precision, low non-linearity, three-port insulation design, having an operating temperature range from minus 20 degrees C to plus 60 degree C, minimum. The device shall be designed to withstand for one minute a hi-pot test of 2,500 volts, rms, 60 Hz applied from input port to output port and from input port to power supply. The isolation amplifier shall be designed to operate on DC supply derived from an external power source.
- b. Isolation amplifiers shall have the electrical ratings and characteristics specified below:

Input differential

For rated linearity	1-10 Volts DC*
Continuous	120 Volts, rms
For 1 minute	240 Volts, rms
Gain, adjustable	1 Volt/1 Volt -to-1 Volt/100 Volts**

Output nonlinearity

Error at 10 volt P-P output	\pm 0.25 percent
Power supply range	15-25 Volts DC
	*With 1 Volt/1 Volt gain
	**Use external potentiometer, if required

3. Power Supply

- a. The DB Entity shall furnish a self-contained DC power supply for the isolation amplifiers. The power supply shall employ solid-state circuitry and shall have a regulated, filtered output.
- b. The power supply shall be rated to simultaneously power all isolation amplifiers. The output of the power supply shall be fully insulated from the input and be protected with suitable circuit breakers or fuses. All components shall be assembled in a metal enclosure, suitable for installation in the DC switchgear assembly.
- c. The power supply shall have the following ratings:
 - (1) Input: 120 Volts AC or 125 Volts DC
 - (2) Output
Voltage: 15-25 Volts DC, adjustable

Current: 3.0 Ampere, minimum

- d. The power supply shall include, but not be limited to, the following accessories:
 - (1) 1 - Red indicating LED for AC supply "on"
 - (2) 1 – Output voltmeter
 - (3) 1 - Voltage adjusting rheostat

1.12 ANNUNCIATORS

- A. Annunciator shall be integral to the Substation Automation System and viewable via the HMI. Refer to specification sections 16311 and 16311A.

1.13 KEY INTERLOCK SYSTEM

- A. Rectifier main DC circuit breaker, Device 72R, and rectifier negative lead disconnect switch, Device 89N, shall be provided with a key interlock system to prevent operation of the negative disconnect switch in either direction, unless the rectifier main circuit breaker is open and in fully disconnected position. To open the negative disconnect switch, the following operations shall be performed:
 - 1. Trip the rectifier main DC circuit breaker and rack it into fully disconnected position. The captive key at the rectifier main circuit breaker is now free to be turned and removed. Turning of the key will mechanically block the circuit breaker removable element from being placed into the test and connected position, but will allow the withdrawal of the circuit breaker removable element from its housing.
 - 2. Insert key in the lock at the negative disconnect switch and turn to unlock the operator of the switch. Key is now held captive.
 - 3. Open negative disconnect switch.
 - 4. Reverse sequence to restore service.
- B. The 15 kV feeder circuit breaker Devices 52-F (unit substations) shall be provided with a key interlock system to prevent the opening of the interrupter cubicle door in the unit substations (provided by others) unless the 15 kV feeder circuit breaker is open and in the fully disconnected position and the associated secondary main circuit breaker in the unit substation is open. The DB Entity shall coordinate the opening sequence of the interrupter cubicle door with the unit substation equipment. The following is a description of the required sequence of operations.
 - 1. Trip the 15 kV circuit breaker and rack it into the fully disconnected position. The captive key (A) at the circuit breaker is now free to be turned and removed. Turning of the key will mechanically block the circuit breaker removable element from being placed into the test or connected position.
 - 2. Trip the main secondary breaker. The captive key (B) at the circuit breaker is now free to be turned and removed. Turning of the key will lock the circuit breaker in the open position.
 - 3. Insert key (B) into the interlock housing of the interruption switch operating mechanism. Turn key (B) to open interrupter switch. Kirk Key (B) is held captive.
 - 4. Insert key (A) into the interlock housing of the interruption switch. Turning key (A) will allow the door to be opened. Once the door is opened both key (A) and key (B) will be held captive.
 - 5. Mechanical interlocks and/or additional key interlocks shall be provided to prevent the turning and removal of keys (A) and (B) unless both the doors and the interrupter switch are closed. Upon

manual closing of the interruption switch, keys (A) and (B) can be turned and removed, locking the manual operator. The keys can now be returned into their respective interlock housings, allowing the closure of the 15 kV and the secondary main circuit breakers for restoration of the service.

- C. Tumbler settings of locks shall be different for each interlock system. Information related to lock settings will be furnished to the DB Entity by the MBTA.
- D. The DB Entity shall prepare and forward to the MBTA for acceptance a detailed schematic diagram of each key interlock system supplied, showing the equipment involved and key travel, identifying each component and fully describing the operation. The accepted key interlock drawings and data shall be included in the instruction and maintenance manual for the substation equipment.
- E. A kirk key diagram shall be engraved on a nameplate and attached to all applicable equipment.

1.14 SURGE ARRESTERS

- A. 15 kV system surge arresters shall be of the intermediate class, suitable for installation in metal clad switchgear. Arresters shall be rated for application on the specific voltage system on which it is being used. The manufacturer shall be responsible to coordinate the size of the surge arresters for the system on which it is being used. DB Entity's proposed intermediate class, MOV type, polymer-housed surge arresters will be subject to the acceptance of the MBTA.
- B. Surge arresters associated with the 600-volt nominal DC power system shall be designed to protect DC traction power equipment and distribution circuits. DB Entity's proposed polymer-housed, MOV type DC surge arresters will be subject to the acceptance of the MBTA.
- C. DC feeder circuit surge arresters shall be mounted in an insulating, blast resistant protective enclosure external to the dc switchgear. Location and enclosure shall be as indicated on the Design Documents. The enclosure and any alternate mounting location shall be proposed by the DB Entity and subject to acceptance by the MBTA.
- D. Surge arrester for the negative equalizer bus and drainage board shall also be MOV type and rated for the intended service, subject to the acceptance of the MBTA. Surge arrester location shall be proposed by the DB Entity and subject to acceptance by the MBTA, but shall not be mounted inside the negative drainage board enclosure.

1.15 FINISH

- A. All metalwork shall be carefully finished to remove sharp edges and burrs.
- B. All surfaces shall be thoroughly cleaned and treated with a rust inhibiting phosphatized coating prior to painting, then finished with two coats of semi-gloss ANSI-61 light gray paint, unless otherwise specified. Electrostatically-applied polyester powder coat of semi-gloss ANSI-61 light gray paint with average final thickness after baking of 2-4 mils, minimum, will also be acceptable.
- C. Unfinished galvanized steel panels inside the enclosures will not be acceptable.

1.16 DELIVERY

- A. Equipment and materials shall be delivered to the site in original containers, suitably sheltered from the elements, but readily accessible for inspection by the MBTA until installed. All items prone to moisture

damage, such as control equipment and electrical apparatus, shall be stored in dry, heated spaces. Equipment and materials shall be tightly covered and protected against dirt, water, chemical and mechanical injury and theft. Damage or defects which occur before acceptance of the work shall be repaired or replaced as directed, without additional cost to the MBTA.

- B. All major electrical equipment shall be shipped with impact indicators attached for inspection by the MBTA. In particular, rectifier transformers, rectifiers, ac switchgear, dc switchgear, SAS and HMI panels to which damage could cause severe failures and delays should be fitted with analog accelerator impact recorders to verify no damage is sustained in transit. The recording shall be inspected upon delivery by suitably trained personnel.

1.17 INSTALLATION

- A. Equipment shall be installed level.
- B. The substation floor shall be surveyed and where the existing floor level under the equipment varies by more than 1/8", the floor shall be leveled by the application of concrete based self-leveling grout/underlayment (Sika Level 125, or equal).
- C. Shims used to level equipment shall be a maximum of 1/8". Use of shims over 1/8" is not acceptable, in such situations the floor shall be leveled by the application of self-leveling grout.
- D. Shim material shall be submitted and accepted by the MBTA.
- E. Self-leveling grout shall not be used in the areas of the epoxy insulated floor.

PART 2 – PRODUCTS

Not used

PART 3 – EXECUTION

Not used

END OF SECTION

SECTION 16300

DUCTBANKS AND DUCTBANK MANHOLES FOR THE TRACTION POWER SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Provide all labor, materials, construction equipment and services necessary for constructing the concrete encased reinforced duct banks, cast-in-place manholes and installing cable support hardware as shown on the Design Documents. DB Entity may propose precast manholes meeting all the requirements identified in the specifications.
- B. The size, configuration, construction features, and approximate locations of the duct banks and manholes required shall be developed and proposed by the DB Entity.
- C. Specification applies to MBTA's AC and DC ductbanks and manholes.
- D. For all ductbanks and manholes related to Eversource incoming line feeders refer to Eversource specifications in Appendix A of this specification provided for reference only. Where ductbanks containing Eversource cables are installed on MBTA's property the MBTA shall determine which specifications take precedence.

1.2 SUBMITTALS

- A. In accordance with Section 2.8, the DB Entity shall submit the following shop drawings and data for the MBTA's review and acceptance.
 - 1. Field data findings
 - 2. Fiberglass reinforced thermosetting conduit and fittings and spacers (DC Ductbanks)
 - 3. PVC conduit and fittings and spacers (AC ductbanks only)
 - 4. Rebar drawings for manhole and duct banks
 - 5. Cable support hardware and grounding provisions

1.3 PERMITS

- A. The DB Entity shall obtain all necessary permits for the work effort. Costs of permits are part of the lump sum cost.

1.4 UNDERGROUND UTILITIES

- A. All the known underground utilities adjacent to the proposed routing of the duct banks and manhole locations are shown on the drawings. The DB Entity shall inform all utilities and DIG SAFE of the proposed work area prior to the commencement of work so that the actual locations can be better identified and marked by the respective utility.
- B. If the performance of this work will cause interruption or discontinuance of service to the public utilities like gas, water, sewer, electrical, telephone and transit systems. The DB Entity shall be solely

responsible for making necessary arrangements for executing the work with the public utility involved at no additional cost to the contract.

- C. Any damage or settlement to existing conditions caused by the work under this contract shall be reconstructed, restored or reset by the DB Entity to the satisfaction of the MBTA at no additional cost to the contract. Pavement shall be in accordance with applicable Mass Highway Standards.

PART 2 - PRODUCTS

2.1 MATERIAL

A. ORDINARY BACKFILL

1. The material removed in excavation may be used for common backfill provided it is clean and free from refuse, debris, organic material, stumps, frozen material, large boulders or lumps of clay larger than 3 inches, or other undesirable material.
2. Backfill against concrete shall be clean fill (free of salt contamination) as accepted by the MBTA.
3. If fill of sufficient quantity and quality is not available at the site, the DB Entity shall furnish ordinary backfill conforming to applicable Mass Highway Standards at no additional cost to the contract.

B. CRUSHED STONE

1. Crushed stone shall be installed beneath the manholes a thickness of 8” to 6” beyond the face of the manhole, if possible, and under the duct banks for a thickness of 4” for the full width of the trench.

C. CONCRETE

1. Concrete mixes for manholes and duct banks shall consist of Portland cement mixes, Classification 4000 psi-3/4” aggregate for manholes and 4000 psi-3/8” aggregate for duct banks. Cement type shall be Type II Portland Cement conforming to ASTM C150.

D. DUCTBANK AND MANHOLE REINFORCEMENT

1. Ductbank reinforcing bars shall be as shown in the Design Documents.

E. WATER STOPS AND DEWATERING

1. The DB Entity shall develop and propose any necessary water-stops. They shall be submitted for review and approval. If dewatering is required during construction, then the DB Entity shall make the appropriate provisions.

F. BITUMINOUS DAMP-PROOFING

1. Damp-proofing shall be applied on the exterior surfaces of all manholes where feasible. Material shall be cold applied liquid asphalt emulsion. Damp-proofing and primer shall be all types specifically recommended for use on similar applications and shall be applied in accordance with the manufacturer’s recommendations.

G. CABLE SUPPORT HARDWARE

1. Cable support hardware such as cable racks, support brackets, porcelain insulators and all other hardware shall be as shown on the Design Documents.
2. In AC manholes, all steel hardware shall be grounded

H. MANHOLE FRAMES AND COVERS

1. Manhole frames and covers shall be of cast iron and shall be manufactured in accordance with MBTA Standards.

I. CONDUITS

1. Conduits (ducts) in the MBTA's DC duct banks shall be fiber reinforced thermosetting resin conduit. Minimum conduit size for DC positive feeder cables and negative return cable shall be 5" diameter.
2. Conduits in the MBTA's AC ductbanks shall be fiber reinforced thermosetting resin conduit or PVC conduit. PVC conduit may only be used if the conduit is fully encased in concrete.
3. Conduit shall be straight and true and shall be furnished in lengths of 20'. A cross section taken at any point perpendicular to the duct shall not vary more than 1/8" from a true circle. Conduits shall be complete with all couplings, adapters, expansion joints, bends and supports as required and/or shown on the Design Documents. All couplings and fittings shall be products of the conduit manufacturer.
4. Fiberglass conduits shall conform to MBTA's Standard Specification P-138 "Specification for Fiberglass Reinforced Thermosetting Resin Conduit".
5. PVC Conduit shall conform to Section 16201.
6. The ends of the conduits entering the manholes shall be provided with end bells. End bells shall be of the fiberglass reinforced compound manufactured using the same process for manufacturing the conduit and machined to the proper flare. End bells require smooth and round surfaces at the edge to prevent injury to the cables during normal movement. If end bells are not used, the DB Entity shall propose an alternative method of conduit termination that will prevent damage to the cables when installed.
7. Duct spacers or separators for the conduit bank shall be plastic suitable for the type of application and shall be of the size required for the size of the conduit, configuration and clearances shown on the Design Documents.

PART 3 - EXECUTION

3.1 CONSTRUCTION METHODS

A. GENERAL

1. Before commencing work, the DB Entity shall familiarize himself with the accepted drawings indicating the work to be done for this effort. The locations are not definitely fixed due to the nature of the work. The exact locations of equipment and materials shall be determined by the DB Entity.
2. If the field conditions warrant change in the routing or configuration of duct banks and/or location, shape and size, DB Entity shall obtain MBTA's acceptance for such changes. Such changes shall be done at no additional costs unless the changes are substantially different than those depicted.
3. Shoring and traffic decking system, if required, for all excavations including those which undermine the tracks shall be stamped by a professional engineer and submitted to the MBTA for review and acceptance.

B. CLEARING

1. Clearing and site preparation before commencing work shall conform to all applicable requirements as determined by the MBTA.

C. REMOVAL OF PAVEMENT

1. The paving on the streets or pathways shall be removed only to the extent necessary for the excavation. Bituminous pavement shall be removed either by breaking up or ripping up. The edges shall be even and neat, cut with a saw or other approved method so that a neat line separates the existing pavement and the pavement removed.

D. EXCAVATION AND BACKFILL

1. Excavation, including support of excavation, dewatering, traffic decking, and filling and backfilling, shall conform to the following requirements:
 - a. The DB Entity shall excavate test pits as may be necessary to locate various obstructions which may occur along the route of the underground duct bank installation. This will enable changes that need to be made in size or configuration of the duct bank to minimize changes in direction due to obstructions.
 - b. The DB Entity shall excavate the entire length of the duct bank, wherever possible, before any conduit is laid. Width and depth of duct bank shall be as shown on Design Documents. Unless otherwise approved, the minimum depth from top of duct bank to finished grade is 30".
 - c. Soft or unstable material encountered below the required sub grade of the duct bank or manhole shall be removed and replaced with compacted gravel borrow as directed by the MBTA. Rocks or boulders greater than 3" shall be removed below the sub grade to a minimum depth of 6" below the bottom of the trench and backfilled with compacted gravel borrow.
 - d. Backfill shall not be placed on surfaces that are muddy, frozen or contain frost, or that have not attained specified strength.

- e. Excavation shall be solidly sheathed with sheathing extending 3' above street level.
- f. All pipes, cables, conduits, sewers, connections, catch basins, edge stones or other structures uncovered by the excavation or adjacent thereto shall be protected from damages and shall be maintained in such a manner as to prevent displacement or damage. The DB Entity shall be solely responsible for and shall make good any damage to such structures.
- g. Steel plating over excavation, if used, shall be of sufficient strength to sustain traffic loads and shall be secured from movement.

E. CONCRETE

- 1. Concrete for duct banks shall be placed the entire length of the run between manholes stopping approximately 4' from the manholes. The remainder shall be placed as an integral part of the manhole.
- 2. Construction joints in duct banks shall be keyed or interlocked in order not to produce a vertical break and weakening of the structure. The concrete in duct banks and manholes shall be well vibrated to ensure complete fill without voids.

3.2 INSTALLATION

A. UNDERGROUND DUCT BANKS (STREET OR UNDER TRACK)

- 1. The conduits shall be installed with a minimum continuous slope of 6" x 100'. Unless otherwise shown or specified or impractical conduits shall slope downward from one manhole to the next in both directions from a high point between the manholes.
- 2. Changes in directions in duct runs exceeding a total of 10 degrees, either vertical or horizontal, shall be accomplished by long sweep bends having a minimum radius of curvature of 25', except when turning up to a switch along the right of way. The bends shall be made by installing five degree angle couplings between successive short lengths of conduit. At the end of the conduit run, manufactured elbows having a minimum radius of 36" may be used.
- 3. The conduit shall be laid in the trench in the designated formation using precast concrete block or plastic spacers for spacing conduit. Metallic spacers shall not be used. Joints in conduits shall be staggered at least 6" horizontally and vertically. Conduits between joints shall be supported by at least two separators. Reinforcing around the conduit envelope, spaced as specified, at the rim of the envelope and reinforcing along the ducts shall be provided as shown on the Design Documents. Reinforcing steel shall not be placed between the ducts. Cross tie members of reinforcing shall be installed so that they will not form loops around any duct or group of ducts.
- 4. Conduit shall be installed in not less than 20' lengths, except at the end runs or at bends. Conduit shall be free of chips and cracks. The DB Entity shall furnish and have available at the job sufficient quantity of conduit so that the cracked or chipped conduits can be discarded.
- 5. Couplings and fittings shall be of the slip on, friction type, assembled without adhesives, except the end bells in manholes. The end bells shall be secured to the conduit with an epoxy adhesive in strict accordance with the manufacturer's recommendations.

6. All field cuts of the fiberglass conduit shall be made with a hacksaw. Cuts shall be smooth and square to conduit axis. The cut end of the conduit shall be reamed smooth. Field cut conduits shall be joined with double ended couplings designed for the purpose.
7. Repairs to new conduits will not be permitted. All individual lengths of broken, cracked, chipped or impaired conduit shall be removed and replaced with new conduits.
8. When changes in the formation of a bank of conduits within a duct run are necessary, the transition shall be accomplished in as straight an alignment as possible, maintaining continuous earth support under the conduits.
9. The entire conduit envelope assembly shall be firmly anchored in position to prevent “floating” when concrete is placed.
10. Following the duct rodding device, a mandrel not less than ¼” smaller than the inside diameter of the conduit preceded by a wire brush tied to the same string shall be pulled through the conduit once in each direction. If difficulty is encountered in passage of the duct rodding device or mandrel, a series of wire brushes shall be drawn through the conduit, once in each direction, using a trailing line. The wire brushes shall be 1/8” less in diameter than the diameter of the conduit, and if the correct size cannot be passed through on the initial attempt, the operation must be repeated until accomplished as specified. When the conduit is partially or fully obstructed with mud, dirt, or gravel, the duct shall be flushed clean by use of water from a long flushing nozzle attached to a water hose which shall be pushed into the conduit and applied until the conduit is clean. After cleaning, the procedure outlined above for rodding and wire brushing shall be followed. Any damaged conduit shall be replaced with a new conduit.
11. After all obstructions have been removed and the conduits wire brushed clean, a nylon cord of suitable strength shall be threaded in each conduit of duct bank and tried to the nearest pulling eye with a 6’ length left at each end. Immediately upon completion of threading the conduit with a nylon cord, both ends of the conduit shall be plugged to prevent entry of foreign matter before the cables are pulled.

B. NEW MANHOLES

1. Manholes shall be of the reinforced concrete, field constructed type or precast manholes.
2. Design and construction of new manholes shall be in accordance with details on Design Documents. Manhole frame and cover shall be per MBTA Standard design and construction.
3. Manholes constructed under this contract shall be complete with the following features, as shown on the Design Documents.
 - a. Manhole frame and cover, supported on brick collar with cement mortar joints.
 - b. Cable racks, brackets, porcelain insulators and other cable racking hardware.
 - c. Pulling in irons.
 - d. Water stop placed around all duct openings and around at bottom of manhole.
 - e. Twelve-inch square sump pit at the bottom of the manhole. Sump pit shall be located directly under the manhole cover casting, unless directed otherwise by the MBTA.

- f. Reinforcement.
 - g. Grounding of frame, cover and support channels as shown on Design Documents, including installation of ground rods, ground cable and ground lugs.
4. Manholes shall be constructed in approximately the locations required by the design. The exact elevations and window locations shall be determined after careful consideration has been given to the location of existing and proposed utilities, drainage systems and grades. Manholes in roadways shall have covers set to finish paving grades.
 5. Manhole floors shall be put in place before the walls are started and the cement finish put on before the concrete has attained a final set. All steel for manhole roofs, and cast iron manhole frames and covers shall be set by the DB Entity.
 6. Pulling irons shall be installed in each manhole in locations determined by the MBTA.
 7. Bituminous damp-proofing shall be applied to the outside of the walls and top of roof.
 8. The DB Entity may propose the use pre-cast manholes subject to acceptance by the MBTA.

C. CABLE SUPPORT SYSTEM

1. In manholes or other location where walls are available to support the cable system for racking and splicing the system shall consist of a channel support system, or equal bolted to the wall structure.
2. Sufficient quantities of channels and channel saddles shall be installed to accommodate the maximum number of cables that could occupy the manhole based on the number of ducts into and out of the manhole.
3. Racks and associated equipment shall be installed on all four walls of a manhole unless otherwise directed.

**MBTA MANHOLES AND DUCTBANKS
SPECIFICATION 16300**

APPENDIX A

EVERSOURCE DUCTBANK AND MANHOLE SPECIFICATIONS

Contents

C1100	Distribution Ductbank Construction and Materials
C3813	Installation of Precast Concrete Manholes
M1204	Precast Concrete Manhole 6 -0 W X 10 -0 L X 8 -0 H Inside Dimensions

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C3813

INSTALLATION OF PRECAST CONCRETE MANHOLES

1.0 Purpose

This purpose of this standard is to detail construction and materials required for the installation of precast concrete manholes, including frames and covers.

2.0 Bill Of Materials

Note: Table lists common standard sizes, covers and frames. Refer to EVERSOURCE Material Standard Index for less commonly needed manholes.

Item	Description	Catalog ID	Compatible Unit
1	<p>Common Manholes (Inside Dim. W x L x Ht), Material Standard Numbers Listed: M1201 - 4'x4'x4'ht -secondary, split fiber w/bottom M1202 - 4'x6'x6'ht - primary splicing (URD) M1203 - 6'x10'x6'ht - primary splicing M1204 - 6'x10'x8'ht - primary splicing M1205 - 6'-6"x12'- 6"x7'-10" ht - HA-300 M1208 - 4'x4'x4'ht -secondary (URD, open bottom) M1212 - 10'x13'x8'ht - 3-way station get-a-way M1214 - 8'x14'x8'ht - station get-a-way M1216 - 5'x5'x5'ht - primary splicing (URD) M1217 - 13'x13'x8' ht - 4-way station get-a-way</p>	16246 16238 16239 16240 16241 9435 16243 16245 9437 18090	NMH-4x4x4 NMH-4x6x6 NMH-6x10x6 NMH-6x10x8 NMH-6x13x8 NMH-4x4x4NB NMH-10x13x8 NMH-8x14x8 NMH-5x5x5 NMH-13x13x8
2	<p>Manhole (MH) Frames and Adapters: Standard Cover and Frame Assembly: No. 1 MH Frame & Solid Cover (2 catalog ID items) M1303 – No. 1 MH Frame only (standard size) M1304 – No. 1-L MH Frame only (low profile) M1305 – No. 0 MH Frame (large round opening) M1306 – Reducing Adapter for No. 0 MH Frame M1307 – No. 00 MH Frame (square opening) M1308 – Square to Round Adapter for No. 00 Manhole Frame</p>	1384 & 1347 1384 1385 1382 & 1097 1383 & 1098	NMCF-1C NMCF-1 NMCF-1L NMCF-LR MCF-SQ

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Item	Description	Catalog ID	Compatible Unit
3	<p>Manhole Covers, Material Standards:</p> <p>M1300 – Solid Cover – line, switch MHs M1301 – Slotted Cover – hot MHs, not in sidewalk M1302 – Venting Hole Cover – Xfmr & sidewalk</p>	<p>1347 1348 16296</p>	<p>NMCC-S NMCC-V NMCC-H</p>
4	5/8 " X 8'L Copperweld Ground Rod	9229	See Page 4
5	Mechanical Connector, 4/0 Cu – Ground Rod	597	See Page 4
6	Mechanical Connector, 1/0 Cu – Ground Rod	9009	See Page 4
7	4/0 Mechanical Connector, 4/0 – 4/0 Cu wire	608	See Page 4
8	Manhole ID Tag Holder	366	See Page 6

3.0 General

- 3.1 The precast manhole(s) to be installed shall be EVERSOURCE approved precast manhole(s). Refer to the Bill of Materials list of commonly used approved EVERSOURCE precast manholes.
- 3.2 The manhole frame and cover shall also be approved EVERSOURCE items, refer to Bill of Materials.
- 3.3 The location of proposed precast manholes shall be approved and located per EVERSOURCE local engineering dept. before installation begins.
- 3.4 All excavation, backfill and paving shall be done in accordance with this standard and all applicable local and state regulations. When conflicts exist between local/state regulations and this standard the more stringent requirement shall be adhered to unless otherwise directed by EVERSOURCE.
- 3.5 DIG Safe marking and notification regulations are to be understood and adhered to prior and during all construction.

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- 3.6 All EVERSOURCE safety standards as well as all applicable OSHA and DOT worker safety requirements shall be adhered to at all in times.
- 3.7 Test pits shall be dug at proposed location of precast manhole before installation is confirmed. Test pits shall extend 12 inches beyond the extreme length and width and depth of the proposed manhole.

4.0 Excavation and Installation

- 4.1 The excavation shall be made to fully accommodate the proposed precast manhole, allowing for a minimum of 12 inches clear all around the outside length and width dimensions (of the manhole) and of sufficient size to safely and properly install all required shoring and bracing.
The depth of the excavation shall be a minimum of 6 inches deeper than the installed underside of the manhole to allow for a minimum of 6 inches of bedding.
- 4.2 Manhole shall be installed using properly rated rigging equipment, adhering to OSHA work methods. The manhole shall be set level on firm well compacted bedding.
- 4.3 Install, operate and maintain pump or dewatering equipment as necessary to prevent water from accumulating in excavation during excavation and installation of manhole.

5.0 Backfill Material

- 5.1 Backfill material to be used for bedding shall be 6 inches (minimum) of ¾” diameter crushed stone per Figure 1, page 7.
- 5.2 Backfill material to be used between the surrounding earth and the exterior sidewalls of the manhole and shall be “Type IE”, (Controlled Density Fill, “CDF”, or excavatable flowable fill).
- 5.3 Backfill material above the top of the manhole to final grade or paving if required shall conform to Massachusetts Highway Department Specification, “MHD M1 M1.03.1 Process Gravel for Subbase”. Backfill shall be compacted mechanically in eight inch (8”) loose layers to 95% of the maximum density per ASTM D1557 unless otherwise approved by EVERSOURCE.

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6.0 Pavement Cuts

- 6.1 All cuts in bituminous or concrete pavement shall be vertical and made with the proper tools to ensure minimum repaving. The pavement cut shall be straight and uniform.
- 6.2 Excavated pavement and street base, if any, shall be kept at least two (2) feet back from the edge of the excavation cut and shall be piled so as not to endanger the work or restrict, hamper or inconvenience Owners or tenants of property or interfere with the normal flow of traffic. All excess materials not suitable for backfill shall be removed from the job site and disposed of as directed by EVERSOURCE.

7.0 Sod Removal

Sod shall be removed carefully, when possible, in regular and uniform blocks with sharp edged tools. It shall be placed in uniform piles along the excavation and kept moist until time for relaying. The DB Entity shall be responsible for suitable reseeding, if necessary and shall maintain until grass has grown.

8.0 Street Restoration

All street paving of open excavations shall be restored using temporary or Interim pavement with two – 1-1/2 inch lifts of compacted hot mix asphalt binder (unless otherwise noted by EVERSOURCE). Cold patch repairs when approved by EVERSOURCE shall be cold patch EVERSOURCE Cat ID 1628. Permanent street paving shall be by the governing municipality.

9.0 Grounding of Manhole

- 9.1 Manhole grounding shall be as detailed on Figure 2, page 8. Refer to table below for typical manhole grounding accessories and compatible unit assemblies.
- 9.2 Install two copperweld ground rods, one outside each corner of manhole. Connect 4/0 bare copper wire to ground rods using grounding mechanical or exothermic connector in two places. Connect 4/0 bare copper wire to 4/0 copper ground wire tails projecting from manhole with two mechanical connectors.

Table of Precast Manhole Ground Ring Accessories

Description	Quantity	Catalog ID	Compatible Unit
4'x4' or 5'x5' – small manhole ground ring includes: -5/8" x 8' Ground rod -1/0 Cu Ground wire -Ground Rod Connector to 1/0 Cu wire -Ground Wire connector 1/0-1/0 Cu wire	 2 40 2 4	 9229 100 9009 608	 UGN4x4

Description	Quantity	Catalog ID	Compatible Unit
10'x6' – standard manhole ground ring includes: -5/8" x 8' Ground rod -4/0 Cu Ground wire -Ground Rod Connector to 4/0 Cu wire -Ground Wire connector, bronze , 4/0-4/0 Cu wire	 2 55 2 4	 9229 116 597 608	 UGN10x6
14'x8' – large manhole ground ring includes: -5/8" x 8' Ground rod -4/0 Cu Ground wire -Ground Rod Connector to 4/0 Cu wire -Ground Wire connector 4/0-4/0 Cu wire	 2 65 2 4	 9229 116 597 608	 UGN14x8

10.0 Manhole Frame & Cover

10.1 EVERSOURCE approved manhole frame(s) shall be installed on a two brick collar course (unless required otherwise by EVERSOURCE) over the opening(s) on the roof of the manhole as shown in Figure 1, page 7. Refer to EVERSOURCE Standards in the Bill of Materials for approved frames and covers.

10.2 The brick collar course shall be installed directly around the manhole roof opening as shown on Fig. 1, page 7. The bricks shall consist of the best

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quality steam cured brick manufactured per the latest revision of ASTM Standard C55 or the latest revision of ASTM Standard C32 (if red brick is specified). The brick collar and flange of the manhole frame shall be completely covered with a concrete seal. The concrete (approved 2500 psi pea stone mix using Type 2 Portland Cement) seal shall completely encase the lower 3 inches of the frame and the brick course layers.

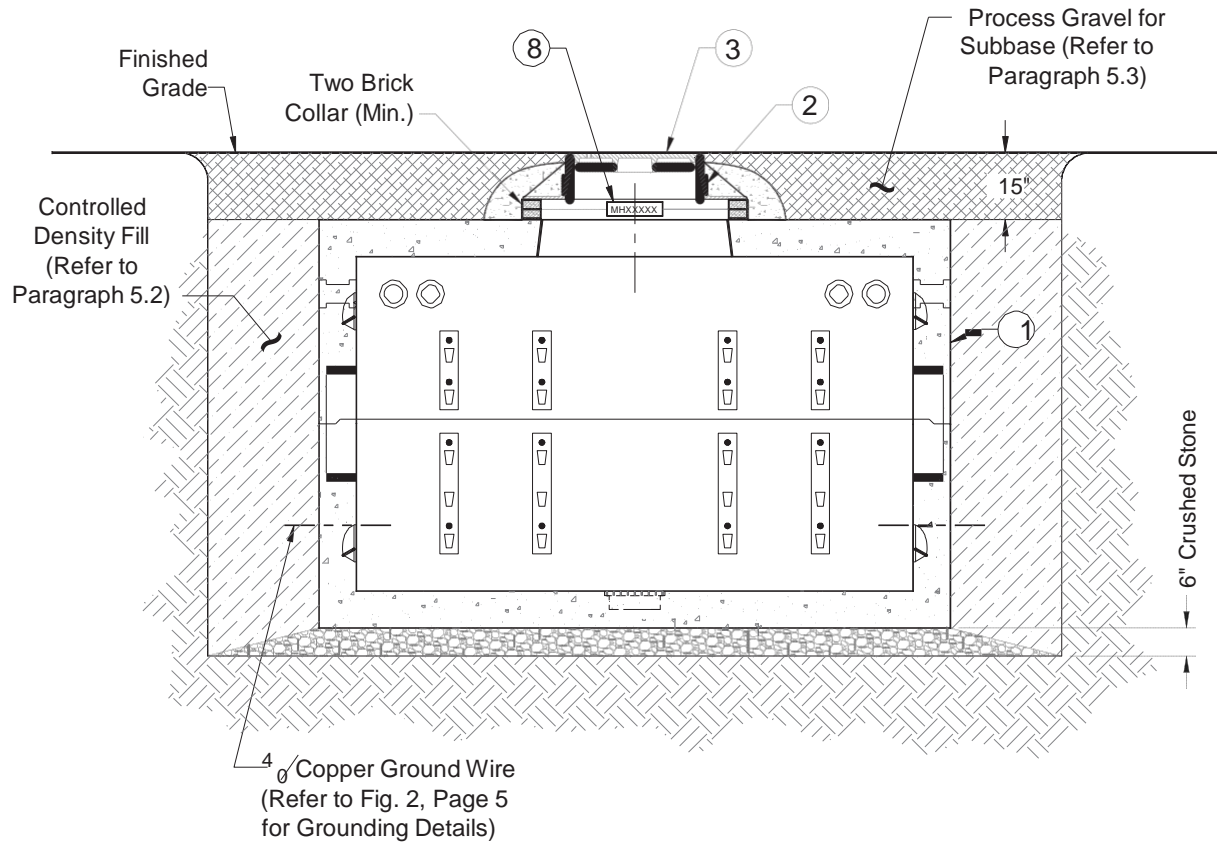
11.0 Miscellaneous Manhole Accessories

- 11.1 The items in the table, on page 6 (not shown on figures in this standard) are either pre-installed by precast manhole vendor or installed as required after installation.
- 11.2 All manholes shall have Manhole ID Tag fastened to the chimney. Refer to Figure 1, page 7.

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Table of Miscellaneous Manhole Accessories

Description	Catalog ID	Compatible Unit
Cable Arm Stanchions: Single Position Two Position Three Position Four Position Five Position Six Position	1750 1751 1752 17534 1754 1755	USTN1 USTN2 USTN3 USTN4 USTN5 USTN6
Cable Support Arms: One Position Two Position Three Position	1140 1141 1146	USTC1 USTC2 USTC3
Duct Plugs: 4 inch diameter 5 inch diameter 6 inch diameter	1636 1637 16896	NFP4-PLUG NFP5-PLUG NFP6-PLUG
Fairleader:	1371	NA-FA
Duct Seal: Small Package Large Package	9469 1239	NAS-DX NAL-DX
Manhole ID Holder	366	N/A



TYPICAL SECTION
Showing Manhole Frame Installation

FIGURE 1

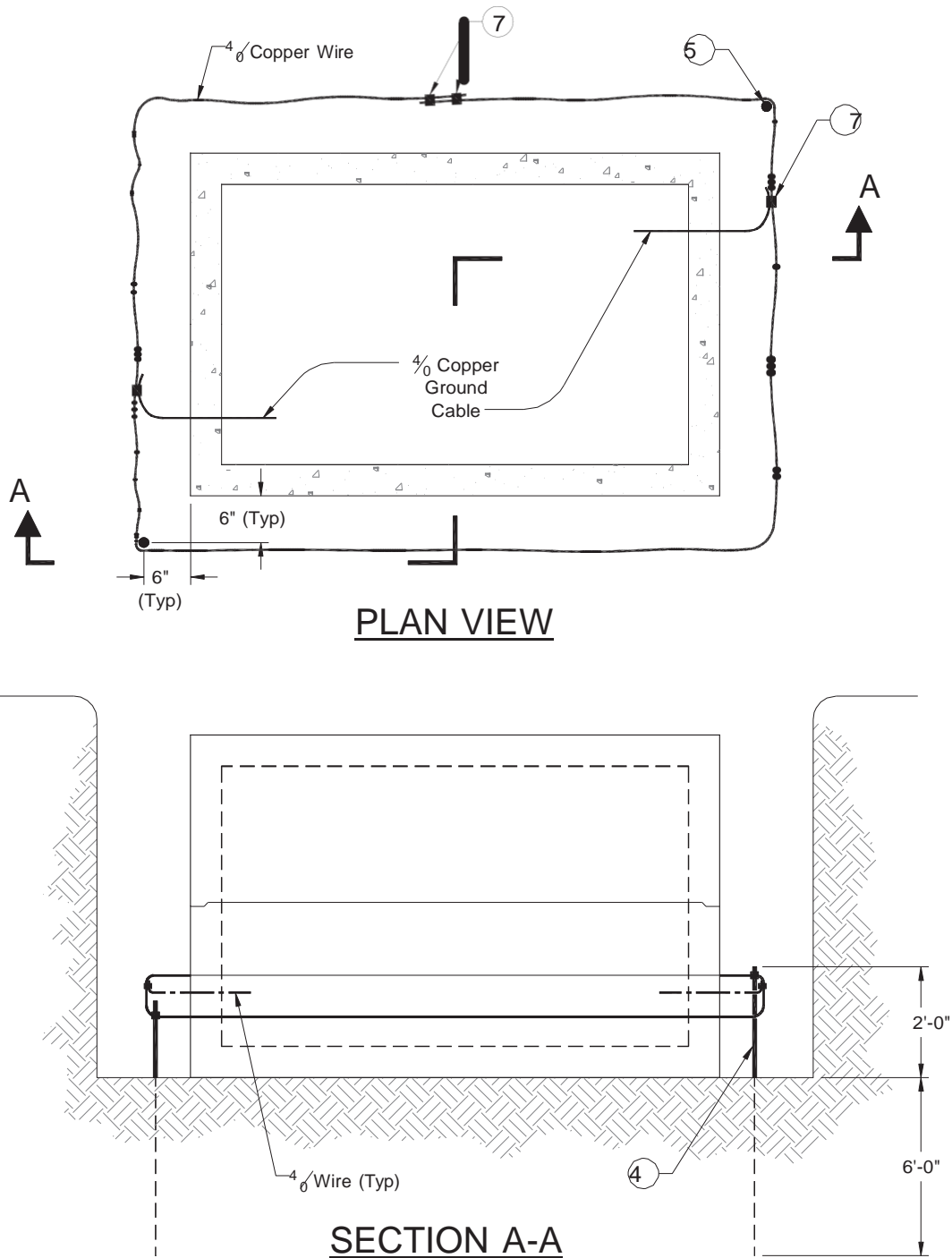


FIGURE 2

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MANHOLE GROUNDING DETAILS

Note: 5'x5' and Smaller Manholes Require 1_0 Ground Wire instead of 4_0 .

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12.0 References

Refer to EVERSOURCE Material Standard Index for complete list of all EVERSOURCE approved precast manholes, frames and covers.

Approved by: _____

Amin Jessa

Director, Distribution Engineering

<p>Issued 16-Aug-07</p>	<p>MATERIAL STANDARD ELECTRIC OPERATIONS ORGANIZATION</p> 	<p>M1204 Revision #0 Page 1 of 5</p>
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M1204

****This standard supersedes BECo U/G Std. 2.10-6.25****

PRECAST CONCRETE MANHOLE
6'- 0"W x 10'- 0"L x 8'- 0"H INSIDE DIMENSIONS

1.0 Scope – This specification details the dimensions, strength, reinforcement, and appurtenances required for fabrication of precast, concrete manholes.

2.0 General – Vendor design and fabrication drawing shall conform to the minimum requirements of this specification and shall be signed and stamped by a Massachusetts registered professional engineer.

3.0 Design Notes

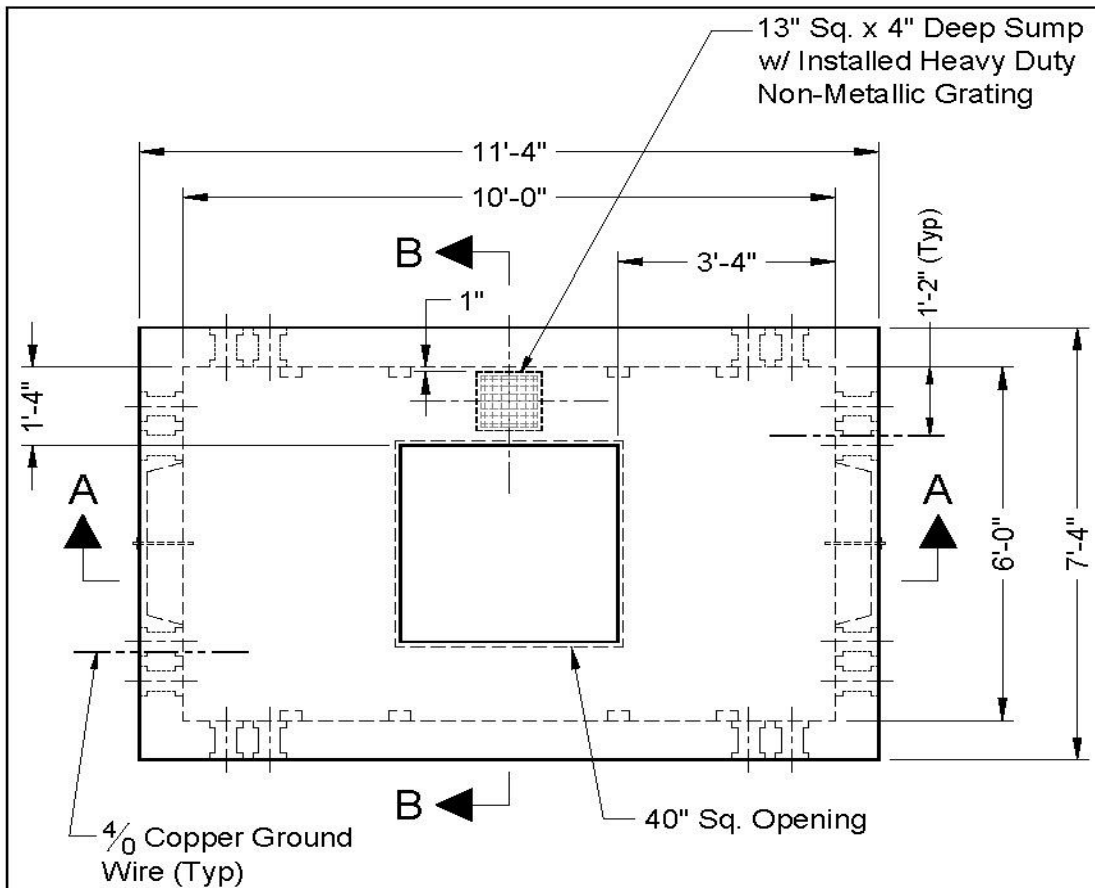
- 3.1 Concrete minimum strength - 5000 psi @ 28 days.
- 3.2 Steel reinforcement - ASTM A615, Grade 60.
- 3.3 Minimum Steel Cover – 1inch.
- 3.4 Design Loading - AASHTO HS20-44.
- 3.5 Design Specifications – ACI 318 & AASHTO Load Factor Design Method.
- 3.6 Manufacturer's name and year of fabrication shall be stenciled on vertical wall of access chimney.
- 3.7 All Termaducts to have bell ends flush with the inside wall.
- 3.8 Termaducts may be specified in lieu of knockouts at the direction of NSTAR.
- 3.9 Construction Joint – Sealed with 1" diameter Butyl Rubber or approved equal.

4.0 Bill of Materials

- 4.1 The catalog ID for the precast manhole is "16240".
- 4.2 The catalog ID's for the "3" & "4" position stanchions are "1752" & "1753". Stanchions shall be manufactured by J. S. Products, Whitman, MA (or approved equal).
- 4.3 The catalog ID for the bonding frame is "1229". Bonding frame consist of 1 - #4/0 stainless steel ground clamp, 1 - #10 x 1-1/2" lg x 5/16" dia SS screw and 1- lead plug as supplied by Tools Unlimited Inc, Stoughton, MA (or approved equal).

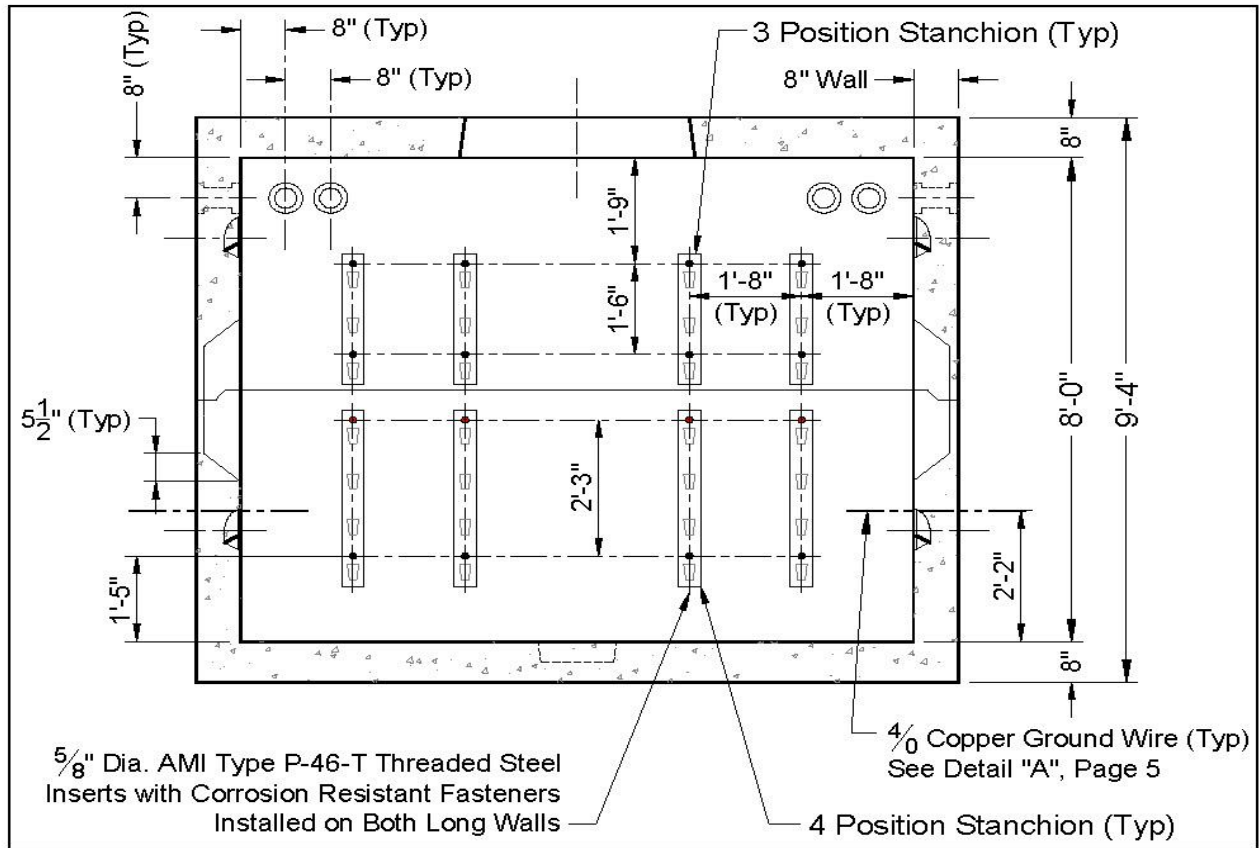


- 4.4 The recessed pulling eye, "New PI-2", shall be manufactured by Pennsylvania Insert Corp., Spring City, PA (or approved equal).
- 4.5 The sump grate shall be "Polylock Part No. 3037" as manufactured by Polylock Corp., Wallingford, CT (or approved equal).



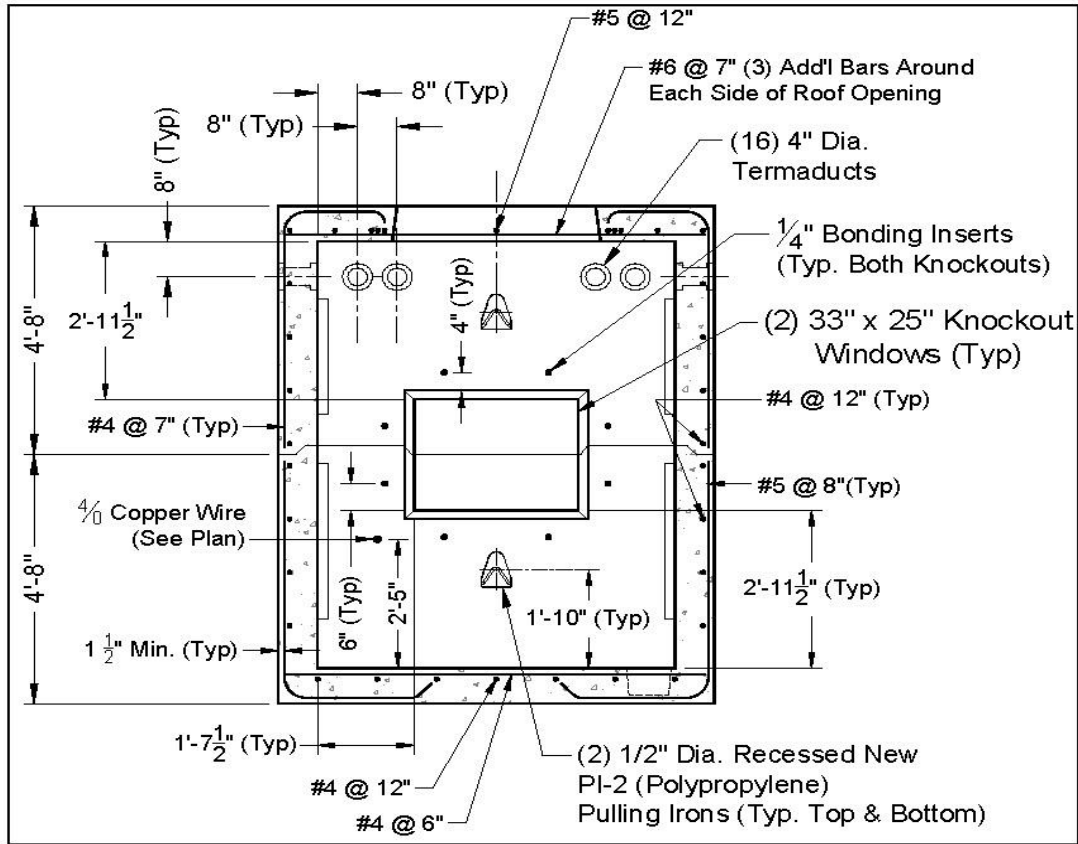
PLAN

NOTE: DRAWING IS NOT TO SCALE



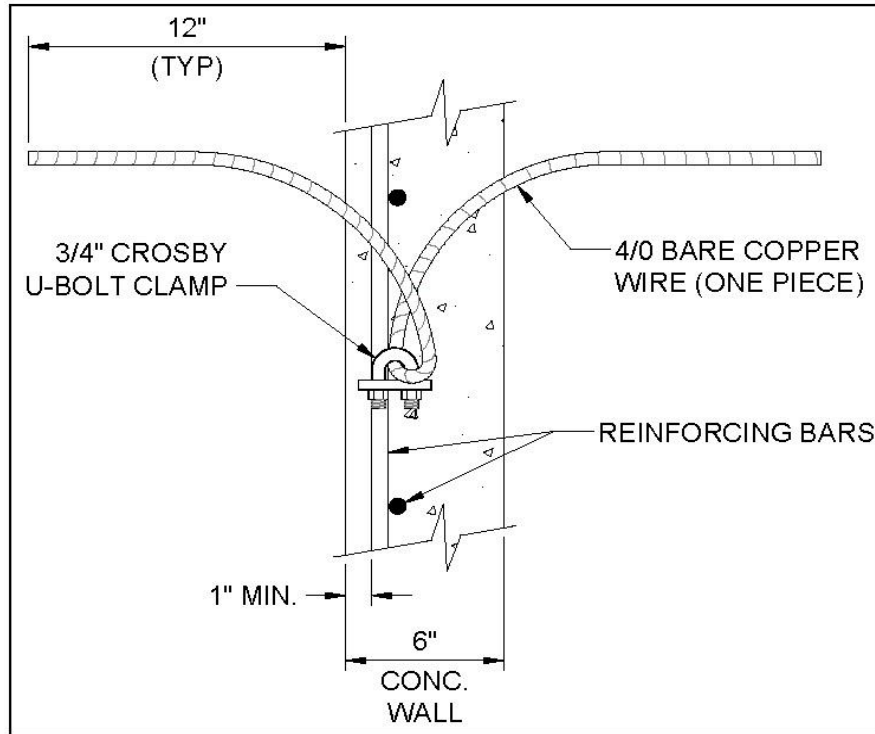
SECTION A-A

NOTE: LONG WALLS ARE MIRROR IMAGES.
DRAWING IS NOT TO SCALE.



SECTION B-B

NOTE: SHORT WALLS ARE MIRROR IMAGES.
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DETAIL "A"

NOTE: DRAWING IS NOT TO SCALE.

Approved by: Elizabeth J. Leonard
 Manager, Distribution
 Technical Engineering

****This Standard Supersedes BECo 2.10-2.1, COM/Elec NEFA****

DISTRIBUTION DUCTBANK CONSTRUCTION AND MATERIALS

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1.0 Scope

The purpose of this standard is to provide ductbank construction details, installation requirements and material lists for concrete-encased and direct buried conduit systems.

2.0 General

- 2.1 All excavation, backfill and paving shall be done In accordance with this standard and all applicable local and state regulations. When conflicts exist between local/state regulations and this standard the more stringent requirement shall be adhered to unless otherwise directed by EVERSOURCE.
- 2.2 Before placing concrete within ductbank forms and backfilling an EVERSOURCE inspection is required to ensure compliance with all referenced specifications.
- 2.3 DIG Safe marking and notification regulations are to be understood and adhered to during all construction.
- 2.4 All EVERSOURCE safety standards as well as all applicable OSHA and DOT worker safety requirements shall be adhered to at all in times. Refer to EVERSOURCE Work Method Standard, "W1000, Entering and Working in Underground Locations including Subsurface Vaults" specific requirements.

3.0 Conduit & Fittings Specifications

All encased conduit shall be PVC conduit (Type EB) and fittings shall be schedule 40 unless otherwise specified by EVERSOURCE. Direct buried conduit and fittings shall be schedule 40 minimum. Refer to EVERSOURCE Material Standard "M1000, PVC Conduit & Fittings" for details.

4.0 Conduit Plan and Records/Data Requirements

- 4.1 All proposed electric utility plans shall be approved by EVERSOURCE local engineering dept. before construction begins. New subdivision or commercial development plans to be submitted for local authority petitions (town approval) shall also be provided to EVERSOURCE as AutoCAD data files. These shall show all proposed and existing utility plan view layers including electric, gas, water, sewer, drain, cable/data, telephone, and fire alarm.

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- 4.2 The proposed electric utility plans shall include profile views that show relative elevation and clearances where proposed electric duct banks or lines intersect with non-electric utilities. Separation in any direction from electric to other utilities of 12" or less shall be detailed on the drawings.
- 4.3 GPS land based x-y-z coordinates shall be in NAD83 state plane feet format, with a minimum one foot accuracy. These plans shall show the road layout, curb lines, property lines (parcel boundaries), utility easements and utilities. Center coordinate positions shall be provided for all new manholes/pull boxes, equipment pads, and riser poles. Conduit location coordinates shall be provided at every 50 ft on straight sections or curves with less than 5 degree radii, and at every 20 ft for curves/sweeps over 5 degrees. GPS data for new conduit and infrastructure shall have accuracy of 6 inches or better.
- 4.4 The DB Entity shall provide EVERSOURCE Survey and Records department (or local engineering) with as-built new facility location data in electronic file format within 20 business days of completing the project (CD or EFT). All files shall be labeled with the project title, town, EVERSOURCE work order number and date of completion.

5.0 Application

- 5.1 Typically all primary and secondary distribution duct banks shall be unreinforced concrete encased using Type EB conduit. Stocked fittings are generally Schedule 40 unless otherwise specified.
- 5.2 If the interval between concrete pours for a continuous duct bank is expected to be more than 4 hours apart, industry standard construction joints shall be formed to ensure that the continuation of the ductbank pour shall create an interlocking joint between different pours. Refer to Figure "E" for detail.
- 5.3 The concrete specified for ductbanks shall be an approved 2500 psi pea stone mix using Type 2 Portland cement.
- 5.4 Reinforced distribution ductbanks maybe required per EVERSOURCE for locations where ductbanks cross over other utilities and/or a future excavation could expose EVERSOURCE ductbank without support. Reinforced ductbanks may also be required when installation is in soils that do not meet EVERSOURCE specified backfill.
For reinforced concrete ductbank standards refer to EVERSOURCE Construction Standard, "C1101, Distribution Duct bank Construction, and (Steel Reinforced Concrete)".
- 5.5 Exceptions to concrete encased ductbanks, i.e. direct buried conduit, may be allowed by EVERSOURCE for secondary conduits installed off roadways and areas not subject to vehicle loads such as greenbelts and yards. Also when approved by EVERSOURCE, single or double primary conduit runs in URD

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residential subdivisions may be direct buried as long as minimum schedule 40 conduit is used and local regulations allow it.

6.0 Excavation, Backfill and Street Restoration

6.1 Excavation

The roadway surface shall be cut in reasonably straight and parallel lines using a jackhammer, saw or other accepted method to insure the least amount of damage to the roadway surface.

Sheeting and bracing shall be required for excavations in excess of 5 feet deep in accordance with the latest OSHA Standards.

6.2 Backfill Material

- A. Backfill material shall conform to "MHD M1.03.1 Process Gravel for Subbase". Backfill shall be mechanically compacted in eight inch (8") loose layers to 95% of the maximum density per ASTM D1557 unless otherwise approved by EVERSOURCE.
- B. Excavated material that has been evaluated as unsuitable for backfill shall be removed from the site and disposed of properly.
- C. If directed by EVERSOURCE only "Type IE", (Controlled Density Fill , "CDF", or excavatable flowable fill), shall be used as backfill in certain instances, such as filling hard to reach areas where maneuvering compaction equipment would be difficult or when directed by the governing municipality.
- D. Note, EVERSOURCE approved red caution tape, marked "CAUTION ELECTRIC LINES BURIED BELOW", shall be installed 6-9 inches below surface grade, centered above the buried line or ductbank.
- E. Backfilling shall not commence less than two hours after the duct bank concrete has been placed.

6.3 Street Restoration

All street paving of open excavations shall be restored using temporary or Interim pavement with two – 1-1/2 inch lifts of compacted hot mix asphalt binder (unless otherwise noted by EVERSOURCE). Cold patch repairs when approved by EVERSOURCE shall be cold patch EVERSOURCE Cat ID 1628. Permanent street paving shall be by the governing municipality.

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7.0 Installation

- 7.1 Duct Bank Forms – In general duct banks shall be constructed using forms for the sidewalls. Where suitable stable soil conditions exist the trench walls may be used to form the sidewalls. Duct bank standards shall be maintained.
- 7.2 Common Trench – Other utilities sharing a common trench with EVERSOURCE ductbank shall not be enveloped within the same concrete formed encasement, but shall be separate from our encasement and a minimum clearance of 12 inches away.
- 7.3 Cutting Duct – Use a fine tooth wood saw to cut conduit. All ruff or abrasive edges shall be sanded smooth.
- 7.4 Duct Plugs – EVERSOURCE approved duct plugs shall be installed in all open conduit. The plugs shall be installed during construction when a conduit installation is partially complete to manhole or equipment as well as at all terminations in manholes.
- 7.5 Joining Duct – All conduit ends shall be cleaned by wiping off all dust, dirt and moisture from the surfaces to be cemented and brushed gently with a fine abrasive paper or cloth. Apply the approved PVC solvent cement with a non-synthetic bristle brush evenly coating the full length PVC socket of the fitting. Refer to manufacturers’ instructions for additional detail.
- 7.6 Depth of Cover – The minimum depth of cover over a single conduit or multiple duct bank shall be 36 inches unless otherwise directed by EVERSOURCE. In limited situations EVERSOURCE may allow shallow depth ductbank installations less than 36 inches. Prior approval from EVERSOURCE is required for shallow depth construction as well as the requirement to use ¼ inch thick steel plates above and adjacent to the side wall of the ductbank.
- 7.7 Clearance– The minimum clearance between an EVERSOURCE conduit or ductbank and any other subsurface structure or utility (EXCEPT Steam Lines) shall be 12 inches unless otherwise approved by EVERSOURCE. Steam lines shall maintain a 10 ft. minimum from EVERSOURCE ductbank or lines.
- 7.8 Conduit Spacers – Conduit Spacers shall be of the approved type per EVERSOURCE Material Standard, “M1000, PVC Conduit and Fittings”. Spacers shall be installed at typically 5 ft. spacing (7 ft. maximum) along the ductbank. Refer to Figure “B” for conduit construction plastic spacers details.
- 7.9 Conduit Sweeps and Bends – Conduit heat bending is not allowed. All sweeps and bends shall be constructed using pre-fabricated approved fittings. Refer to “Table 3 – Conduit Sweeps and Angle Fittings”.
- 7.10 Mandrel – Upon completion of the duct bank installation or direct buried ducts, a standard flexible mandrel, (not less than 12 inches long with a diameter not less than ½ inch less than the inside diameter of the duct) shall be pulled through each duct to loosen particles of earth, sand and other foreign material left in the

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line. A brush with stiff bristles shall then be pulled through each duct to remove the loosened particles. The diameter of the brush shall be the same as, or slightly larger than the diameter of the duct.

- 7.11 Building Wall Construction – When conduit or ductbank enters a structure and differential settlement is expected, construction details shall be per Figure “C”.
- 7.12 Riser Construction – When conduit transitions from underground to above ground a galvanized steel conduit with a 36 inch radius sweep shall be used. For typical riser construction details refer to Figure “D”.
- 7.13 All conduit shall have “mule tape” or equal, i.e. pulling tape made of woven polyester with a strength of 2500 lbs. installed within.
- 7.14 Transposition of Ducts – When ducts leaving one manhole/pad/equipment foundation require altering the duct bank cross section along the run, the revised configuration (and corresponding duct numbering) shall be as shown on Figure “G” unless otherwise approved by EVERSOURCE.

8.0 Breaking into existing Manholes

- 8.1 Manhole breaks for new ductbank penetrations shall receive prior approval from EVERSOURCE inspector. The DB Entity must be pre-qualified by EVERSOURCE to work in or break into live manholes. Sidewall breaks are generally not allowed unless prior approval from EVERSOURCE inspector.
- 8.2 All newly formed bell mouths shall be installed per Figure “F”.

9.0 Compatible Unit Format for Conduit & Fittings

The Compatible Unit format for Conduit & Fittings, which are considered Non-electric Facilities, is described below:

- 9.1 Conduit, Banks and Riser CU Formats -unit lengths are noted in CU title:

NC (Application/Material) (Size) - (Quantity {row x height})

(Application/Material) -

- D** – Direct Buried (schedule 40 PVC)
- E** – Concrete Encased PVC (Type EB with spacers needed)
- RP** – Riser PVC (pipe and sweep- schedule. 40)
- RS** – Riser steel (pipe and sweep – galv. steel)
- S** – Steel Conduit
- FLEX** – flexible PVC, schedule 40
- (Size)** – Conduit inside diameter (inches)

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(Quantity) – Cross section, rows x height (greater than one only, if one leave blank)
Examples: NCE4-3x3: 3x3 duct bank, 4”, PVC type EB
NCRS4: 4”, galvanized steel, riser pipe and sweep
NCD2: single 2” schedule 40 PVC duct, direct buried

9.2 Conduit Fitting CU Formats:

NF (Material) (Size) - (Type) – {detail below}

(Material) – **P** – PVC schedule 40 or DB/EB, **S** – Steel, **I** - Iron
(Size) – Conduit inside diameter in inches
(Type) - **SW** – Sweeps & angle fittings in degrees
(Angle)-(Radius) - For 36 in. radius bends leave blank, show all others.
R - Reducers (**A side – B side**) – in inches
CAP - Riser Caps, **PLUG** – Duct Plugs, **CPL** – Straight Couplings
RADP - Riser Adapter, **FA** – Fairleader, **BEL40** – Endbell – Sch 40,
BELEB - Endbell – EB, **SLIP** – Slip Coupling, **SPLIT** – Split Repair
PS - PVC to Steel Coupling, **GNDBUSH** – Grounding Bushing,
GNDUCONN – pipe ground connector
Examples: NFP4-SW90-24: 4”, PVC, 90 degree angle sweep with 24 in radius
NFP5-SW22: 5” PVC duct, 22.5 degree sweep, 36 in radius
NFP6-CAP: 6” PVC riser cap (for spare)
NFP5-CPL: 5” PVC straight coupling
NFS4-GNDBUSH: 4” Grounding Bushing:

9.3 Conduit Accessory CU Formats:

NA (Material) - (Size option if any)

Material – **CM** - PVC cement, **MT** - marker tape, **FL**- fish line, **DX** - duxseal,
DF - duct foam, **CP** - cold patch, **FA** – fairleader

10.0 Ductbank Compatible Units

- 10.1 Ductbanks shall be designed using Compatible Units (CUs). The table below references the CUs for the most commonly used ductbanks for distribution construction. Refer to EVERSOURCE Material Standard, “M1000, PVC Conduit & Fittings” for additional information.
- 10.2 Refer to Figure “E” for typical ductbank construction details.
- 10.3 Figures 1 thru 21 noted below refer to standard cross sections on pages 19-24.

DUCTBANK COMPATIBLE UNIT REFERENCE TABLE

Note: Each single duct bank CU includes 20 ft of trenching, needed lengths of conduit, spacers, concrete, backfill & resurfacing.

FIG	4" Ducts	5" Ducts	6" Ducts
1	NCE4-2x1	NCE5-2x1	NCE6-2x1
2	NCE4-3x1	NCE5-3x1	NCE6-3x1
4	NCE4-2x2	NCE5-2x2	NCE6-2x2
5	NCE4-3x2	NCE5-3x2	NCE6-3x2
8	NCE4-4x2	NCE5-4x2	NCE6-4x2
9	NCE4-3x3	NCE5-3x3	NCE6-4x2
13	NCE4-4x3	NCE5-4x3	NCE6-4x3
21	NCE4-4x4	NCE5-4x4	NCE6-4x4

11.0 Bill of Materials and Compatible Units – Conduit, Fittings & Accessories – Tables 1- 6

Material	Size (ID)	Wall Thickness (Type/ Sch)	Unit Length (Ft)	Catalog ID	Compatible Unit
PVC – rigid	2	40	10	1197	NCD2
“	3	40	10	1198	NCD3
“	4	40	10	1195	NCD4
“	4	EB	20	1362	NCE4
“	5	40	10	1196	NCD5
“	5	EB	20	1363	NCE5
“	6	40	10	15174	NCD6
“	6	EB	20	16047	NCE6
PVC – flexible	1-1/2	40 flex	1	15968	NCFLEX1.5
“	2	40 flex	1	9480	NCFLEX2
“	2-1/2	40 flex	1	15969	NCFLEX2.5

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“	3	40 flex	1	9481	NCFLEX3
“	4	40 flex	1	9482	NCFLEX4
Steel, Galv	2	40	10	9474	NCS2
“	3	40	10	1246	NCS3
Steel, Galv	4	40	10	1248	NCS4
“	5	40	10	1249	NCS5
“	6	40	10	15177	NCS6

Table 2 – Straight Couplings, Split Duct and Reducers (PVC to PVC Only)					
Material	Type	Size(s)	Application	Catalog ID	Compatible Unit
PVC	Straight Coupling	2	Joining	1208	NFP2-CPL
“	“	3	Joining	1209	NFP3-CPL
“	“	4	Joining	1210	NFP4-CPL
“	“	5	Joining	16375	NFP5-CPL
“	“	6	Joining	16355	NFP6-CPL
PVC	Split Duct	2	Repair	16873	NFP2-SPLIT
“	“	3	Repair	16874	NFP3-SPLIT
“	“	4	Repair	16875	NFP4-SPLIT
“	“	5	Repair	16876	NFP5-SPLIT
“	“	6	Repair	16831	NFP6-SPLIT
PVC	Reducer	3 to 2-1/2	change dia.	13661	NFPR3-2.5
“	“	3 to 2	change dia	13639	NFPR-3-2
“	“	4 to 3	change dia.	16043	NFPR-4-3
“	“	5 to 4	change dia.	16044	NFPR-5-4
“	“	6 to 5	change dia.	16045	NFPR-6-5

Table 3 – Conduit Sweeps and Angle Fittings					
Material	Angle (deg)	Size (ID)	Radius	Catalog ID	Compatible Unit
PVC	5	4	N/A	1357	NFP4-SW5
“	“	5	N/A	1358	NFP5-SW5
“	“	6	N/A	16354	NFP6-SW5
“	22.5	3	13	15319	NFP3-SW22-13
“	“	4	36	1168	NFP4-SW22
“	“	5	36	1169	NFP5-SW22

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"	"	6	48	16359	NFP6-SW22-48
PVC	45	3	13	15320	NFP3-SW45-13
"	"	4	36	1166	NFP4-SW45
"	"	5	36	1170	NFP5-SW45
"	"	6	48	16358	NFP6-SW45-48
"	90	2	18	1158	NFP2-SW90-18
"	"	3	24	1159	NFP3-SW90-24
"	"	4	36	1167	NFP4-SW90
"	"	4	24	16374	NFP4-SW90-24
"	"	4	16	7746	NFP4-SW90-16
PVC	90	4	48	16385	NFP4-SW90-48
"	"	5	36	1171	NFP5-SW90
"	"	5	60	16361	NFP5-SW90-60
"	"	6	36	16363	NFP6-SW90
"	"	6	60	16364	NFP6-SW90-60
Galv. Steel	90	2	30	16854	NFS2-SW90-30
"	"	3	30	1173	NFS3-SW90-30
"	"	4	36	9898	NFS4-SW90
"	"	5	36	9899	NFS5-SW90
"	"	6	36	15176	NFS6-SW90

Material	Description	Size (ID)	Ends	Catalog ID	Compatible Unit
PVC/rubber	Duct Plug	2	n/a	1634	NFP2-PLUG
"	"	3	n/a	1635	NFP3-PLUG
PVC/rubber	Duct Plug	4	n/a	1636	NFP4-PLUG
"	"	5	n/a	1637	NFP5-PLUG
"	"	6	n/a	16869	NFP6-PLUG
PVC	Sched 40 End Bell	2		9423	NFP2-BEL40
"	"	3		9424	NFP3-BEL40
"	"	4		9425	NFP4-BEL40
"	"	5		16428	NFP5-BEL40
"	"	6		16367	NFP6-BEL40
PVC	Type EB End Bell	2		16365	NFP2-BELEB
"	"	3		16366	NFP3-BELEB
"	"	4		1156	NFP4-BELEB

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“	“	5	1157	NFP5-BELEB
“	“	6	16429	NFP6-BELEB

Table 5 – Pole Riser Sections including Fittings (Steel to PVC, Steel to Steel)					
Material	Description	Size (ID)	Ends	Catalog ID	Compatible Unit
PVC	External Cap	2		16918	NFP2-CAP
“	“	3		16917	NFP3-CAP
“	“	4		9460	NFP4-CAP
“	“	5		16393	NFP5-CAP
“	“	6		16394	NFP6-CAP
Galv. Steel	Riser Pipe Section (steel sweep, 10 ft Rigid steel conduit, iron slip coupling & PVC-steel coupling)	2	sweep RS cond slip cplg thrd cplg	16854 9474 16351 9513	NCRS2
“	“	3	sweep RS cond slip cplg thrd cplg	1173 1246 1343 9514	NCRS3
“	“	4	sweep RS cond slip cplg thrd cplg	9898 1248 1345 1099	NCRS4
Galv. Steel	Riser Pipe Section (steel sweep, 10 ft Rigid steel conduit, iron slip coupling & PVC-steel coupling)	5	Sweep RS cond slip cplg thrd cplg	9899 1249 1346 1100	NCRS5
“	“	6	sweep RS cond slip cplg thrd cplg	15176 15177 n/a 16368	NCRS6
Steel	Grounding Bushing	2	threads	15971	NFS2-GNDBUSH
“	“	3	“	1190	NFS3-GNDBUSH
“	“	4	“	1188	NFS4-GNDBUSH
“	“	5	“	1189	NFS5-GNDBUSH
“	“	6	“	16934	NFS6-GNDBUSH
Copper	Pipe Ground Conn.	2”	U bolt	9011	NFS2-GNDUCONN
“	Pipe Ground Conn.	4”	“	15363	NFS4-GNDUCONN

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“	Pipe Ground Conn.	5”	“	15363	NFS5-GNDUCONN
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Table 6 – Conduit Installation Accessories

Material	Description	Size	Catalog ID	Compatible Unit
PVC Cement	All season, quick setting cement	Quart	1213	NA-CM
Marker Tape	Caution Tape to install over buried electric lines	1000 ft roll	9913	NA-MT
Fish Line	Pull line, 2500lb strength	3000 ft	16860	NA-FL
Duct Foam	Expands and seals around cables at duct mouths	13 oz can	1380	NA-DF
Dux Seal	Plug compound, nonhardening	Large, 5lb	1239	NA-DX5
“	“	Small, 1lb	9469	NA-DX1
Cold patch	Temporary Pavement	60 lb	1628	NA-CP
Fairleader	For Duct Mouths	3-5	1371	NA-FA

12.0 Typical Construction Plans - Figures A thru F

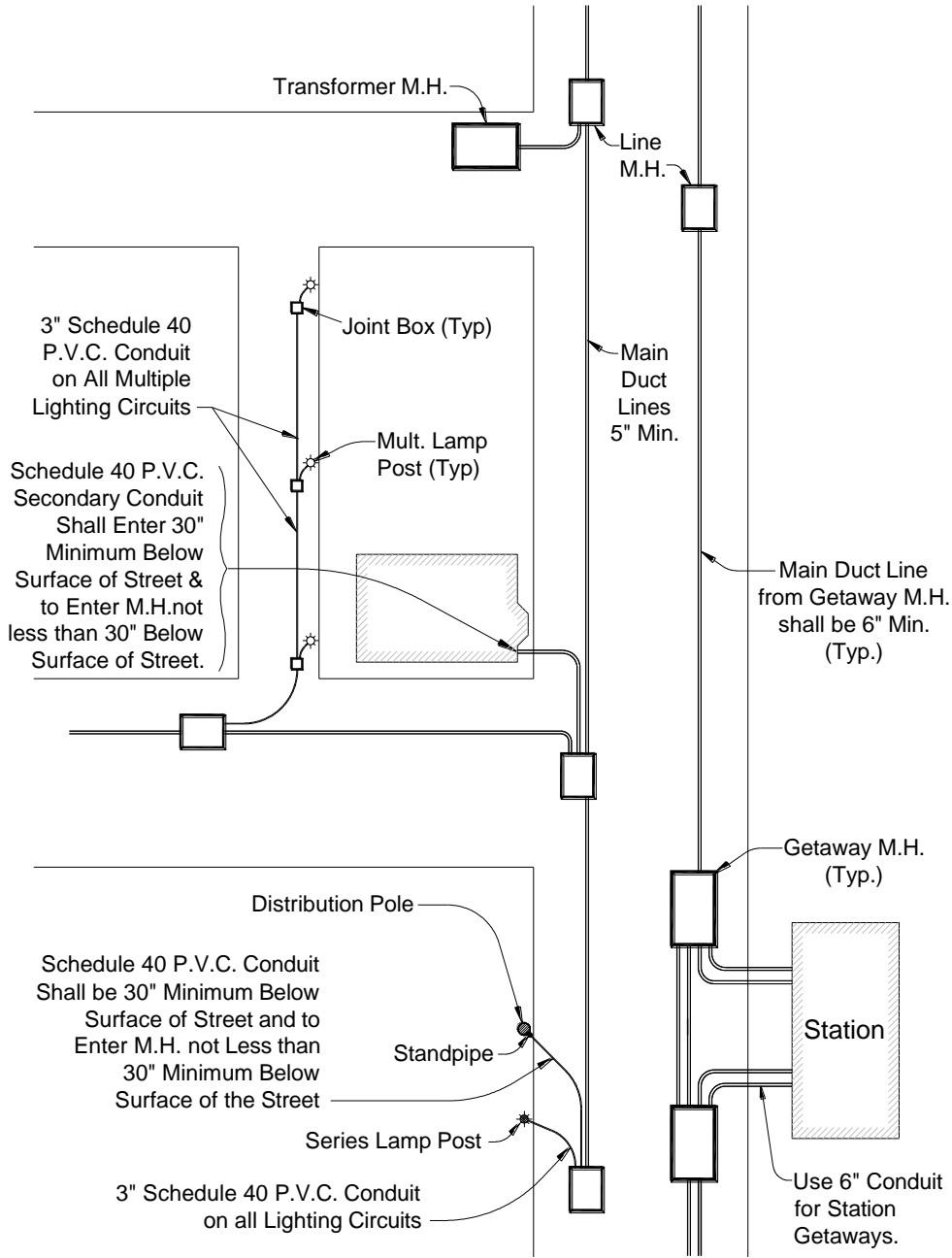
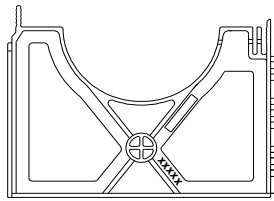
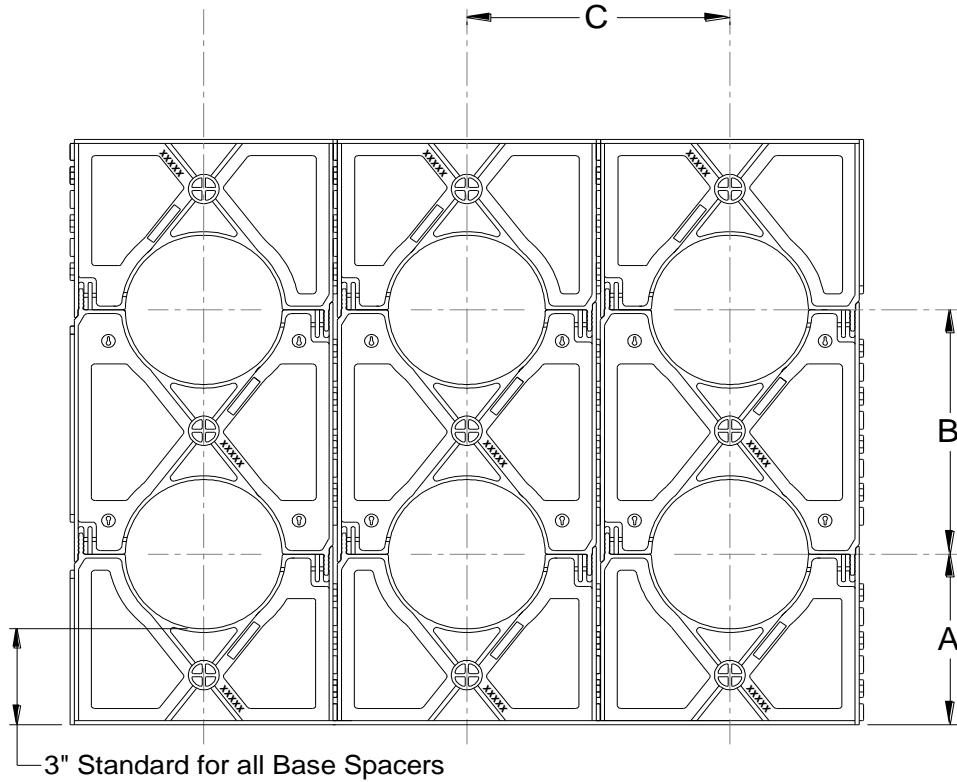
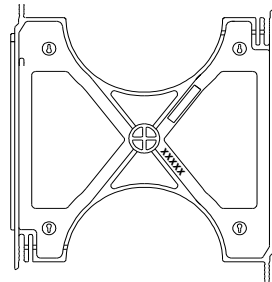


FIGURE A - PLAN VIEW
TYPICAL DISTRIBUTION CONDUIT CONSTRUCTION DETAILS



BASE SPACERS

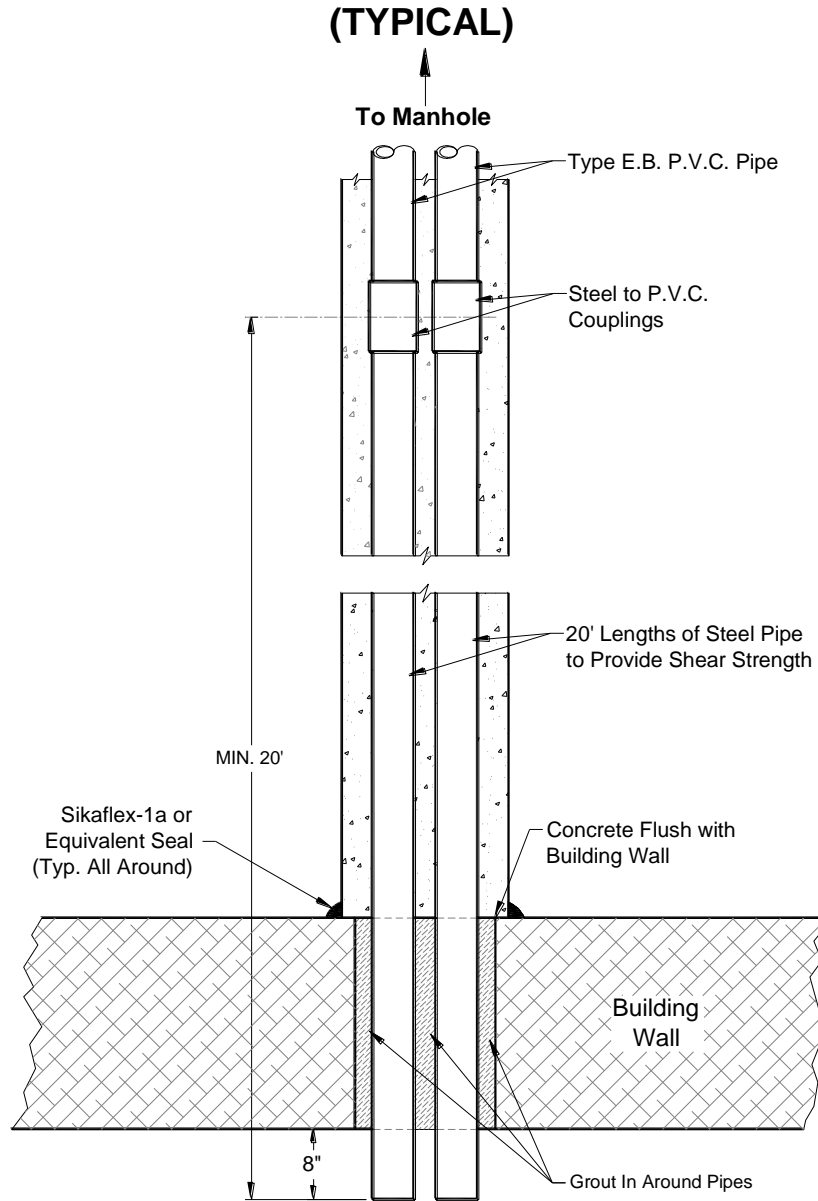


INTERMEDIATE SPACERS

Size	Spacing	A	B	C	Base Spacer; Cat. ID	Intermediate Spacer; Cat. ID
4"	1 1/2"	5.310	6.010	6.250	9462	9464
5"	1 1/2"	5.840	7.070	7.310	9465	9463
6"	1 1/2"	6.380	8.140	8.380	16378	16379

Note: Conduit spacers shall be installed every 5 ft. (7 feet maximum).

FIGURE B
CONDUIT CONSTRUCTION PLASTIC SPACER



Note:

Building wall construction to be used wherever settlement of building or conduit is anticipated.

FIGURE C – PLAN VIEW
BUILDING WALL CONSTRUCTION

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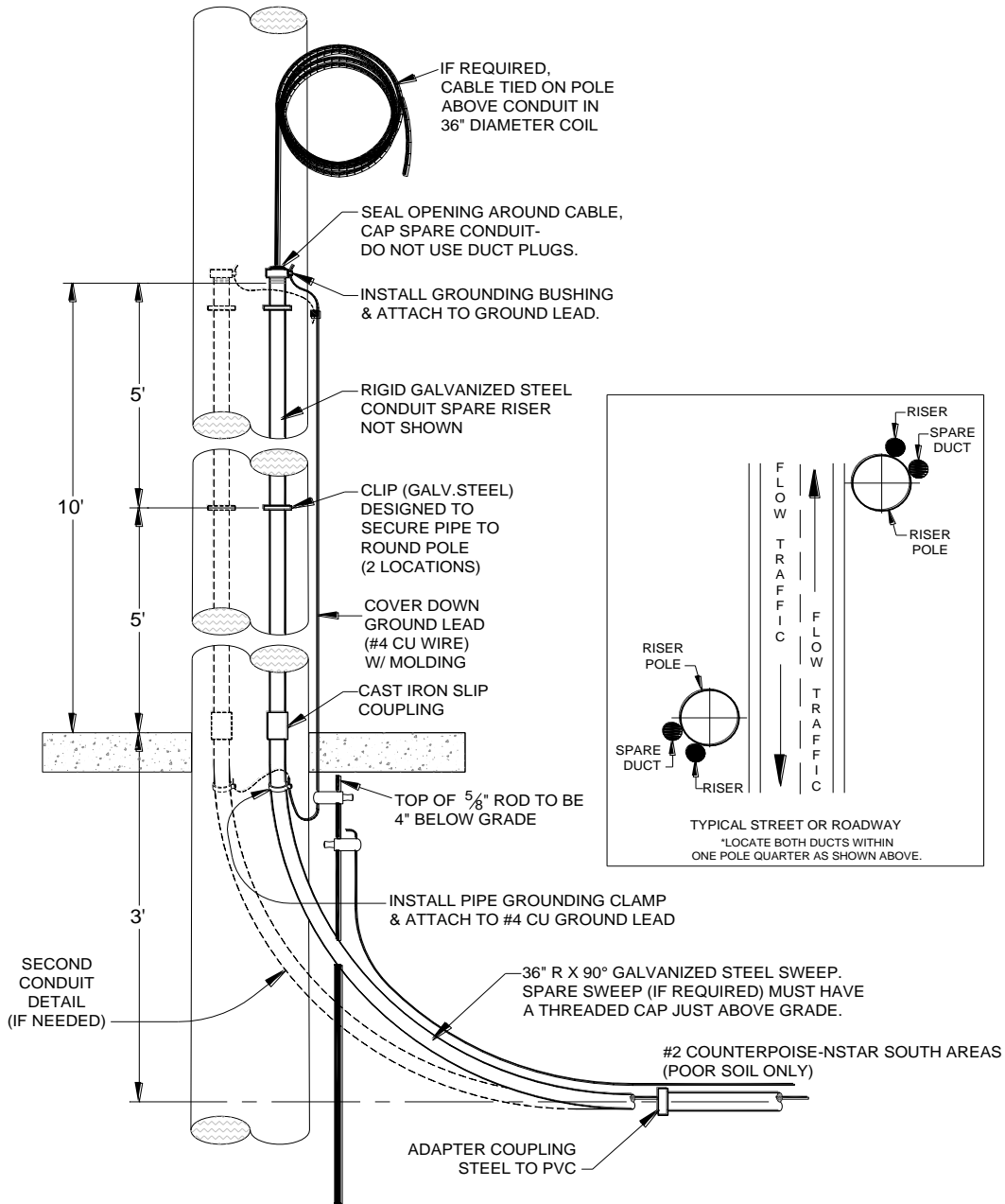


FIGURE D – PROFILE
TYPICAL RISER CONSTRUCTION DETAIL

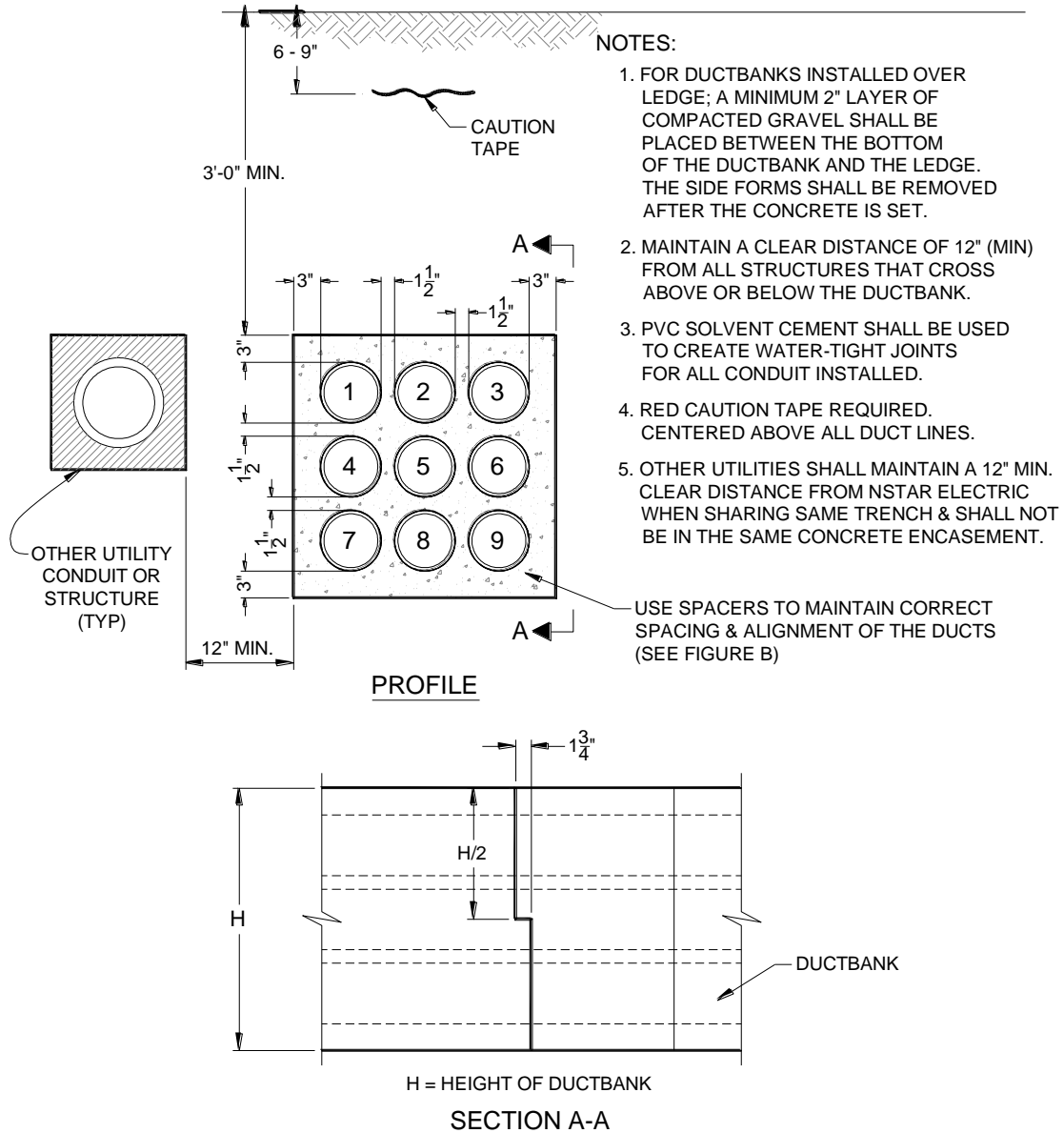
**CONSTRUCTION STANDARD
ELECTRIC OPERATIONS ORGANIZATION**

C1100

Issued
24-Apr-08



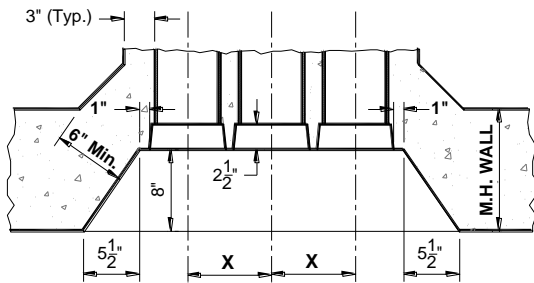
Revision 0
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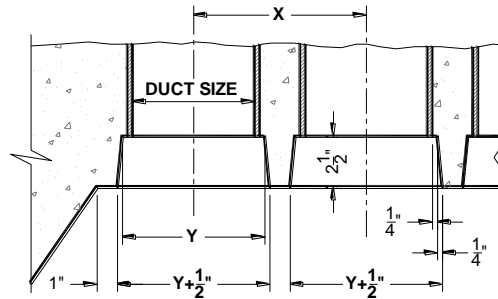
CONCRETE SPECIFICATION:

CONCRETE SHALL BE NORMAL WEIGHT WITH PEASTONE MIX, 2500 PSI @ 28 DAY COMPRESSIVE STRENGTH. UNLESS OTHERWISE SPECIFIED, CONSTRUCTION SHALL CONFORM TO ACI-318 (LATEST EDITION) WHERE REINFORCEMENT IS SPECIFIED.

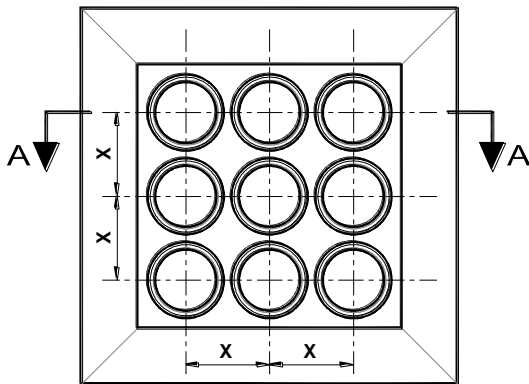
**FIGURE E – PROFILE & SECTION VIEWS
STANDARD UNREINFORCED CONCRETE DUCTBANK CONSTRUCTION
DETAILS**



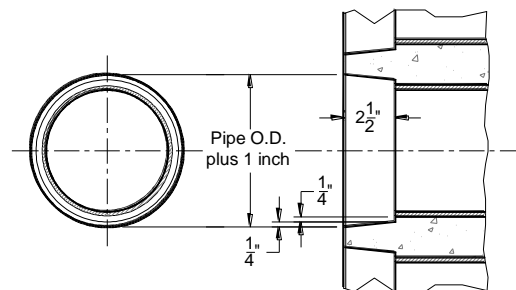
SECTION "A-A"



DETAIL OF DUCT MOUTH



DUCT FACE



DUCT MOUTH FOR SERVICE PIPES, ETC.

Duct Size	X	Y
4"	6 1/2"	5"
5"	7 1/2"	6"
6"	8 1/2"	7"

Notes:

1. Ducts shall be 5" size unless otherwise specified.
2. Ducts shall be terminated with a matching schedule PVC end bell, which shall then be sealed around with mortar mix.

FIGURE F
MANHOLE BELLMOUTH CONSTRUCTION

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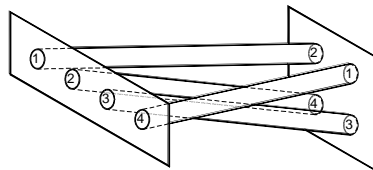


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This Standard Specifies the Typical Arrangement of Transposed Duct Numbering as the Configuration changes from Horizontal to Vertical or vice versa.

Connect Left to Right as Follows:

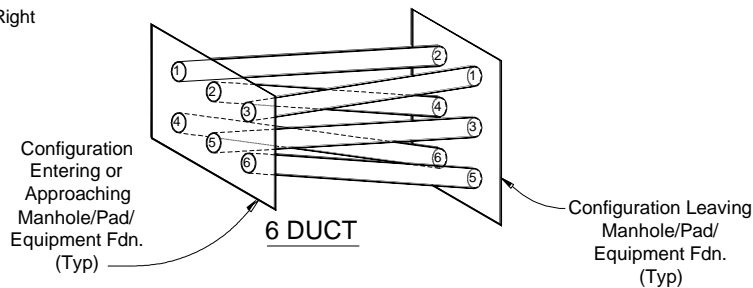
- 1 to 2
- 2 to 4
- 3 to 3
- 4 to 1



4 DUCT

Connect Left to Right as Follows:

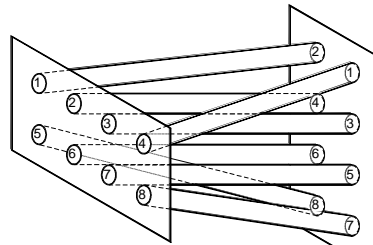
- 1 to 2
- 2 to 4
- 3 to 1
- 4 to 6
- 5 to 3
- 6 to 5



6 DUCT

Connect Left to Right as Follows:

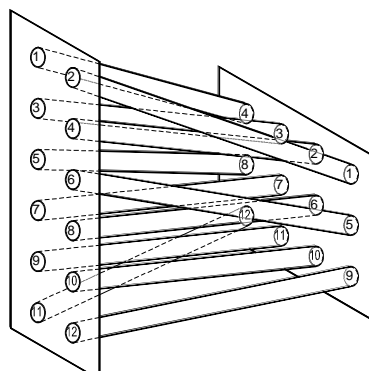
- 1 to 2
- 2 to 4
- 3 to 3
- 4 to 1
- 5 to 8
- 6 to 6
- 7 to 5
- 8 to 7



8 DUCT

Connect Left to Right as Follows:

- 1 to 4
- 2 to 1
- 3 to 3
- 4 to 2
- 5 to 8
- 6 to 5
- 7 to 7
- 8 to 6
- 9 to 11
- 10 to 10
- 11 to 12
- 12 to 9



12 DUCT

Notes:

1. The open duct ends, as viewed from the center of the Manhole/Pad/Equipment Foundation, shall be numbered as shown on Figures No. 1 - 23.
2. If other duct transpositions are required prior approval from NSTAR is required.

**FIGURE G
TRANSPPOSITION OF DUCTS – (WHEN NECESSARY)**

13.0 Duct Bank Cross Sections – Figures 1 thru 23
Standard and Nonstandard (Alternate) Designs shown to support old construction.

**DUCT BANK LAYOUT FOR 4", 5", & 6" CONDUIT
 (NON-REINFORCED CONCRETE)**

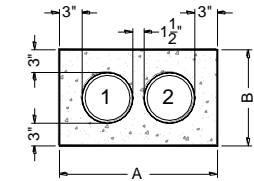


FIG. 1 2-DUCTS

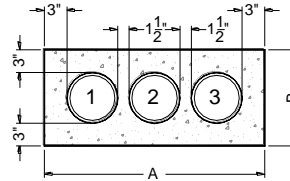
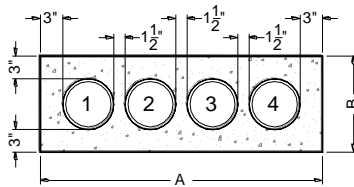


FIG. 2 3-DUCTS



**FIG. 3 4-DUCTS
 (Alternate)**

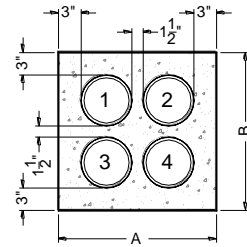


FIG. 4 4-DUCTS

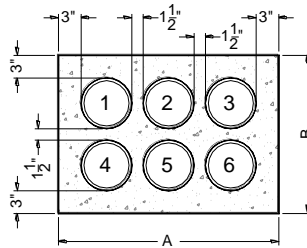


FIG. 5 6-DUCTS

Numbers in Duct Indicate Numbering System when
 Viewed from the Open End of a Ductbank.

DIMENSIONS						
FIG	4" Ducts		5" Ducts		6" Ducts	
	A Inches	B Inches	A Inches	B Inches	A Inches	B Inches
1	16 1/2"	10 1/2"	18 1/2"	11 1/2"	21"	12 1/2"
2	22 1/2"	10 1/2"	25 1/2"	11 1/2"	29"	12 1/2"
3	28 1/2"	10 1/2"	32 1/2"	11 1/2"	37"	12 1/2"
4	16 1/2"	16 1/2"	18 1/2"	18 1/2"	21"	21"
5	22 1/2"	16 1/2"	25 1/2"	18 1/2"	29"	21"

NOTE: See pages 25 for duct bank weights and concrete quantities.

DUCT BANK LAYOUT FOR 4", 5", & 6" CONDUIT
(NON-REINFORCED CONCRETE)

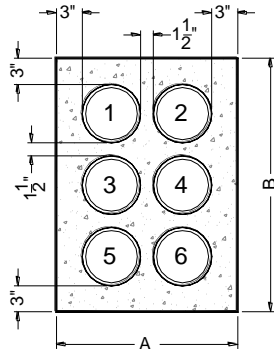


FIG. 6 6-DUCTS
(Alternate)

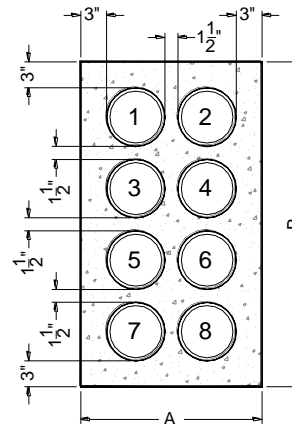


FIG. 7 8-DUCTS
(Alternate)

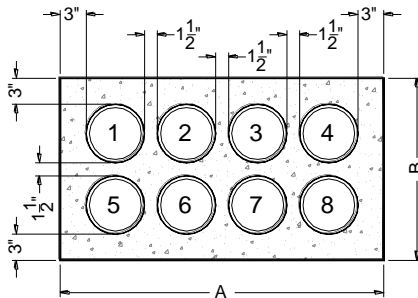


FIG. 8 8-DUCTS

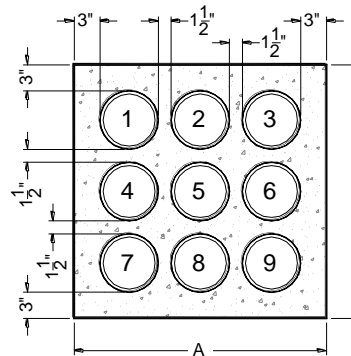


FIG. 9 9-DUCTS

Numbers in Duct Indicate Numbering System when Viewed from the Open End of a Ductbank.

DIMENSIONS						
FIG	4" Ducts		5" Ducts		6" Ducts	
	A Inches	B Inches	A Inches	B Inches	A Inches	B Inches
6	16 1/2"	22 1/2"	18 1/2"	25 1/2"	21"	29"
7	16 1/2"	28 1/2"	18 1/2"	32 1/2"	21"	37"
8	28 1/2"	16 1/2"	32 1/2"	18 1/2"	37"	21"
9	22 1/2"	22 1/2"	25 1/2"	25 1/2"	29"	29"

NOTE: See pages 25 for duct bank weights and concrete quantities.

**DUCT BANK LAYOUT FOR 4", 5", & 6" CONDUIT
(NON-REINFORCED CONCRETE)**

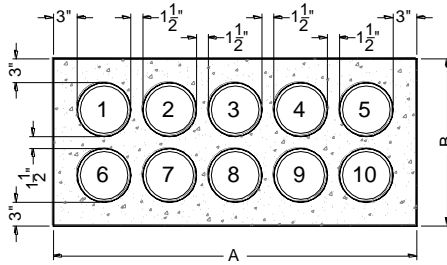
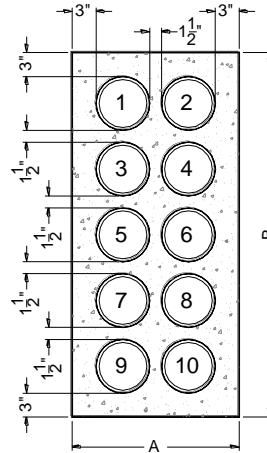
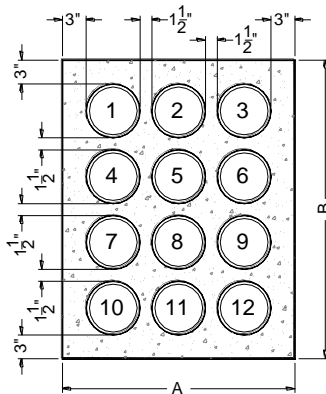


FIG. 10 10-DUCTS



**FIG. 11 10-DUCTS
(Alternate)**



**FIG. 12 12-DUCTS
(Alternate)**

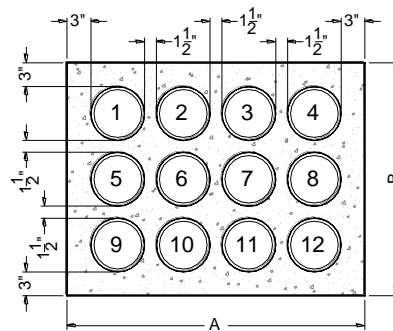


FIG. 13 12-DUCTS

Numbers in Duct Indicate Numbering System when Viewed from the Open End of a Ductbank.

DIMENSIONS						
FIG	4" Ducts		5" Ducts		6" Ducts	
	A Inches	B Inches	A Inches	B Inches	A Inches	B Inches
10	34 1/2"	16 1/2"	39 1/2"	18 1/2"	45"	21"
11	16 1/2"	34 1/2"	18 1/2"	39 1/2"	21"	45"
12	22 1/2"	26 1/2"	25 1/2"	32 1/2"	29"	37"
13	28 1/2"	22 1/2"	32 1/2"	25 1/2"	37"	29"

NOTE: See pages 25 for duct bank weights and concrete quantities.

**DUCT BANK LAYOUT FOR 4", 5", & 6" CONDUIT
(NON-REINFORCED CONCRETE)**

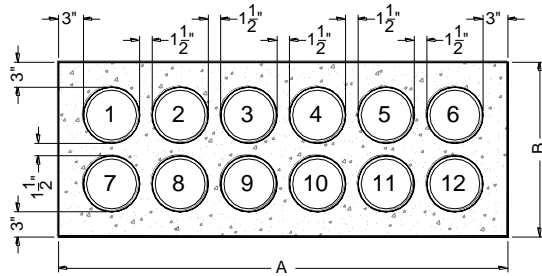
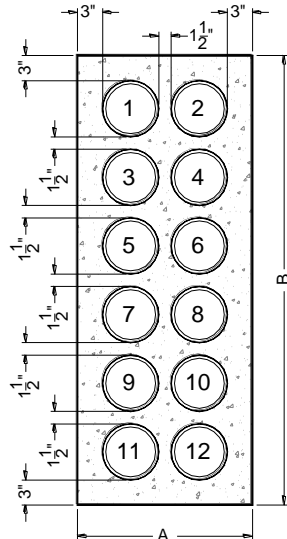
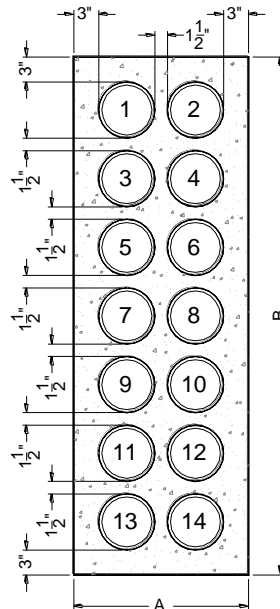


FIG. 14 12-DUCTS



**FIG. 15 12-DUCTS
(Alternate)**



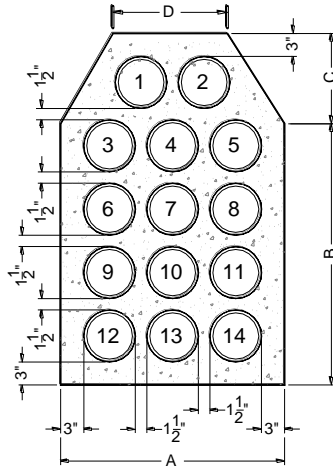
**FIG. 16 14-DUCTS
(Alternate)**

Numbers in Duct Indicate Numbering System when Viewed from the Open End of a Ductbank.

DIMENSIONS						
FIG	4" Ducts		5" Ducts		6" Ducts	
	A Inches	B Inches	A Inches	B Inches	A Inches	B Inches
14	40 1/2"	16 1/2"	46 1/2"	18 1/2"	53 1/2"	21"
15	16 1/2"	40 1/2"	18 1/2"	46 1/2"	21"	53 1/2"
16	16 1/2"	46 1/2"	18 1/2"	53 1/2"	21"	61"

NOTE: See pages 25 for duct bank weights and concrete quantities.

**DUCT BANK LAYOUT FOR 4", 5", & 6" CONDUIT
(NON-REINFORCED CONCRETE)**



**FIG. 17 14-DUCTS
(Alternate)**

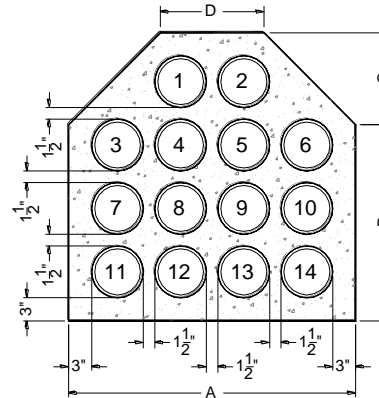
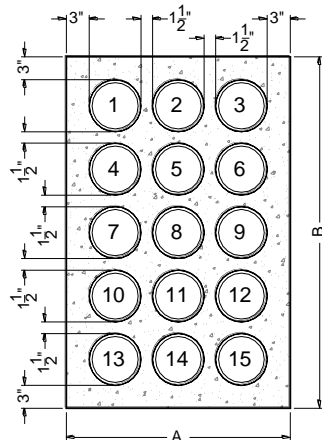


FIG. 18 14-DUCTS



**FIG. 19 15-DUCTS
(Alternate)**

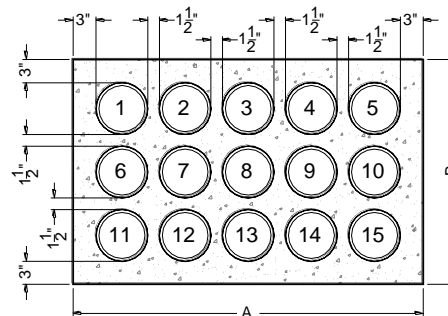


FIG. 20 15-DUCTS

Numbers in Duct Indicate Numbering System when Viewed from the Open End of a Ductbank.

FIG	DIMENSIONS											
	4" Ducts				5" Ducts				6" Ducts			
	A Inches	B Inches	C Inches	D Inches	A Inches	B Inches	C Inches	D Inches	A Inches	B Inches	C Inches	D Inches
17	22 1/2"	25 1/2"	9"	12"	25 1/2"	29 1/2"	10"	14"	29"	33 1/2"	11"	16"
18	28 1/2"	19 1/2"	9"	10"	32 1/2"	22 1/2"	10"	12"	37"	25 1/2"	11"	14"
19	22 1/2"	34 1/2"	N/A	N/A	25 1/2"	39 1/2"	N/A	N/A	29"	45"	N/A	N/A
20	34 1/2"	22 1/2"	N/A	N/A	39 1/2"	25 1/2"	N/A	N/A	45"	29"	N/A	N/A

NOTE: See pages 25 for duct bank weights and concrete quantities.

DUCT BANK LAYOUT FOR 4", 5", & 6" CONDUIT
(NON-REINFORCED CONCRETE)

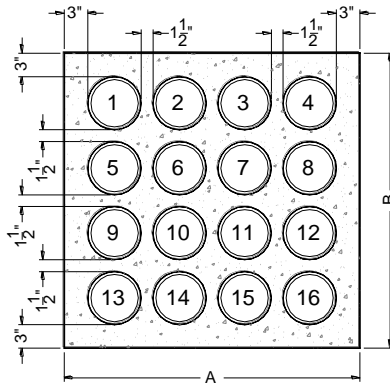
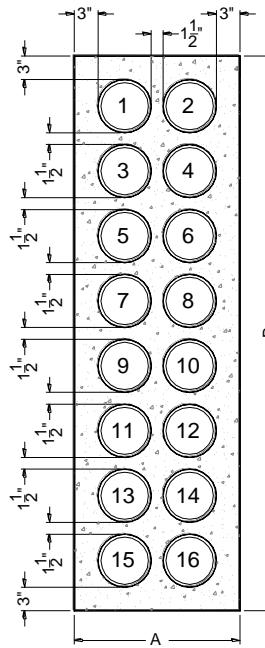


FIG. 21 16-DUCTS



**FIG. 22 16-DUCTS
(Alternate)**

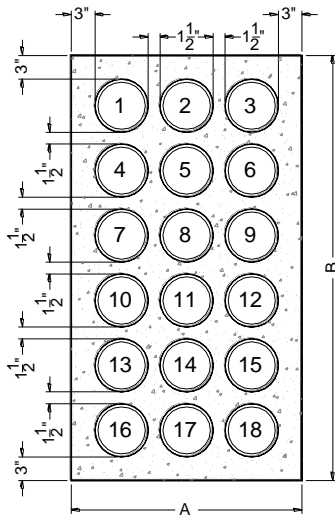


FIG. 23 18-DUCTS

Numbers in Duct Indicate Numbering System when
Viewed from the Open End of a Ductbank.

FIG	DIMENSIONS											
	4" Ducts				5" Ducts				6" Ducts			
	A Inches	B Inches	C Inches	D Inches	A Inches	B Inches	C Inches	D Inches	A Inches	B Inches	C Inches	D Inches
21	28 1/2"	28 1/2"	N/A	N/A	32 1/2"	32 1/2"	N/A	N/A	37"	37"	N/A	N/A
22	16 1/2"	52 1/2"	N/A	N/A	18 1/2"	60 1/2"	N/A	N/A	21"	69"	N/A	N/A
23	22 1/2"	40 1/2"	N/A	N/A	25 1/2"	46 1/2"	N/A	N/A	29"	53 1/2"	N/A	N/A

NOTE: See pages 25 for duct bank weights and concrete quantities.

Conduit Bank Concrete Requirements and Weights per linear foot.

CONDUIT CONSTRUCTION DUCT SIZES, WEIGHTS & CONCRETE QUANTITIES						
No. of Ducts	<u>4 Inch Dia.</u>		<u>5 Inch Dia.</u>		<u>6 Inch Dia.</u>	
	Unreinforced Concrete PVC Duct & Cable		Unreinforced Concrete PVC Duct & Cable		Unreinforced Concrete PVC Duct & Cable	
	lbs/lin. ft.	cu.yds/lin. ft	lbs/lin. ft.	cu.yds/lin. ft	lbs/line. ft. ft.	cu.yds/lin. ft.
2	180	0.0363	200	200	228	0.05
3	245	0.0483	274	274	312	0.067
4(2wx2D)	285	0.0536	316	316	373	0.078
4 (4W)	315	0.0606	347	347	394	0.083
6	385	0.0709	432	432	508	0.1037
8	490	0.0882	548	548	641	0.129
9	530	0.0931	590	590	687	0.1367
10	600	0.106	663	663	774	0.154
12 (4Wx3D)	675	0.116	748	748	867	0.17
12 (6Wx2D)	700	0.123	778	778	918	0.183
14	810	0.141	858	858	984	0.191
15	815	0.138	904	904	1048	0.203
16 (4Wx4D)	840	0.141	948	948	1095	0.211
16 (2Wx8D)	865	0.155	961	961	1186	0.231
18 (3Wx6D)	946	0.161	1063	1063	1261	0.24

14.0 Reference Standards

13.1 W1000, “Entering and Working in Underground Locations including Subsurface Vaults”

13.2 C1101, “Distribution Duct bank Construction, and (Steel Reinforced Concrete)”

15.0 Signature Approval

Approved by: Amin Jessa
Director, Distribution Engineering

END OF SECTION

SECTION 16311

TRACTION POWER ELECTRICAL EQUIPMENT

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies the conditions and technical requirements for the furnishing and installation of AC and DC switchgear, rectifier transformers, rectifiers, busducts, negative drainage board and accessory equipment for traction service.
- B. This Section also identifies the requirements of the design submittals required as part of this Project.
- C. Installation includes the furnishing of all labor, materials, tools, equipment, facilities, permits, insurance and incidentals necessary for design completion, testing, shipping, rigging, installation and commissioning of the following major electrical equipment:

(* indicates some of the equipment has been procured by the MBTA)

- 1. 15 kV class AC switchgear assembly (Article 2.1)(*)
 - 2. Rectifier transformers (Article 2.2)(*)
 - 3. Traction power rectifiers (Article 2.3)(*)
 - 4. 750 Volt class DC switchgear assembly (Article 2.4)(*)
 - 5. Anode (AC) and cathode (DC) buses (Article 2.5)
 - 6. Negative equalizer bus and drainage board (Article 2.6)
 - 7. 15 kV circuit breaker control and instrument panel (ACCP)(Article 2.7)
 - 8. Station battery, charger and accessories (Article 2.8)
 - 9. Supervisory equipment (Article 2.9)
 - 10. Substation Automation Equipment – Refer to Appendix A
 - 11. Technical Support Equipment
 - 12. Testing and Safety Equipment
- D. The DB Entity shall furnish, install and connect any additional components, parts, items and devices not specifically mentioned in this Section or shown on the Contract Documents, but necessary for the proper operation of the equipment in accordance with the intent of the Contract Documents, at no additional cost to the MBTA.

- E. The DB Entity shall employ or retain the services of a Designer and Power Engineer. The duties and responsibilities of the Designer / Power Engineer shall include but not be limited to the following.
1. Participate at Design Submittal Review Conferences
 2. Participate at the Design Conference.
 3. Review equipment shop drawings to insure they comply with the requirements of specifications and plans. This will occur prior to submittal of shop drawings to the MBTA.
 4. Develop relay co-ordination curves/settings for AC switchgear and DC switchgear.
 5. Review Factory and Field Testing Procedures to insure they comply with the specifications. This will occur prior to submitting the procedures to the MBTA.
 6. Attend Factory Design and Production Tests.
 7. Make monthly visits to the substations during equipment installation to resolve problems.
 8. Attend Field Testing of the Substations.
 9. Co-ordinate As-Built Equipment Drawings.

1.2 RELATED WORK

- A. Related requirements are included in, but not limited to, the following Sections.
1. Section 16100, Power Utility Coordination for the Traction Power System
 2. Section 16201, Basic Materials and Methods for Electrical Work For the Traction Power System
 3. Section 16203, Traction Power Equipment General Requirements
 4. Section 16492, SCADA Master Station and SCADA interface

1.3 EQUIPMENT ENVIRONMENT

- A. All substation equipment specified in this Section shall be installed indoors, in the substation building with the exception of the oil filled rectifier transformers and connected section of the AC busducts.
- B. The substation site is located at approximately sea level with a normal barometric pressure of 29.21 inches Hg. Outdoor temperatures in the Boston area range approximately from minus 15°F to plus 105°F.
- C. Ventilation shall be supplied to the substation building with filtered outside air when the inside temperature reaches 90°F and above. Maximum expected air temperature within the building is

104°F during hot summer days. During cool periods the temperature within the substation shall be maintained at 50°F and above by thermostatically controlled heaters.

- D. The atmosphere in Boston has a combination of industrial pollutants expected of a metropolitan area with a concentration of various types of industries.
- E. All equipment and materials supplied under this Contract shall be designed to resist dynamic earthquake loadings based on the Massachusetts State Building Code (Seismic Zone 2A).

1.4 INSTALLATION DESIGN CONFERENCE and DESIGN SUBMITTAL REVIEW CONFERENCES

- A. The DB Entity shall start design development immediately upon Notice to Proceed. The design development shall provide submittals for each TPSS for the 30%, 60%, 90% and 100% design stages as is normal for the MBTA.
- B. The design submittal schedule shall be developed in accordance with the Contract requirements.
- C. The DB Entity shall provide a Contract Deliverable Requirements List (CDRL) for the design phase of the project for review and acceptance by the MBTA within 21 days of the Notice to Proceed.
- D. The design submittals shall include as a minimum but not be limited to design plans, specifications, reports, calculations and studies necessary to clearly show the detailed design at the appropriate stages. Documents shall include:
 - 1. Substation location plans
 - 2. Substation layout plans (integrating MBTA procured equipment as necessary)
 - 3. Single line diagrams
 - 4. System configuration diagrams
 - 5. Equipment schematic diagrams
 - 6. Typical equipment drawings (integrating MBTA procured equipment as necessary).
 - 7. Section views and elevations
 - 8. Access and egress details
 - 9. SCADA system points list
 - 10. SAS block diagrams and details
 - 11. Cable and conduit routing drawings
 - 12. Interface drawings
 - 13. Grounding and bonding design drawings

- E. Upon completion of each design stage, the MBTA shall be provided an 8 week period to review the design plans. Upon completion of that period, the DB Entity shall arrange for a design submittal review conference. All necessary parties of the MBTA and its representative shall be invited. The DB Entity shall present the design and receive comment verbally or in written form. The DB Entity shall reply to all comments and record in the meeting minutes. The intent of the meeting is to enable the DB Entity to proceed to the next design stage with agreed actions and issues resolved. The DB Entity shall take the meeting notes and distribute accordingly.
- F. The final design documents shall be stamped and sealed by a PE in the State of Massachusetts.
- G. Upon completion of the design, the DB Entity shall proceed to develop the specific detailed equipment designs from its selected vendors. The DB Entity's vendors shall start detail design and drafting work for all equipment immediately upon Notice to Proceed and shall process design work to completion without delay and without regard to normal manufacturing schedule.
- H. An Installation Design Conference shall be arranged in the Metropolitan Boston area as directed by the MBTA. The Design Conference shall be scheduled so that it can be completed within 60 calendar days from the Notice to Proceed. It is estimated that the Design Conference, dealing with the design and manufacturing of traction power and substation auxiliary equipment, will take not more than two full working days, provided the DB Entity will produce the data and drawings specified herein in full compliance with the Specification requirements. The Design Conference will be attended by the MBTA, MBTA's consulting Engineer for the Project, DB Entity's Project Manager, DB Entity's Power Engineer and, on as-needed basis, technical personnel from major equipment manufacturers. All of the DB Entity's costs associated with arranging and attending the Design Conference, including meeting space and incidentals, shall be borne by the DB Entity.
- I. A minimum of 21 days prior to the Design Conference, the DB Entity shall submit the following for the MBTA's review:
1. Certified overall dimension drawings showing weights and bases of all equipment covered by the Contract.
 2. Contract Deliverable Requirements list (CDRL) – see 1.5.A below.
 3. Compliance / Non-Compliance List – see 1.5.B below.
 4. Written notification of any difficulties encountered with fitting the proposed equipment into the equipment outlines shown on the Design Documents.
 5. Complete design calculations as specified in Part 2, Products, of this Section for MBTA's review and comment. Design details are to be accepted by the MBTA in accordance with this Specification. Specific design calculations that will be reviewed are the calculations for the transformer and rectifier. The submitted calculations should include:
 - a. Resistance
 - b. Impedance
 - c. X/R Ratio
 - d. Temperature Rise Curve
 - e. Power Loss Curve
 - f. Efficiency - Load Curve

6. Power Factor - Load Curve: All pertinent information for equipment proving general compliance with the Specification requirements. The submittal shall include published product literature showing construction features of equipment offered, electrical ratings of equipment, reference list of users in USA, and any other information useful in illustrating the compliance with the Specification requirements.
 7. Performance data of rectifier main DC circuit breaker during the operation on forward current at rated, overhead and short-circuit condition with and without polarizing supply applied and on reverse current, with and without polarizing supply.
 8. Sketches or drawings clearly showing the conceptual design of the ground and test devices associated with the 15 kV switchgear, including the list of components. Written descriptions of all known deviations from the Specifications. Without this written statement the DB Entity shall be assumed to be fully compliant with all clauses in the Specifications. A clause by clause commentary is preferred.
- J. During the Design Conference, the DB Entity shall provide the following:
1. Detailed traction power engineering/design and construction schedule showing as a minimum: DB Entity drawing submittals for each main item of equipment; drawing review periods; equipment design period; manufacturing period; and, delivery, installation and testing periods including test notification milestones. Schedule shall show start and finish milestones for the project and identify the critical path items. A detailed list of drawings to be submitted shall also be provided.
 2. Manufacturing plan, specifically showing material planning for equipment, estimated period of manufacture, planned date of completion, and scheduled date for witnessing of tests.

1.5 SUBMITTALS

- A. Provide submittals in accordance with Volume 2 Technical Provisions Subsection 2.8, Construction Submittal Requirements. The DB Entity shall develop and submit a Contract Deliverable Requirements List (CDRL) for the installation drawings and submit within 15 calendar days of Notice to Proceed. The List shall include all proposed submittals and the associated specification section which specifies the deliverable.
- B. The DB Entity shall submit a compliance / non-compliance list for the traction power specifications 16100, 16120, 16203, this Section, 16450, 16495. The list shall identify all specification clauses in the Traction Power Specifications and adjacent to each listed clause a category of 'compliant' or 'non-compliant'. All non-compliances shall be listed however small and insignificant it may appear and shall include the technical support equipment sections of the specifications. Each non-compliance shall be provided with a description or explanation and the DB Entity's proposed alternative or solution.
- C. Drawings and reference data: The below listed drawings, diagrams and instruction manuals, shall be submitted for all equipment furnished for the substation, in accordance with the requirements in Contract Technical Provision Subsections 2.7 and 2.8. The documentation shall be submitted separately for each main item of equipment. The documentation shall be further split into separate submittals for equipment drawings, calculations, nameplate list, product data book and bill of material list.

- D. Within 45 calendar days after the Design Conference, the DB Entity shall submit the following for acceptance:
1. Certified outline drawings of all major equipment, indicating overall dimensions, space requirements, location of control and protective devices on panels and reference tables to other drawings furnished. The submittal shall include the front and rear view of the AC and DC switchgear, rectifier transformer, rectifier, negative drainage board and the 15 kV circuit breaker control panel, substation automation equipment cabinets showing all door and panel mounted devices, equipment and device nameplates and door swings.
 2. Certified floor plans of equipment, showing dimensions necessary for installing equipment, clearances from building structure, equipment base details; dimensions and weights of shipping sections.
 3. Certified top and bottom views of equipment, showing available space for entrance of power and control circuit wiring from the top or bottom, as specified and entry of anode and cathode buses; for DC switchgear, clearance above from grounded objects and structures.
 4. Certified section views of each non-identical unit showing buses and bus supports, location of circuit breakers in withdrawn, test and fully connected positions and the location of outgoing power and control terminals. Drawings must be in sufficient detail to illustrate accessibility for maintenance and for adjustments while energized.
 5. Certified front view and side panel views of each non-identical control compartment unit, with control compartment door(s) open, showing internally mounted control devices. All devices shall be shown in their respective locations with identifying nameplates.
 6. One line diagram of equipment supplied, showing all power and auxiliary circuits, protective devices, and the location of all current, potential and auxiliary transformers and shunts with the devices energized by them. Also, inclusive of equipment interlocking requirements (electrical and mechanical).
 7. Block diagrams for the substation communications system and automation, function diagrams and logic diagrams, product data and equipment dimensions and housings.
 8. Schematic diagrams of transformer, rectifier, negative board and DC circuit breakers and circuit connections, controls and alarms, as follows.
 - a. Schematic diagrams shall be self-explanatory and shall be specifically prepared for this Contract and shall include AC schematic (three line) and DC elementary diagrams for all circuits.
 - b. Wire numbers shall be assigned to each schematic and elementary diagram so that each segment of all circuits can be identified on internal wiring diagrams of the equipment and on the interconnection diagrams. Wire sizes shall also be identified.
 - c. Wire numbers of similar schematics of different circuits shall be prefixed or suffixed to differentiate between the wires of separate pieces of equipment.
 - d. Terminal blocks in all equipment shall be assigned unique labels.

- e. Circuits and portions of circuits which will be routed external to the originating cubicle shall be clearly indicated as external wiring. Interconnection wire sizes shall also be identified.
 - f. Schematic diagrams shall show originating and terminating terminal block numbers for all wiring which enters or leaves an equipment compartment (“external wiring”). These terminal block numbers shall match the terminal block numbers shown on subsequent wiring diagrams.
 - g. Circuit breaker reference position for all equipment contacts shall be: circuit breaker racked-in and open (tripped).
- 9. Internal connection diagrams of devices, including relays and meters. Contact development of control, selector and instrument transfer switches, test switches and lockout relays.
 - 10. Equipment trip and lockout schedule, in tabulated form.
 - 11. Calculations of 125 volt DC control power requirements and for sizing of station battery, charger, and DC panel.
 - 12. SCADA points list and SAS equipment, locations and product information.
- E. After the return of the schematic diagrams marked "For Approval", or equivalent, the following drawings shall be submitted within 60 calendar days for acceptance (wiring diagram submittal):
- 1. Dimensioned general arrangement plans and elevation views of the substation, locating all DB Entity's furnished and installed equipment.
 - 2. Bus duct layout plans, sections, and support and connection details.
 - 3. Composite one line diagram of the substation power systems.
 - 4. Connection diagrams of each non-identical unit showing the following:
 - a. Terminal block arrangement, identifying each outgoing power and control terminal and showing interconnections between individual units and shipping splits of an equipment assembly. Each terminal block shall have a unique numbering convention (unique within a unit, and among all units)
 - 5. Internal wiring diagrams of rectifier transformer, rectifier, AC and DC switchgear cubicles and circuit breaker drawout elements, and 15 kV breaker control and instrument panel, showing electrical devices in their relative physical locations, left to right and top to bottom. Each wire and jumper shall be shown on the wiring diagrams. Terminal blocks for external control cable connections shall be shown in their relative physical locations. Inboard wiring connected to these terminal blocks shall be positively identified and marked so as to be readily located at the device end. All wiring shall be identified with the wire numbers shown on schematic and elementary diagrams.
 - 6. Wiring diagrams shall also comply with the following requirements:

- a. Schematic or figurative type wiring diagrams which do not portray the physical wiring of the panels will not be accepted.
 - b. Wiring diagrams shall provide sufficient empty space next to terminal blocks for interconnecting wiring cable bundle numbers and individual wire color designations.
 - c. Circuit purpose/description shall be noted adjacent to the terminal blocks to which the circuits are connected.
 - d. Wiring diagrams shall be orderly, legible and neat in appearance. Line crossings and drawing call-outs, if used, shall make use of different line widths or CAD line screening techniques to improve readability. Wiring diagrams that, in the opinion of the MBTA, do not meet this requirement, will be rejected.
 - e. Circuit breaker reference position for all contacts shown on the diagrams shall be: circuit breaker racked-in and open (tripped).
 - f. Substation automation functional and wiring diagrams showing communications ports, equipment location, cable numbering and logic diagrams with points list, programming and software.
7. Substation cable routing block diagram and wire/cable schedule including fiber optic cabling.
 8. Equipment rating nameplate data, bills of materials of equipment, devices and accessories with catalog cuts of all devices and accessories listed.
 9. Instrument transformer ratio, phase angle and excitation characteristic curves.
 10. Protective device coordination as follows.
 - a. Protective device settings and relay co-ordination requirements shall be provided. The study to develop the required settings shall be produced and approved by the DB Entity's Power Engineer. The study shall be submitted to the MBTA for acceptance.
 - b. The studies shall include but not be limited to portions of the electrical distribution system from the 13.8 kV infeed power sources, ring network and the 750 VDC system and shall include normal system connections as well as those which result in maximum fault conditions.
 - c. All supporting calculations shall be clear and neatly documented and submitted to the MBTA.
 - d. The studies shall be submitted by the DB Entity prior to receiving final acceptance from the MBTA for shop drawings on the power equipment.
 - e. The studies shall be certified (prepared and stamped) by a registered professional electrical engineer registered in the Commonwealth of Massachusetts.
 - f. The DB Entity shall be responsible for gathering all necessary data for the studies and shall expedite the data collection process to assure completion of the studies as required for final approval of the distribution equipment and/or prior to release of the equipment

for manufacture. As necessary, the DB Entity may obtain relay information and short circuit data from the MBTA via a request for information. The DB Entity shall coordinate with the MBTA in obtaining short-circuit data from Eversource (Formerly NSTAR) (incoming lines).

- g. The studies shall be in accordance with applicable IEEE and ANSI standards, and shall satisfy the requirements of the National Electrical Code.
- h. The DB Entity shall submit graphic proof of protective device coordination of equipment furnished for the substation. Coordination curves shall be submitted on 11 x 17" log-log paper showing full load currents, phase and ground fault currents, and relay and fuse coordination for all equipment furnished, including new rectifier transformers and their associated 13.8 kV AC circuit breakers. The plots shall include complete titles, representative one-line diagram and legends and complete parameters of transformers. The coordination plots shall indicate the types of protective devices selected, proposed relay taps, time dial and instantaneous trip settings, transformer magnetizing inrush and ANSI transformer withstand parameters, cable thermal overcurrent withstand limits and significant symmetrical and asymmetrical fault currents. All restrictions of the National Electrical Code shall be conformed to and proper coordination intervals and separation of characteristic curves shall be maintained. Special attention shall be paid to the Rectifier-Transformer permissible overloads and the coordination of the upstream AC relays. The rate of rise relay shall be properly set to distinguish between short circuits and vehicle starting currents. Plots shall be provided to demonstrate achievement of coordination. Current values shall be shown on 13.8 kV base; a multiplier shall be noted for conversion to DC output current. Electronically produced coordination curves will be acceptable.
- i. Coordination curves shall include a plot of rectifier output capability and shall clearly indicate the time margin of coordination between breaker trip and output capability at each of 150, 300 and 450 percent full load current and short circuit current, taking into account de-rating due to rectifier phase leg current unbalance and loss of one diode in each phase leg. In addition, the coordination shall prove that the rectifier equipment is capable of delivering maximum through-fault current for 1.5 seconds, or longer, without exceeding the safe operation limits of diodes and other components within the rectifier package. Final coordination will be subject to MBTA's acceptance.
- j. The settings of the protective devices shall be provided separately in a tabulated form listing circuit identification, IEEE device number, current transformer ratios and connection, manufacturer and type, range of adjustment and recommended settings. For multifunction electronic relays a complete listing of all relay setting and parameters shall be provided to ensure the complete configuration of the relay is provided. This shall be in hardcopy format with the downloaded setting file being made available during testing and commissioning. Settings provided shall include timer settings, alarm and trip setting of thermal devices, shunt ratios and transducer ratios/settings.
- k. Bound copies of the final report shall be submitted in quantities identical to the quantities required for shop drawing submissions. The report shall include:
 - Description, purpose, base and scope of the study and an overall single line diagram of the power system at each substation which is included within the scope of the study

- Tabulation of circuit breaker, fuse and other protective device ratings versus calculated short circuit duties, and commentary regarding the same.
 - Protective device time versus current coordination curves, tabulations of relay and circuit breaker trip settings and commentary regarding the same.
 - Calculations
11. Certified outline drawings of battery charger, battery and battery rack; schematics and wiring diagrams of battery charger; battery and charger installation details and connection diagrams.
 12. 125 Vdc distribution panel and substation low voltage AC distribution panel details and schedules.
- F. After the return of the wiring diagrams submittal marked "For Approval", or equivalent, the following drawings, schedules and diagrams shall be submitted within 60 calendar days:
1. Cable tray and conduit layout plans and sections.
 2. Bus duct drawings as follows:
 - a. Dimensioned detailed plan and elevation drawings.
 - b. Connection details.
 - c. Support details, including loads on supports and weight capacity of proposed supports and anchors.
 - d. Electrical ratings and weights of bus sections.
 - e. Bill of materials for bus duct components, keyed to detail drawings.
 3. Detail drawings of cable tray and conduit.
 4. Installation/Mounting details of equipment and auxiliary devices. Busduct supports for DC cathode busses shall be provided with in-line insulation. Insulation shall meet or exceed 1000V and shall be installed in the trapeze hanger vertical rods at a minimum of 6" from the anchor into the ceiling.
 5. Interconnection cable schedules and cable routing block diagram including submission of cables/wire types and sizes proposed to be utilized.
 6. Bills of installation materials.
 7. Cable tray loading schedule including support details, loads on supports and weight capacity of proposed supports and anchors. Cable tray directly above the area of the epoxy insulated floor, above the traction rectifiers and above the DC switchgear shall be fiberglass.
 8. Spare parts list.
 9. Interconnection wiring diagrams, showing the terminal blocks of each individual unit, interconnections between each piece of equipment and each device installed external to the

equipment. Interconnection diagrams shall show cable and terminal numbers, make reference to internal wiring of the equipment and note the drawing on which the cable run is continued. Characteristic curves of circuit breaker trip elements and fuses, on log-log paper.

11. Equipment nameplate drawings for all equipment.
 12. Factory test procedures and proposed factory test schedule for all items of equipment. See Article 3.03 of this Section for test requirements.
- G. Upon successful completion of factory tests and at the same time the equipment is shipped for installation, the following documents shall be submitted:
1. Instruction materials for each piece of equipment furnished, including installation instructions, operating instructions, maintenance manuals and recommended spare parts lists (with manufacturer's part or drawing numbers). The instructions shall be comprehensive, descriptive and illustrative enough to install, operate and maintain all the equipment furnished. All instruction materials shall be in the form of manufacturer's printed originals; photo-reproductions of manufacturer's originals are not acceptable.
 2. Factory test reports, punch list and punch list clearance records.
 3. Training Plan and proposed training schedule.
 4. On-site installation, field testing and commissioning plan and schedule. Schedule is required to show the individual tests to be performed, expected duration and personnel required. See Article 3.03 of this Section for test requirements.
- H. Submittals of "As-Built" drawings shall be in accordance with requirements set forth in Section 16465 Drawings and Records for the Traction Power System.
- I. Completed and properly indexed instruction/maintenance manuals and "As-Built" drawings, incorporating all field changes and corrections, must be delivered to the MBTA before the completion of the Contract.

1.6 DESIGN REQUIREMENTS

A. General

1. The rectifier, rectifier transformer, switchgear assemblies and auxiliary equipment specified herein and shown on Design Documents shall function as a complete, coordinated package for normally continuous and unattended operation within the Massachusetts Bay Transportation MBTA's traction power system. All components shall be sized and selected for safe, reliable operation.
2. Unless otherwise specified, all similar equipment of the same ratings shall be identical and shall be electrically and mechanically interchangeable.
3. The rectifier and switchgear assemblies specified herein shall be designed to permit ready installation in the substation as indicated on the Design Documents. The Design Documents

show space available and the extent of overall equipment to be installed. They also set forth certain limiting area dimensions which are to be maintained for MBTA's exclusive usage and the minimum clearances as required by the MBTA for safe operation. Dimensions of equipment supplied shall have approximately the same dimensions but under no circumstance exceed those shown on the Design Documents.

4. The DB Entity may make MBTA-accepted changes in the layouts shown as may be required to fit the equipment in the substation, provided that relative positioning of equipment is not altered, limiting area dimensions and minimum clearances are maintained and that the arrangement will provide for safe operation of all equipment and that there will be no extra charges to the MBTA for such modifications of the building structure and other systems affected.
5. All equipment to be installed within the substation shall be shipped in pieces small enough to be moved into the designated location assuming all other equipment is in place. Shipping dimensions shall be such that any piece can be removed from the building in the future without dismantling and minimal disturbance to other equipment. Final arrangements will be subject to the acceptance by the MBTA. It is required that all equipment and the AC and DC buses be designed, manufactured and shipped in such manner as to require a minimum of erection, assembly and wiring work in the field.
6. The DB Entity shall be responsible for the proper application and satisfactory operation of each component furnished under this Specification. Proposed designs and materials which in the judgment of the MBTA, would require unreasonable and frequent maintenance, repair or replacement shall be reason for rejection of the equipment. The MBTA reserves the right to make this judgment after all equipment has been installed and tested on site. Such items shall be placed on the project punch list for resolution.
7. The threads of all bolts, nuts and screws installed in the equipment and those that are used during initial assembly or normal maintenance shall be Unified Threads as per ANSI Standards B1.1 and B1.10.

B. Service Conditions

1. Power at 13.8 kV is supplied to the traction power substation 15 kV AC switchgear from Eversource (Formerly NSTAR) Electric. Refer to Specification 16100 for coordination requirements with the Utility. The available maximum and minimum phase and ground short circuit currents for each substation supply circuit as of the date of this specification are listed below. Data shall be obtained during design by the MBTA and provided to the DB Entity upon request.

MBTA Substation	Supplying Utility	Supply Circuit #	3-Ph. Max. SC Amps	3-Ph Min. SC Amps	3-Phase SC X/R	Phase-Gnd. SC Amps
Redbridge	Eversource (Formerly	850-1308 (STA. 850 Q BUS)	12kA	n/a	11.8 **	5kA

	NSTAR)	850-1315 (STA. 850 S BUS)				
Pearl Street	Eversource (Formerly NSTAR)	250-1N35H (N.C.) 250-1N38H (N.C.)	14.3kA	9.7kA	13 **	8.3kA
Ball Square	MBTA Ring Feeders	TBD	TBD	TBD	TBD	TBD

** X/R ratios are approximate. Designer shall use X/R of 15 for a conservative approach.

(TBA is for information that is awaited from Eversource (Formerly NSTAR))

2. The substation 15 kV bus tie breaker Device 52-BT will be operated normally-open. For substations with three AC busses, two Bus-tie breakers will be provided and interlocked according to the project requirements. One 52-BT will be operated normally open, the other normally closed. Additional interlocking as specified in Section 2.01 will be required,
3. Voltage at the substation 15 kV buses during light and heavy traction load periods is expected to vary from a maximum of 14.4 kV to a minimum of 13.2 kV.
4. The rectifiers and DC switchgear assemblies specified herein will supply DC traction power to the MBTA Green Line 600Vdc distribution system.
5. It is expected that this installation, if properly manufactured and installed, will not present harmonic or other interference problems for public telephone systems and the MBTA's two-way communication system and signal systems. Should such problems arise, the DB Entity shall give immediate and full engineering assistance to the MBTA in determining proper corrective measures, including preparation of specifications for additional equipment, if required.

C. Equipment Control, Supervision and Alarms

1. General

- a. The switchgear and rectifier equipment furnished by the DB Entity shall be provided with protective, control and interlocking features to safeguard personnel and the various pieces of equipment. It shall permit local, HMI workstation and supervisory control as specified herein and as shown on Design Documents. The Contract Specifications and Drawings indicate the basic protection and control requirements which shall be implemented. However, the DB Entity may submit alternate schemes to the MBTA for consideration and acceptance.
- b. The listed devices included in the discussion hereinafter so that the DB Entity can have a more complete understanding of the integration of the equipment.

- c. The actual equipment is specified elsewhere in this Section. For purposes of discussion, the following device numbers are used, which shall also be used on DB Entity's schematic and wiring diagrams, arrangement drawings, and bill of materials (Note – not all device numbers are used):

DEVICE NO.	FUNCTION
01 – Master Element (e.g. Control Switch)	
01	AC circuit breaker remote control switch (located on station 15 kV control and instrument panel)
01-R	Rectifier 15 kV AC circuit breaker remote control switch (located on rectifier DC main breaker, Device 72R)
11 – Communications Failure	
11	Communications watchdog relay. DC equipment - IED – loss of power or communications failure.
111	Communications watchdog relay. AC equipment IED – loss of power or communications failure.
04 – Master Contactor	
04	Rectifier master control relay
25 – Sync Check relay	
25	Sync check relay (AC breaker interlocking)
26 – Apparatus Thermal Devices	
26R 26RX	Rectifier heat sink over-temperature - Alarm - Auxiliary relay for 26R
26RH 26RHX	Rectifier heat sink over-temperature - Trip - Auxiliary relay for 26RH
26T 26TX	Rectifier transformer oil over-temperature (alarm) - Auxiliary relay for 26T
26TH	Rectifier transformer oil over-temperature (trip)
27 – Undervoltage Relays	
27B1 27B2	15 kV Bus 1 and Bus 2 - Bus differential relay DC supply undervoltage
27BA	AC output circuit undervoltage relay
27BB	DC output circuit undervoltage relay
27Q	Oil Containment – Sump Pump – Supply Fail
27R	Rectifier - DC circuit undervoltage – Lockout relay
27RA	Rectifier/transformer DC auxiliary circuit undervoltage relay
27RB	Rectifier reliable AC supply under-voltage relay
27SA	DC switchgear reliable AC supply undervoltage relay
27SB	DC switchgear DC auxiliary circuit undervoltage relay
30 – Annunciator Relay	
30	Annunciator
30X	Auxiliary relay for Device 30

DEVICE NO.	FUNCTION
32 – Directional Power Relay	
32	Rectifier DC breaker directional/reverse current instantaneous overcurrent trip device
32X/32PX	Auxiliary relay for Device 32
33 – Position Switches	
33R	Rectifier compartment door safety interlock
33T	Rectifier transformer compartment door safety interlock
33	Substation door alarm
43 – Manual Transfer or Selector Device	
43	AC breaker control mode selector switch
47 – Phase Sequence / Phase Balance Voltage Relays	
47-1 47-2 47-3	15 kV bus 1, 2 and 3 phase sequence/undervoltage
47-1X	Time delay relay for bus No. 1 under-voltage alarm
48 – Incomplete Sequence Relay	
48	Rectifier incomplete starting sequence relay
49 – Machine or Transformer Thermal Relays	
49WT	Rectifier transformer winding overtemperature (alarm)
49WTH	Rectifier transformer winding overtemperature (trip)
50/51 – Instantaneous & Timed Overcurrent Relays	
50/51	Phase
50N/51N	Ground
51 – AC Timed Overcurrent Relays	
51	Phase
51C	Cable overload detection
51CX	Auxiliary relay for Device 51C
51N	Ground
51R	Rectifier overload detection
52 – AC Circuit Breaker	
52-RF	Ring Feeder
52-BT	Bus Tie
52-F	Feeder
52-L	Line (Sub-transmission system)
52-T	Rectifier Transformer
58 – Rectification failure relay	
58A	Diode failure monitoring relay (alarm) – single diode failure
58AX	Auxiliary relay for Device 58AX
58T	Diode failure monitoring relay (trip) – multiple diode failure

DEVICE NO.	FUNCTION
59 – Overvoltage relay	
59	DC output circuit overvoltage relay
62 – Time-delay stopping or opening relay	
62	Time delay relay
63 – Pressure switches	
63MR	Pressure relief device
63P	Sudden pressure relay (for oil-filled transformers) -
63PX	Lockout Relay
64 – Ground Detector Relays	
64R	Rectifier ground relay, hot structure (trip)
64RX	Rectifier ground relay, grounded structure (alarm)
67 – AC Directional Overcurrent Relay	
67	Directional overcurrent relay - phase
67N	Directional overcurrent relay – ground
71 – Level Switches	
71T	Oil level relay (for oil-filled transformers)
71W	Oil Containment – High Water Level
72 – DC Circuit Breaker	
72R	Rectifier DC circuit breaker
74 – Alarm Relays	
74, 74X	Alarm auxiliary relays
83 – Automatic Selective Control or Transfer Relay	
83	Reliable AC power source inverter – transfer to inverter
83A	Reliable AC power source automatic transfer switch – transfer to standby supply
86 – Lockout Relay	
86-T1	Rectifier No. 1 lockout relay, hand reset
86B-1	Bus No. 1 bus differential lockout relay, hand reset
86X-T1	Rectifier No. 1 conditional lockout relay, electrically reset
87 – Differential Protective Relay	
87B-1	Bus differential relay for bus No. 1
89 – Line Switch	
89N	Rectifier negative lead disconnect switch
Custom Device Numbers	
95D	Annunciator flasher and bell cutoff relay
98	Rectifier Diode failure
98A	
98T	
99Q	Oil Containment – Oil Detected - Alarm

DEVICE NO.	FUNCTION
99Y	Rectifier surge protection auxiliary circuit monitoring relay
101	DC circuit breaker local control switch
102	DC feeder reclosing cycle timer
102X	Auxiliary for Device 102
127	Reliable AC control supply undervoltage relay
129	DC feeder load measuring contactor
143	DC breaker control mode selector switch
150M	DC feeder multifunction instantaneous, time overcurrent and rate-of-rise relay
164S	DC switchgear ground relay, hot structure (alarm)
164SX	DC switchgear ground relay, grounded structure (alarm)
169	DC feeder permissive setup relay
172	DC traction feeder circuit breaker
176	DC feeder breaker instantaneous series (direct acting) trip device
176F	DC feeder breaker timed overcurrent trip device – may be combined in 150M multi-function relay
182	DC feeder load measuring relay
183	DC feeder voltage measuring transfer relay
197X	DC feeder cable energized monitoring relay
201C	Supervisory interposing relay (close)
201T	Supervisory interposing relay (trip)
AM	Ammeter
A-XD	Current transducer
CS	AC circuit breaker local control switch (located on AC breaker cubicle)
HAM	Heater Ammeter
HS	Heater selector switch
IA	Isolation Amplifier
LMR	Load measuring resistor
LMBP	Load measuring by-pass switch
VS	Voltage selector switch
V-XD	Voltage transducer

2. Basic Breaker Control and Interlocking.

- a. The control circuits of 15kV AC and all 750 Volt DC traction circuit breakers shall be arranged for the following:

- (i) LOCAL Local control (for the 15kV AC switchgear this is either at the circuit breaker or at the ACCP);
- (ii) HMI Remote control via the local PLC via the HMI;
- (i) SUPERVISORY Remote control via the MBTA's SCADA system.
- (ii) OFF

Each of these circuit breakers shall be provided with a four position control mode selector switch, Device 43 and Device 143, for transferring the circuit breaker between local control, workstation control (HMI) and supervisory control. The selector switch positions shall be "LOCAL", "HMI", "OFF", "SUPV". The selector switch positions shall be "LOCAL", "HMI", "OFF", "SUPV". The switch shall be integrated into the SAS system via the DIO device at the ACCP. The switch position status shall be reported to SCADA system via the substation automation system.

- b. All control switches (Device CS, Device 01 and Device 101) shall be provided with green and red indicating LED lights, mounted above the switch, green at left, red at right. For circuit breakers with stored energy type operating mechanisms the red light shall be connected in series with the trip coil to monitor the trip circuit; in addition, a third white indicating LED shall be provided at the breaker to indicate mechanism-charged condition. The LED lights shall be provided with nameplates as follows:
 - (i) Green LED "BREAKER OPEN"
 - (ii) Red LED "BREAKER CLOSED"
 - (iii) White LED "SPRING CHARGED"
- c. Control switch Device 01 and associated indicating lights, and the control mode selector switch Device 43, for all 15 kV circuit breakers except Device 52-T, shall be located on the 15 kV circuit breaker control and instrument panel/ AC Control Panel as specified in Article 1.06.C.2.e below and Article 2.07 of this Section.
- d. A local control switch Device CS with indicating lights shall be provided in front of each 15 kV switchgear unit to allow the following functions:
 - (i) Close the circuit breaker only when the removable element is in the "TEST" position;
 - (ii) Trip the circuit breaker when the removable element is either in the "OPERATING" or "TEST" position (Note: a 52-T trip when the a 52-T breaker is in the "OPERATING" position will also trip the associated 72-R breaker if the 72-R breaker is closed and in the "CONNECTED" position).
- e. Control circuits of all 15 kV circuit breakers except Device 52-T shall be arranged to provide the following scheme of operation:
 - (i) With the 43 switch in the "SUPERVISORY" position local closing functions will be disabled and the circuit breaker can be closed only via the MBTA's

supervisory systems and only when the removable element is in the "OPERATING" position. Tripping function of the control switch, Device 01, at the 15 kV circuit breaker control and instrument panel (ACCP) will be disabled and the circuit breaker can be tripped via the supervisory systems only when the circuit breaker removable element is in the "OPERATING" position, or by the control switch, Device CS, at the 15 kV switchgear.

- (ii) With the 43 switch in the "LOCAL" position i.e. operable from the ACCP, all supervisory control functions will be disabled. When the removable element is in the "OPERATING" position, the closing function of the control switch at the 15 kV AC switchgear will be disabled and the circuit breaker can be closed only by the control switch at the 15 kV circuit breaker control and instrument panel (ACCP), the circuit breaker can only be tripped by the control switches at the control panel and at the AC switchgear. When the removable element is in the "TEST" position, the closing and tripping functions of the control switch at the 15 kV circuit breaker control and instrument panel will be disabled and the circuit breaker can be closed and tripped only from its control switch at the 15 kV switchgear.
 - (iii) With the 43 switch in the "HMI" position, all supervisory control functions will be disabled. When the removable element is in the "OPERATING" position, the closing function of the control switch at the 15 kV AC switchgear will be disabled and the circuit breaker can be closed only by the HMI, the circuit breaker can only be tripped by the HMI, or the control switches at the AC control panel and at the AC switchgear. When the removable element is in the "TEST" position, the closing and tripping functions of the control switch at the 15 kV circuit breaker control and instrument panel will be disabled and the circuit breaker can be closed and tripped only from its control switch at the 15 kV switchgear.
 - (iv) With the 43 switch in the "OFF" position, all local, HMI and supervisory control functions will be disabled, except the tripping function of the control switch Device CS at the AC switchgear, if the removable element is in the "OPERATING" position.
- f. Rectifier AC circuit breaker Device 52-T control switch, Device 01-R, and indicating lights and the control mode selector switch, Device 43, shall be located on the front of the rectifier main DC circuit breaker unit, Device 72-R. The rectifier main DC circuit breaker control switch Device 101 and indicating lights shall also be located on the front of the main DC circuit breaker unit. In addition, a control switch Device CS with indicating lights shall be provided on the front of the rectifier 15 kV AC circuit breaker unit 52-T to close the breaker only when the removable element is in the "TEST" position and trip the circuit breaker when the removable element is either in "OPERATING" or "TEST" position. Circuit breaker Device 52-T control circuits shall be configured to provide the following schemes of operation:
- (i) With the 43 switch in the "SUPERVISORY" position, local and HMI closing functions will be disabled and the rectifier AC and DC circuit breakers, Devices 52-T and 72-R, can be closed only via MBTA's supervisory systems and only when the respective circuit breaker removable elements are in the

"OPERATING" position. Tripping function of the rectifier AC circuit breaker control switch on the DC circuit breaker, Device 01-R, and the tripping function at the HMI will be disabled and the AC circuit breaker can be tripped via the supervisory systems if the circuit breaker removable element is in the "OPERATING" position.

- (ii) With the 43 switch in "HMI" position, all supervisory functions will be disabled and all LOCAL functions will be disabled and the rectifier AC and DC circuit breakers, Devices 52-T and 72-R, can be closed only via HMI system and only when the respective circuit breaker removable elements are in the "OPERATING" position. Tripping function of the rectifier AC circuit breaker control switch on the DC circuit breaker, Device 01-R, will be disabled and the AC circuit breaker can be tripped via the HMI system if the circuit breaker removable element is in the "OPERATING" position. Closure of rectifier AC circuit breaker shall automatically close the rectifier DC breaker as described in Article 1.06, paragraph C.3, of this Section
- (iii) With the 43 switch in "LOCAL" position, all supervisory and HMI functions will be disabled. When the removable elements of the rectifier AC and DC circuit breakers are in the "OPERATING" position, the closing function of the AC circuit breaker control switch Device CS on the 15 kV switchgear will be disabled and the rectifier AC circuit breaker can be closed only by its Device 01-R control switch on the rectifier DC circuit breaker. Closure of rectifier AC circuit breaker shall automatically close the rectifier AC breaker as described in Article 1.06, paragraph C.3 of this Section. With the circuit breaker removable element in the "OPERATING" position, the rectifier AC circuit breaker can be tripped by the Device 01-R control switch on the DC circuit breaker unit and by the Device CS switch on the 52-T breaker. The rectifier DC circuit breaker can be tripped from its Device 101 control switch on the DC switchgear. When the rectifier AC circuit breaker removable element is in the "TEST" position, the closing and tripping function of the Device 01-R control switch on the 72-R unit will be disabled and the 52-T circuit breaker can be closed and tripped only from its control switch Device CS. Similarly, the rectifier DC circuit breaker 72-R, when racked into "TEST" position, can be closed and tripped only from its Device 101 control switch on the DC switchgear.
- (iv) With the 43 switch in the "OFF" position, both the local, HMI and supervisory control functions will be disabled except the following:
 - (a) Tripping function of the rectifier AC circuit breaker control switch Device CS at the 15 kV switchgear
 - (b) Tripping function of the DC circuit breaker control switch Device 101 at the DC switchgear, provided that the circuit breaker removable element is in the "OPERATING" position.
- (v) The control scheme for the rectifier transformer AC breaker Device 52-T is summarized in the following table.

Breaker Position	Control Switch Being Actuated (and location)	Status of Breaker 52-T Control Switch According to Breaker Device 43 Position					
		43-L (LOCAL)		43-S (SUPV.) or 43-H (HMI)		43-O (OFF)	
		close	trip	close	trip	close	trip
OPERATING	CS	NO	YES	NO	NO	NO	YES
TEST	on 52-T	YES	YES	NO	NO	NO	NO
OPERATING	01-R	YES	YES	NO	NO	NO	NO
TEST	on 72-R	NO	NO	NO	NO	NO	NO

(vi) The control scheme for the rectifier DC breaker Device 72-R is summarized in the following table.

Breaker Position	Control Switch Being Actuated (and location)	Status of Breaker 72-R Control Switch According to Breaker Device 43 Position					
		43-L (LOCAL)		43-S (SUPV.) or 43-H (HMI)		43-O (OFF)	
		close	trip	close	trip	close	trip
OPERATING	101 (on 72-R1)	NO	YES	NO	NO	NO	YES
TEST	101 (on 72-R1)	YES	YES	NO	NO	NO	NO

g. In addition to the above 52-T control features, the rectifier circuit shall be provided with a 'transformer soak' mode within the SAS system. This mode will enable the MBTA to energize the rectifier and transformer and leave energized without connection to the DC bus. This would be used to 'soak' the rectifier transformers, or keep them operating while the DC switchgear and/or cable work is being completed over a pro-longed period.

- (i) Initiating the "Soak" would only be allowed with 52-T/72-R 43 device in the HMI position. The requirements for the control and switch positions per 16311.1.06.C.2.f still apply when the 43 device is in the HMI position. Separate functions to be provided for each rectifier/rectifier transformer circuit.
- (ii) AC switchgear bus/lockout protection, Transformer and rectifier protection would still be active and trip the AC Breaker (as if the DC breaker was connected), including SAS loss of communications.

- (iii) To achieve this, the SAS shall be provided with a separate on-screen button to allow 'Xfmr soak override' to be initiated. To initiate override 43 switch must be in HMI, 72-R breaker must be OPEN and in NOT CONNECTED/DISCONNECTED position, no 86T or 86B lockout in place, 52-T in CONNECTED/OPERATING position, 89N should be open.
 - ** NOTE: that in soak override mode the open position of 89N for the respective rectifier needs to be disabled in the rectifier lockout circuit – proposed methodology is that when personnel setup the circuit the open 89N will activate the 86T lockout (prior to selecting soak mode on the HMI). When soak mode is initiated this should enable the lockout to be reset/or should reset it automatically but only if 89N is the only lockout activator i.e. a check routine on the 86T lockout inputs). The 89N open status will be disabled from the 86T lockout circuit until ‘soak override’ is cancelled. The remaining functions of the 86T lockout will remain and activate the lockout if operated. **
 - (iv) Closure of the circuit may only be done from the HMI and would be as normal for energizing the rectifier i.e. operate command for close 52-T/72-R; 52-T shall close but 72-R closure shall not occur i.e. the timing circuit for DC breaker closure and incomplete sequence (device 48) monitoring following AC breaker closure that is used under normal rectifier energization is not required.
 - (v) The closure of 72-R will be inhibited while in 'soak override'.
 - (vi) Once soak mode has been initiated through the HMI and the 52-T breaker has closed the 43 device shall be operable.
 - (vii) Tripping of the circuit can only be achieved only via the HMI system in HMI mode, via the CS on the 52-T breaker, via SCADA when 43 device is in REMOTE or HMI position or by operation of the 01-R on 72-R when in LOCAL.
 - (viii) Tripping 52-T shall cancel the ‘soak override’ mode.
 - (ix) The following actions shall also trip the 52-T breaker:
 - (a) Closure of the 89N switch shall should trip the 52-T breaker and cancel the ‘soak override’ mode.
 - (b) The 72-R being placed in CONNECTED position should trip the 52-T breaker and cancel the ‘soak override’ mode.
 - (x) In addition, status indication of ‘XFMR ## IN SOAK OVERRIDE IN EFFECT’ should be provided to the SCADA system for indication to the Power Control Center.
- h. DC traction feeder circuit breaker control switch, Device 101, associated indicating lights and the control mode selector switch, Device 143, shall be located on the front of the circuit breaker unit, Device 172. The control circuit of the circuit breaker will be provided with load measuring and automatic reclosing features described in

Article 1.06.C.4 of this Section. Circuit breaker control circuit shall be configured to provide the following scheme of operation:

- (i) With the 143 switch in the "SUPERVISORY" position, local and HMI closing functions will be disabled and the closing (load measuring) cycle can be initiated only via MBTA's supervisory systems and only when the circuit breaker removable element is in the "OPERATING" position. Breaker can be tripped via local control switch 101.
 - (ii) With the 143 switch in the "HMI" position, supervisory and local closing functions will be disabled and the closing (load measuring) cycle can be initiated only via the HMI system and only when the circuit breaker removable element is in the "OPERATING" position. Breaker can be tripped via local control switch 101.
 - (iii) With the 143 switch in the "LOCAL" position, the supervisory control functions and HMI system will be disabled. The closing (load measuring) cycle can be initiated and the circuit breaker tripped only from its control switch and only when the breaker removable element is in the "OPERATING" position. With the breaker removable element in the "TEST" position, the breaker can be closed and tripped only from its control switch, initiating the load measuring cycle, but not actuating the load measuring contactor, Device 129.
 - (iv) With the 143 switch in the "OFF" position, local, HMI and supervisory closing functions and supervisory tripping functions will be disabled. The circuit breaker can be tripped by its local control switch, if the circuit breaker removable element is in the "OPERATING" position.
- i. At all locations, the control mode selector switches, Device 43 and Device 143, shall be mounted directly above their respective breaker control switches Devices 01, 01-R and 101.
 - j. The protective device and relay circuitry of circuit breakers shall not be affected by the control mode selector switches, Device 43 and Device 143; when actuated, these devices shall trip their respective breakers regardless of the position of the 43 and 143 switches. Similarly, these devices shall trip their devices regardless of the status of the communications system associated with substation automation i.e. the breaker and its associated protection relay(s) shall operate independently of the SAS system.
 - k. Control circuits of the 15 kV circuit breakers shall be so arranged that manual trip or trip via supervisory systems will not actuate circuit breaker auto trip alarm.
 - l. For substations with two AC 13.8kV busses, the 15 kV switchgear is normally operated with the tie circuit breaker between the two bus sections, Device 52-BT, open. At substations with three 13.8kV busses, the 15 kV switchgear is normally operated with one tie circuit breaker between two bus sections, Device 52-BT1, open and the other, Device 52-BT2, closed, or vice versa.
 - m. In the event of the loss of an incoming line at any substation, the open bus-tie breaker shall be closed. Any closed 52-RF breakers connected to the affected source shall be tripped.

- n. In the event of the loss of both incoming lines at Red Bridge or Pearl Street substations, the associated ring feeder circuit breaker shall be closed to supply power one half of the AC circuits at the affected substation.
- o. 15kV AC Circuit Breaker interlocking shall be required as follows:
 - (i) 52-L (incoming line circuit breaker) (Subject to approval by Eversource (Formerly NSTAR))
 - (a) At 2 bus substations: 2 out of 3 interlocking for 52-L1, 52-L2, 52-BT (i.e. only 2 out of the 3 listed circuit breakers can closed at any one time). This shall be hardwired within the AC switchgear equipment
 - (b) Breaker can only be closed if the associated 15kV AC bus is not energized.
 - (ii) 52-BT (Bus Tie breaker) (Subject to approval by Eversource (Formerly NSTAR))
 - (a) At 2 bus substations: 2 out of 3 interlocking for 52-L1, 52-L2, 52-BT. This shall be hardwired within the AC switchgear equipment
 - (b) Breaker cannot be closed while both busses either side of the BT breaker are energized.
 - (iii) 52-F (Feeder circuit breaker)
 - (a) For circuit breakers supplying unit substations refer to key interlocking requirements in Section 16203 Article 1.13.
 - (iv) 52-RF (Ring Feeder Circuit breaker.)
 - (a) Breaker cannot be closed when line side and load side of circuit breaker are energized.

3. Rectifier Control

Under substation automation the functionality of the rectifier controls shall be as stated below. The functions shall be employed within the software programming of the substation automation PLC. The operating logic is provided in the Design Documents. All such programming shall be centrally located at the PLC and not distributed to IEDs/DIOs within the substation. Input/output modules shall be provided as necessary to interface the equipment with the PLC. The lockout functions shall be programmed within the substation SAS and manually reset using at the HMI.

- a. Rectifier equipment shall be started by energizing the operating coil of the latching type master control relay, Device 4. This can be accomplished, depending on the positioning of rectifier AC circuit breaker control mode selector switch, Device 43, by operating the rectifier AC circuit breaker control switch, Device 01-R, or remotely via supervisory control through operation of the supervisory closing relay, Device 201C. Note that the rectifier equipment shall be able to be energized locally while the associated DC breaker Device 72-R is in the disconnected position. The following shall prevent energization of Device 4 operating coil:
 - (i) Operation of rectifier lockout relay, Device 86-T
 - (ii) Operation of rectifier conditional lockout relay, Device 86X-T.

- (iii) Operation of bus differential lockout relay, Device 86B, for the 15 kV bus section supplying the rectifier.
 - (iv) Loss of voltage to rectifier lockout relay control circuit, as detected by Device 27R.
- b. Energization of Device 4 operating coil shall cause closure of the rectifier transformer 15 kV circuit breaker, Device 52-T and start the timing cycle of the incomplete sequence relay, Device 48. Closure of breaker 52-T shall energize the closing circuit of the rectifier DC breaker, Device 72-R, but only if Device 72-R is in the CONNECTED/OPERATING position. Failure of breaker 72-R to close and remain closed within the preset length of time will cause Device 48 to operate which shall result in rectifier lockout.
 - c. After closure of rectifier AC and DC circuit breakers, an "a" contact from each of the two breakers, connected in series, shall energize the Device 4 reset coil, setting up the master control relay for the next rectifier starting operation. Device 4 reset coil shall also be energized by a reset operation for Device 86-T, provided that Device 48 has completed its timing cycle.
 - d. Shutdown of the rectifier (via the 52-T breaker) shall be accomplished, depending on the positioning of Device 43, locally by operating the rectifier AC breaker control switches Devices CS or 01-R (if Device 43 selector switch is set to "LOCAL"), or via the HMI or remotely via the supervisory control through operation of the supervisory trip relay, Device 201T.
 - e. Automatic shut-down of the rectifier shall be caused by operation of Devices 86-T, 86X-T, 86B, and 27R. The rectifier shall be shut down by these devices via direct tripping of the rectifier transformer 15 kV breaker 52-T, regardless of the positioning of Device 43. The rectifier shall also shut down upon failure of the respective components of the substation automation system
 - f. The following devices shall operate Device 86-T and cause shutdown of the rectifier unit until Device 86-T is manually reset. This type of shut-down is termed LOCKOUT. Loss of AC control power shall not cause operation of any of these devices.
 - (i) Open door on rectifier diode and positive 600 Volt bus compartment, Device 33R.
 - (ii) AC fault, Devices 50/51 and 50N/51N.
 - (iii) Equipment overload detected by AC relay, Device 51R.
 - (iv) Incomplete starting sequence, Device 48.
 - (v) Rectifier negative disconnect switch open, Device 89N.
 - (vi) Operation of rectifier DC breaker directional overcurrent trip device, Device 32.
 - (vii) Operation of "rectifier hot structure" relay, Device 64R.
 - (viii) Operation of transformer sudden pressure relief, Device 63P.

- (ix) Operation of transformer low oil level trip, Device 71T.
 - (x) Multiple diode failure monitoring relay trip, Device 58T.
- g. The following overtemperature devices shall energize the Device 86X-T operating coil and cause shutdown of the rectifier unit until the normal condition is restored. This type of shut-down is termed 'CONDITIONAL LOCKOUT'.
- (i) Rectifier diode heat sink overtemperature second step and auxiliary power circuit undervoltage, Devices 26RHX and 27RA.
 - (ii) Transformer winding hot spot overtemperature second step, Device 49WTH.
 - (iii) Transformer oil overtemperature second step, Device 26TH.
- h. Device 86X-T shall be automatically reset by energization of its reset coil when the equipment which caused the conditional lockout has cooled down to safe operating temperatures.

4. DC Traction Feeder Breaker Control

Under substation automation the functionality of the DC circuit breaker controls shall be as stated below. The functions shall be employed within the software programming of the substation automation PLC. Each DC feeder breaker shall self-protect and function independently of the PLC as stated below. Input/output modules shall be provided as necessary to interface the equipment with the PLC.

- a. All DC traction feeder breakers shall be provided with a load measuring scheme to prevent closing of the DC feeder circuit breaker, Device 172, on a faulted circuit. Load measuring circuits shall be provided that are in service during both local and supervisory control of the DC feeder breakers. This circuit shall also permit the testing of the entire load measuring scheme with the circuit breaker removable element in the "TEST" position, including closure of the breaker, except that the operation of Device 129 shall be blocked.
- b. Equipment associated with the load measuring scheme shall include:
 - (i) A load measuring, or resistance measuring relay, Device 182, to measure "feeler" current through a load resistor during the load measuring cycle. Circuit shall be provided with means to allow load measuring only when the voltage drop in the negative return circuit is below a preset value that is adjustable over a range of 10-100 Volts.
 - (ii) A voltage measuring relay, Device 183, with an adjustable range of 300 Volts to 625 Volts, for measuring feeder DC voltage.
 - (iii) A load measuring resistor, Device LMR, for limiting the "feeler" current to approximately 50 Amperes.
 - (iv) A contactor, Device 129, for connecting Device LMR across the open feeder circuit breaker, Device 172.

- (v) Associated accessory devices, as required.
- c. The load measuring system shall be insensitive to variations in DC bus voltage from 750 Volts to 300 Volts and shall be arranged to determine feeder load condition automatically, whether connected to an independent (single feed) power section or a multi-feed power section. Traction feeder circuit breaker closing circuit shall be provided with devices which will allow the closing of the circuit breaker at a switchgear bus voltage of 450 Volts or higher. Load measuring circuit and its components will be subject to the acceptance of the MBTA.
- d. Each DC traction feeder circuit breaker shall also be equipped with a scheme for automatic reclosing of the breaker in conjunction with load measuring. Reclosing into unfaulted energized or unfaulted de-energized traction feeder circuits shall occur after a feeder breaker is tripped by automatic protective devices. The automatic reclosing of the circuit breaker shall be initiated by an unsuccessful attempt to close the breaker from its local control switch or via the MBTA's supervisory systems. The reclosing-load-measuring circuitry shall not be actuated if the traction feeder circuit breaker is tripped by its local control switch or tripped via the supervisory systems.
- e. The reclosing cycle, once initiated, shall be continued for a maximum of four cycles (reclosures) and shall be stopped only by one of the following: successful closure of the circuit breaker; lockout upon completion of the minimum number of unsuccessful reclosing cycles; or, by tripping of the breaker permissive setup relay, Device 169, either locally or via supervisory. A cycle timer, Device 102, shall be provided for repeated load measuring and circuit breaker closing on a 14 second cycle, including a four-second interval between the end of load measuring phase and the energization of breaker closing circuit. Circuitry shall provide for anti-pump circuit breaker operation and for verification of resetting of the load measuring devices for each cycle. The initiation of each reclosing cycle shall be indicated to SCADA.
- f. In addition to the above-specified control and protective devices, each DC traction feeder circuit breaker shall be equipped with a direct-acting, series, bi-directional instantaneous trip device, Device 176, adjustable for at least 100 to 400 percent of rated current.
- g. Each DC traction feeder circuit breaker shall be equipped with a microprocessor-based, multifunction feeder protection package Device No. 150M for each DC feeder breaker. Proposed device shall be of proven design in current use and manufacture, and will be subject to the MBTA's acceptance. This device shall include the following features as a minimum. Operation of protection provided by the relay shall be independent of the status of the substation automation system.
 - (i) Current rate-of-rise detection channel providing unidirectional overcurrent detection with target indication, and adjustable initial current slope (di/dt), current step, and time duration.
 - (ii) Instantaneous overcurrent detection channel providing unidirectional high current detection with target indication, and adjustable pickup with maximum pickup setting equal to at least 400% of the feeder breaker frame rating.

- (iii) Short time overcurrent channel (STOC) providing unidirectional overcurrent detection with target indication, and adjustable pickup and time delay based on a family of inverse-time characteristic curves.
 - (iv) Long time overcurrent channel (LTOC) providing unidirectional overcurrent detection with target indication, adjustable pickup and time delay suitable for thermal protection of DC feeder cables and overhead contact systems. LTOC channel operation shall trip the feeder breaker but not lock it out.
 - (v) Adequate shielding for radiated and conducted EMI to prevent false operations from other equipment and devices, including portable radios.
 - (vi) Isolated inputs, rated 5 kV DC for 1 minute, minimum.
- h. The closing and reclosing cycle for the DC traction feeder circuit breaker shall be started by energizing the operating coil of the latching type permissive setup relay, Device 169. This shall be accomplished, depending on the positioning of the circuit breaker control mode selector switch Device 143, locally by operating the circuit breaker control switch, Device 101, or remotely via supervisory closing relay, Device 201C.
 - i. Energization of the Device 169 reset coil shall cause tripping of the circuit breaker or stop the reclosing cycle in case it is in progress. This shall be accomplished, depending on the positioning of Device 143, locally by operating the circuit breaker control switch or remotely via the supervisory control through operation of the supervisory trip relay, Device 201T.
 - j. A key-operated switch shall be provided to bypass the load measuring scheme to permit closing of traction feeder circuit breakers during an emergency, and when the Device 143 is in "LOCAL" position. Closing circuit shall be arranged to provide a ten-second interval between the rotation of the breaker control switch to "CLOSE" position and the energization of breaker closing circuit. A "LOCAL" contact of Device 143 shall be wired in series with the timer so that the timer can be actuated only when Device 143 is in the "LOCAL" position and the load measuring by-pass switch is operated.

5. Supervisory Control and Indication

- a. The MBTA has in operation two independent supervisory systems for remote control of power system AC and DC circuit breakers and for monitoring equipment and auxiliary circuits at their substations: a computer-assisted systemwide SCADA system and a "one-on-one" backup system for each of the individual traction power substations and switching stations. The master station and computer equipment for the SCADA system is located at the MBTA's High Street Operations Center in Boston. The substation SCADA interface shall be provided via the PLC and a traditional SCADA RTU is not required. In addition, the back-up SCADA system RTU (one-on-one) is not required for the Green Line Extension Project.
- b. Under substation automation the functionality of the SCADA operation shall be as stated below. The functions may be employed within the software programming of the substation automation PLC. All such programming shall be centrally located at the PLC and not distributed to IEDs/DIOs within the substation. The substation automation PLC

shall interface with the SCADA system. Input/output modules shall be provided as necessary to interface the SCADA equipment with the PLC.

- c. The DB Entity shall furnish, install and connect interposing relays or PLC software equivalent, Devices 201C and 201T, for proper interfacing of breaker control and indication circuits and contacts with the supervisory systems. The DB Entity shall also provide all contacts, relays and devices necessary for remote monitoring of below-listed equipment and circuits. The interposing relays shall be supplied from the 125 Vdc control bus of the switchgear via fused circuits. The load side of the positive fuse, one side of the interposing relay coil and all supervised status contacts shall be wired to outgoing wiring terminal blocks at new switchgear and rectifier equipment. As necessary to interface substation wiring, the DB Entity shall provide a Supervisory terminal Board (STB). The wiring between the STB and new equipment and any new wiring required between the STB and the supervisory equipment cabinets shall be furnished and installed by the DB Entity.
- d. The following equipment at the substation shall be provided with devices for remote close-trip control and indication (a normally open circuit breaker contact) via the MBTA's Power SCADA system. Independent and separate contacts shall be used for indications via SCADA. Trip/Close control shall also be via independent and separate contacts.
 - (i) 15kV Incoming Line Circuit Breakers (52-L)
 - (ii) 15kV Ring Feeder Circuit Breakers (52-RF)
 - (iii) 15kV Feeder Circuit Breakers (52-F)
 - (iv) 15kV Bus-Tie Circuit Breakers (52-BT)
 - (v) Rectifier transformer 15 kV circuit breakers, Devices 52-T. The interposing relays, Devices 201C and 201T shall start the rectifier transformer breaker closing and tripping cycles by energizing the latching type master control relay, Device 4, and by tripping Devices 52-T as described in Article 1.06.C.3, of this Section.
 - (vi) 750 Volt DC traction feeder circuit breakers, Device 172. The interposing relays, Devices 201C and 201T, shall start the circuit breaker closing cycle and trip the breaker by energizing and resetting the latching type permissive setup relay, Device 169, as described in Article 1.06.C.4, of this Section.
 - (vii) 480V unit substations Main circuit breaker
 - (viii) 480V unit substation bus-tie circuit breaker
- e. Circuits and devices listed below that are furnished and installed under this Contract shall be provided with independent monitoring contacts/points for remote indication via MBTA's SCADA system. All local alarms reported on the annunciator screen on the SAS system HMI (see C.8 below) shall also be provided to SCADA as discrete points.

Item	Alarm Function	Actuating Device
(i)	Position of control mode selector switches for all supervisory-controlled breakers. (Provide SCADA indication contacts for each Device 43 and 143)	Device 43 Device 143
(ii)	Rectifier DC circuit breakers.	Device 72R
(iii)	DC traction feeder circuit breaker load measuring cycle in progress	Device 102 or 102X
(iv)	Rectifier lockout relays	Device 86-T
(v)	15kV Bus Lockout Relays	Device 86-B
(vi)	15kV Bus Differential Relays	Device 87-B
(vii)	15kV Phase Loss/Undervoltage Relays	Device 47
(viii)	DC feeder circuit breaker trip via the instantaneous direct acting series overcurrent trip un	Device 176
(ix)	DC feeder circuit breaker trip via the rate-of-rise channel of multifunction relay	Device 150M
(x)	DC traction feeder circuit breaker trip via the timed overcurrent channel of multifunction relay May be combined with device 150M	Device 176F
(xi)	DC traction feeder cable energized indication	Device 197X
(xii)	13.8 kV feeder cable overload auxiliary relay	Device 51CX
(xii)	13.8 kV feeder breaker overcurrent Instantaneous / Overcurrent phase / Overcurrent Neutral	Device 50/51/51N
(xiii)	Station Battery Trouble	
(xiv)	Substation access door alarm	Device 33
(xv)	Negative disconnect switch open.	Device 89N
(xvi)	Rectifier structure alive/grounded	Device 64R Device 64RX
(xvii)	DC switchgear structure alive/grounded	Device 164S Device 164SX
(xviii)	Rectifier DC breaker reverse current trip	Device 32
(xvix)	Room high temperature and room low temp alarm	
(xx)	Rectifier transformer sudden pressure relief trip	Device 63P
(xxi)	Rectifier/Transformer over-temperature	Device 49WT / 26T / 26R (combined indication)
(xxii)	Oil containment sump pump fail or power failure (if applicable)	
(xxiii)	PLC / Communications Healthy	Device 11 / 111
(xxiv)	Rectifier Transformer in Soak Override	-

6. Telemetry Requirements

- a. Under substation automation the provision of analog metering shall be as stated below. The functions may be employed within the software programming of the substation automation PLC. All such programming shall be centrally located at the PLC and not

distributed to IEDs/DIOs within the substation. Input/output modules shall be provided as necessary to interface the equipment with the PLC.

- b. The DB Entity shall furnish, install and connect all measuring devices, transducers, amplifiers, totalizers, resistors and all other devices necessary for providing proper inputs to the MBTA's SCADA system for remote telemetering of below-listed quantities. The transducers shall have the characteristics specified in Section 16203, Article 1.11. The telemetering signal circuits shall be wired to outgoing wiring terminal blocks at the switchgear. As necessary, the circuits shall be extended by the DB Entity through the interface Supervisory Terminal Board (STB) to the supervisory equipment, as described in Article 1.06.C.5 of this Section for supervisory control and indication circuits.
 - c. The following power quantities shall be provided with devices for telemetering:
 - (i) Voltage of each 15 kV switchgear bus section (signals from bus voltage transducers). One voltage per bus section required.
 - (ii) Phase B current of each 13.8 kV feeder circuit except rectifier transformer (signals from current transducers).
 - (iii) Voltage of 600 Volt nominal DC switchgear bus (signal from voltage transducer). One required.
 - (iv) Kilowatt hour demand of each 13.8 kV feeder circuit.
 - (v) Totalized kilowatt hour demand of the 13.8 kV sub-transmission system supply feeder circuits. One per 13.8 kV bus section required.
 - (vi) DC traction feeder current (signal from feeder shunt through isolation type transducer). One per feeder breaker required.
 - (vii) Rectifier DC output current (signal from rectifier shunt through isolation type transducer). One per rectifier breaker required.
 - (viii) Totalized kilowatt hour demand of the 13.8 kV sub-transmission system supply feeder circuits (52-L1 and 52-L2). The totalizer shall be located at the AC common control panel.
 - (ix) Totalized DC kilowatt hour demand of the Traction power supply main circuits (72-R1 and 72-R2). The totalizer shall be located in the DC switchgear.
7. Ground Detection/Hot Structure of Rectifier and DC Switchgear
- a. Rectifier and DC switchgear shall be installed with enclosures insulated from ground, from the substation building structure and from each other. For the rectifier and the DC switchgear lineup, the DB Entity shall provide a set of ground detection equipment, including:
 - (i) High resistance ground relay, Device 64R, for rectifier;
 - (ii) High resistance ground relay, Device 164S, for DC switchgear;

- (iii) Solid state rectifier for auxiliary DC power supply (copper oxide or selenium rectifiers are not acceptable);
 - (iv) Relay, Device 64RX, for monitoring the continuity of the Device 64R detecting circuit and associated devices, for continuous monitoring of the insulation of the rectifier enclosure from station ground and negative bus and from rectifier positive bus and components operated at bus potential; and
 - (v) Relay, Device 164SX, for monitoring the continuity of the Device 164S detecting circuit and associated devices, for continuous monitoring of the insulation of the DC switchgear enclosure from station ground and negative bus and from DC switchgear positive bus and components operated at bus potential.
- b. Ground detection equipment shall be rated for operation on 120 Volts, 60 Hz, supplied from the reliable AC source at the AC control and instrument panel or 125V DC control power. The ground relay, monitoring relay and associated circuit components shall be rated for 750 Volt DC service, minimum.
 - c. For the rectifier, the Device 64R shall be set to pick up at 50 Volts positive potential of the high resistance grounded rectifier structure or enclosure and shall cause lockout and de-energizing of the rectifier as described in Article 1.06.C.3 of this Section. Pickup of Device 64R shall also provide local alarm on annunciator Device 30 and remote indication via supervisory. Electrical contact of a transformer secondary lead to the ungrounded structure or enclosure shall also cause rectifier lockout. Device 64RX shall provide local alarm on Device 30 and remote indication, via supervisory, in the event of loss of AC control power, opening of the ground detection circuit or an electrical contact of the ungrounded structure to ground or the negative bus. Device 64RX alarm and remote indication circuits shall be provided with two second time delay to override momentary dips in the AC control power supply.
 - d. For the DC switchgear, Device 164S shall be set to pick up at 50 Volts positive potential of the high resistance grounded switchgear structure or enclosure and shall provide local alarm on Device 30 and remote indication via supervisory. Device 164SX shall provide local alarm and remote indication, via supervisory, in the event of opening of the ground detection circuit or an electrical contact of the ungrounded structure to ground or negative bus. Device 164S shall not be activated during the normal fault clearing operation of the rectifier AC circuit breaker. Device 164SX alarm and remote indication circuits shall be provided with a two-second time delay to override momentary dips in the AC control power supply.
 - e. For the DC switchgear assembly, the DB Entity shall provide a 120 Vac alarm bell, supplied from the reliable 120 Volt AC or 125V DC control bus of the DC switchgear through a set of fuses, energized by operation of Device 164S. The bell shall be wired through each personnel access substation door switch, to prevent operation during substation unattended periods. An adjustable timer shall be provided to limit the bell operation. In addition, the DB Entity shall provide for the DC switchgear assembly a flashing illuminated sign bearing the legend "SWITCHGEAR FRAME ALIVE", supplied from the 125 Volt DC control bus of the DC switchgear through a set of fuses, also energized by operation of Device 164S. The sign shall be prominently mounted on the switchgear assembly. The alarm bell circuit shall be provided with a relay to energize the warning sign. The warning sign shall also be energized in the event of the 120 Volt

AC or 125V DC alarm supply failure. The alarm devices and the warning sign shall be insulated from switchgear enclosure for a minimum of 1,000 Volts DC.

- f. All ground detection alarm, supervisory and auxiliary circuits requiring external connections shall be wired to outgoing wiring terminal blocks for connection to field wiring.

8. Local Alarm

- a. Each of the following trouble conditions of substation equipment and circuits shall be provided with an alarm point on the local HMI that shall be installed at each substation. Each alarm point shall be available to SCADA.

- (1) HMI Annunciation

Item	Alarm Function	Actuating Device
1.	Rectifier #1 lockout (for Rectifier #1)	86-T1
2.	Rectifier #1 conditional lockout	86X-T1
3.	Rectifier/transformer #1 DC auxiliary supply failure	27RA
4.	Rectifier/transformer #1 AC auxiliary supply failure	27RB
5.	Rectifier #1 surge protection circuit failure	99Y
6.	Rectifier #1 heat sink overtemperature	26RHX
7.	Rectifier #1 Diode Failure/Fuse Blown	98/58A/58T
8.	Rectifier #1 structure grounded	64RX
9.	Rectifier #1 structure hot	64R
10.	Rectifier #1 incomplete start	48
11.	Rectifier #1 door open	33R
12.	Rectifier Transformer #1 oil/winding overtemperature	26TH/ 49WTH
13.	Rect. Transformer #1 Low Oil Level Alarm (oil filled xfmrs only)	71-T1
14.	Rect. Transformer #1 Sudden Pressure Relay/Pressure Relief (oil filled xfmrs only)	63P-1/63MR-1
15.	Rectifier #1 negative disconnect switch open / closed	89N-1
16.	72-R1 Main DC breaker reverse current trip	32X
17.	72-F DC feeder breaker Rate of rise	150
18.	72-F DC feeder breaker Direct Acting Overcurrent	176
19.	72-F DC feeder breaker Timed/backup overcurrent	176F
20.	72-F DC feeder breaker Load measuring	182 / 183 / 102
21.	DC switchgear structure grounded	164SX
22.	DC switchgear structure hot	164S

Item	Alarm Function	Actuating Device
23.	DC protective relay / IED Device failure	111
24.	15 kV Bus 1, 15kV Bus 2, 15kV Bus 3 lockout	86B-1/ 86B-2/ 86B-3
25.	15 kV Bus 1, 15kV Bus 2, 15kV Bus 3 differential	87B-1/ 87B-2/ 87B-3
26.	15 kV feeder cable overload	51CX
27.	15 kV feeder protective relay	50 / 51 / 51N
28.	15 kV Bus 1 and/or 2 and/or 3 phase loss/undervoltage	47-1, 47-2, 47-3
29.	15 kV Bus 1 and/or 2 differential circuit DC supply failure	27B1, 27B2
30.	15 kV feeder protective relay / IED device failure	11
31.	Oil Containment Sump pump trouble	
32.	Unit Substation Trouble	
33.	Rectifier #2 lockout (for Rectifier #2)	86-T2
34.	Rectifier #2 conditional lockout	86X-T2
35.	Rectifier/transformer #2 DC auxiliary supply failure	27RA
36.	Rectifier/transformer #2 AC auxiliary supply failure	27RB
37.	Rectifier #2 surge protection circuit failure	99Y
38.	Rectifier #2 heat sink overtemperature	26RHX
39.	Rectifier #2 Diode Failure/Fuse Blown	98/58A/58T
40.	Rectifier #2 structure grounded	64RX
41.	Rectifier #2 structure hot	64R
42.	Rectifier #2 incomplete start	48
43.	Rectifier #2 door open	33R
44.	Rectifier Transformer #2 oil/winding overtemperature	26TH/ 49WTH

Item	Alarm Function	Actuating Device
45.	Rect. Transformer #2 Low Oil Level Alarm (oil filled xfmrs only)	71-T2
46.	Rect. Transformer #2 Sudden Pressure Relay/Pressure Relief (oil filled xfmrs only)	63P-2/63MR-2
47.	Rectifier #2 negative disconnect switch open / closed	89N-2
48.	72-R2 Main DC breaker reverse current trip	32X
49.	208/120V AC supply failure	27A
50.	Station battery trouble	59, 27BA, 27BB
51.	Fire	FIRE ALARM PANEL
52.	Fire Alarm Trouble	FIRE ALARM TROUBLE SW.
53.	DC Switchgear 125Vdc supply fail	27SA

D. Protective Device Coordination

1. General

- a. The DB Entity shall furnish protective devices in the switchgear and power rectifier equipment as listed elsewhere in this Section, or as may be required, to provide reliable, coordinated electrical protection for the system. All such devices shall be adjustable and shall be factory calibrated to provide the general scheme of protection outlined below. The DB Entity shall submit to the MBTA, for acceptance, the recommended settings of the protective devices. The recommended settings shall include all settable relay parameters whether enabled or disabled, used or unused. In addition, the protective device settings shall be provided on log-log paper for graphic proof of the required device coordination based on requirements specified in Article 1.05.C.9 Paragraph C of this Section.

2. Protective Devices at 15 kV Switchgear

- a. Rectifier Transformer AC feeder instantaneous overcurrent relay, Device 50, shall trip rectifier transformer circuit breaker, Device 52-T, for 13.8 kV circuit and rectifier transformer faults. Pickup shall be set 125 percent above the maximum inrush current of

the transformer-rectifier package, or 125 percent above bolted secondary fault at the DC traction feeder load terminal, whichever is greater.

- b. Rectifier Transformer AC feeder time overcurrent relay, Device 51, shall trip the rectifier AC and DC circuit breakers for rectifier transformer secondary circuit faults and DC switchgear bus faults. Pickup shall be set to coordinate with the reverse current trip, Device 32, of the rectifier DC circuit breaker, Device 72-R of the second rectifier operating in parallel and with the protective devices of DC traction feeder circuit breakers, Device 172. In addition, the settings of Device 51 shall be selective with the individual series fuses of the rectifier diodes so that the diode fuses will not blow on a fault external to the rectifier.
 - c. Rectifier AC feeder time overcurrent relay, Device 51R, shall trip the rectifier AC circuit breaker for rectifier overload. Relay shall be set to pick up in approximately 60 seconds at 300 percent of rectifier full load current. The setting shall also allow two hour operation of the rectifier at 150 percent of rated full load and 450% full load current for 15 seconds. The setting of Device 51R shall provide selectivity with the rectifier series diode fuses and with the DC traction feeder circuit breaker protective relays.
 - d. An automatic trip of the rectifier AC circuit breaker 52-T shall sequentially trip the rectifier DC circuit breaker, Device 72-R.
 - e. The devices for 52-T / 72-R shall interface with the substation automation system within the substation.
 - f. Each 15kV AC Circuit breaker shall be provided with a Microprocessor-based multifunction relay and metering unit with the following minimum functions (for additional required features see Article 2.01, Paragraph O, this Section). Protection requirements for the 52-L1 and 52-L2 circuit breakers shall be subject to approval by Eversource (Formerly NSTAR) who may insist on specific relays meeting their system requirements:
 - Phase overcurrent relay with instantaneous function for each phase, Devices 50/51, initially programmed with very inverse time coordination curve (TCC). For Ring Feeder circuit breakers and Bus-Tie Circuit breakers this protection shall be bi-directional.
 - Residually-connected ground overcurrent relay with instantaneous function, Devices 50N/51N, initially programmed with very inverse TCC.
 - Breaker failure detection contact closure which trips associated line breaker and bus tie breaker when rectifier breaker fails to trip after a user-selectable time delay.
3. Protective Devices at Rectifier Transformer
- a. Rectifier transformer winding over-temperature device, Device 49TH, and oil over-temperature device, Device 26TH, shall be set to trip the rectifier conditional lockout relay, Device 86X-T, following operation of the rectifier at 160 percent of full load for approximately two hours at the design temperature listed in Article 2.02 of this Section.
 - b. These devices shall interface with the substation automation system within the substation.

4. Protective Devices at Rectifier
 - a. Each diode shall be protected with an individual series current limiting fuse selected to blow for a diode-shortening failure only.
 - b. Rectifier heat sink overtemperature devices, Device 26RH, shall be set to trip the rectifier conditional lockout relay, Device 86X-T, on heat sink high temperature that could result in failure of rectifier elements and fuses before AC and DC switchgear protective devices can operate.
 - c. These devices shall interface with the substation automation system within the substation.
5. Protective Devices at DC Switchgear
 - a. Rectifier DC circuit breaker reverse current device, Device 32, shall instantaneously trip the rectifier DC and AC circuit breakers, Devices 72-R and 52-T, and shall be nominally set between 10%-20% of the DC circuit breaker rated current. The adjustable setting range shall be provided by the manufacturer.
 - b. The settings of all DC feeder circuit breaker protective devices shall be coordinated with the protective devices of the 15 kV rectifier transformer circuit breakers so that DC traction feeder faults will not cause the tripping of the AC circuit breaker. Load measuring and automatic reclosing features of DC traction feeder circuit breakers will cause automatic re-closure as soon as the condition that caused tripping is corrected.
 - c. These devices shall interface with the substation automatic system within the substation.

PART 2 - PRODUCTS

2.1 15kV AC SWITCHGEAR

A. General

1. The switchgear assembly shall consist of indoor, metal-clad, single-height, self-supporting units rated for operation on nominal 13.8 kV, three-phase, three wire, 60 Hz grounded neutral service. The switchgear shall be arranged for future extensions to the switchgear at either end.
2. The DB Entity shall submit within 30 days before the Design Conference, for MBTA's acceptance, design calculations or test data defining the amplitudes of transient overvoltages produced by the proposed vacuum circuit breaker during switching operations. The data submitted shall address switching transients caused by pre-striking, current chopping, virtual chopping and repetitive re-ignition phenomena for the following switching operations:
 - a. On- and off-switching of the transformer and rectifier package at no load, rated load and 150 percent of rated load. Circuit from the circuit breaker to rectifier transformer high voltage terminals shall be assumed to consist of 30' of three single conductor, 350kcmil 15 kV, EPR insulated (133%), shielded cables in conduit unless more precise cable distances are available from the Design Documents.

3. If the data submitted during the Design Conference or obtained during the rectifier package test, as specified in Article 3.03.C. of this Section, indicates a transient peak surge voltage in excess of 50 kV at circuit breaker or transformer terminals, the DB Entity shall furnish and install intermediate class surge arresters at the load side terminals of each of the circuit breakers feeding the rectifier, and at unit substation transformers provided under this Contract. Surge suppressor equipment and proposed installation location will be subject to the acceptance by the MBTA.
4. Where a 13.8kV AC breaker supplies aerially installed cables, surge arresters shall be installed within the AC switchgear. Surge arrester requirements shall be as identified in Section 16203, Article 1.14.

B. Ratings

1. The switchgear assemblies shall be rated as follows, in accordance with IEEE C37.20.2:
 - a. Nominal voltage 13.8 kV
 - b. Rated maximum voltage 15.0 kV
 - c. Rated power frequency 60 Hz
 - d. Power frequency withstand voltage 36 kV
 - e. Lightning impulse withstand voltage 95 kV
 - f. Main bus continuous (rated) current 1200 Amperes
 - g. Rated short-time withstand current, minimum 36 kA
 - h. Rated momentary withstand current, kA crest 97 kA
 - i. Nominal MVA class 750 MVA

C. Switchgear Assembly

1. The metal-clad switchgear assembly shall consist of rigid, self-supporting and self-contained, electrically-welded steel structure units. Individual units shall be enclosed with not less than 11 gauge formed steel sheets on all exterior surfaces and minimum of 12 gauge on other surfaces. Each unit shall be bolted to each other to form a continuous, free standing switchgear assembly.
2. The switchgear dimensions shall be of sufficient depth and height to allow the racking-in of the ground and test device with the front door of the circuit breaker compartment closed, as specified in Article 2.01.F of this Section. The depth and height of the switchgear shall be increased, as required, if manufacturer's standard switchgear does not allow the specified operation of the ground and test device. Ground and test device clearances shall not be compromised due to switchgear cubicle size. All required modifications and additional equipment necessary for each breaker cell to maintain the original functionality of the standard arrangement shall be provided in each cell at no extra cost to the MBTA. Modified operating tools necessary for the proper operation of the equipment shall also be included at no extra cost.
3. Hinged doors shall be provided with each unit, located both on the rear and on the front of the switchgear assembly, for access to breakers, instruments and terminal blocks, relays, meters, control devices, and buses. Instruments and relays mounted on the front door and not

barriered or compartmented from the circuit breakers are acceptable with the exception of the incoming line (52-L) breakers supplied directly by Eversource (Formerly NSTAR), where controls shall be located on the adjacent metering cubicle. Doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be heavy duty of a type accepted by the MBTA. Full height doors shall be securely fastened in the closed position with a minimum of three latches easily opened without the use of tools. For doors less than the full height of the switchgear, a minimum of two latches will be acceptable.

4. Front doors shall be provided with two-position automatic self-stopping mechanism with the first automatic stop at 90 degrees and the second at 120 degrees. Manual defeating feature of the mechanism shall be provided for moving the door from one position to the other. At each stop, the door shall be held securely in the open position. With the front door of any compartment open at 90 degree position, it shall not prevent the adjacent compartment door from being opened and its breaker completely removed from its housing. Rear doors shall be provided with stops to hold them securely open at 90 degrees in a manner to allow the opening of the doors of adjacent cubicles.
5. The circuit breakers, buses, instrument transformers, incoming and outgoing cables, instruments, and control devices in each switchgear unit shall be isolated within separate grounded compartments formed by sheet steel barriers. All compartments shall be sufficiently gas tight to assure that no ionized gas will pass from one compartment to another. Each compartment shall be provided with a separate hinged door or a removable bolted-on cover with handles for gripping for servicing, without exposing circuits in adjacent compartments. All unused holes and openings between compartments shall be sealed.
6. Vent openings on top of switchgear shall be installed through vertical surfaces to prevent the entry of foreign objects. Openings shall be arranged so that hot gases or other materials cannot be discharged through them in a manner which might be injurious to operating personnel. Grills located on top of switchgear shall be reinforced so that they will not be damaged if stepped on.
7. Each circuit breaker unit shall be provided with protective shutters which are forced to close and cover live high voltage terminals as the removable element of breaker is racked out of the cubicle. If the shutters are made of steel, the clear distance from the shutter plate to any un-insulated primary circuit component on the circuit breaker shall not be less than seven inches at any point during the circuit breaker and the ground and test devices racked-in and withdrawal operation.
8. Primary circuit portholes shall be identified with permanently attached nameplates engraved "BUS" and "CABLE" at each circuit breaker housing, and phases "A", "B", "C".
9. Finish of inside and outside of the switchgear assembly shall be in accordance with Section 16203 Article 1.15, Section 16203.
10. The front door of each circuit breaker housing shall be provided with a properly sized opening covered with a sliding door, for the passage of the push button station and the control cable of the ground and test device.

D. Buses

1. Main buses and bus taps shall be in accordance with Section 16203 Article 1.06 and as follows:
 - a. Main buses and bus taps shall be fully insulated with flame-retardant, track-resistant molded insulation rated for 15 kV in accordance with IEEE C37.20.1 and C37.20.2. Bus conductors shall be supported and braced to withstand short circuit stresses at least as great as those for which the circuit breakers are rated. Insulated supports of main bus shall be arranged to form a gas-tight barrier which shall isolate each unit from the adjacent unit.
2. Two ground buses shall be provided in the switchgear assembly in accordance with the following:
 - a. A continuous copper “equipment” ground bus, minimum 2” x ¼”, shall extend throughout the entire length of the switchgear assembly. Each switchgear unit shall be grounded directly to this bus. The frame of each circuit breaker shall be grounded through a rugged contact shoe at all times, except when the primary disconnecting devices are separated by a safe distance. A bolted-type terminal lug, with a NEMA two bolt tongue in accordance with Section 16203 Article 1.07, shall be provided at each end of ground bus for field connection to the station ground. The lugs shall be suitable for stranded copper ground cable within the range of No. 4/0 AWG through 500 kcmil.
 - b. A continuous copper “isolated” ground bus, 1-1/2” x 1/4”, insulated from the switchgear frame, shall be provided for bonding the shields and sheaths of 13.8 kV feeder cables that are connected to the MBTA’s 13.8 kV cable network. The isolated ground bus shall be installed near the rear doors, at a maximum of six inches above floor, and shall extend throughout the entire length of the switchgear assembly. A bolted type terminal lug, with a NEMA two bolt tongue in accordance with Section 16203 Article 1.07, suitable for stranded copper cable within the range of No. 4 through No. 4/0 AWG, shall be provided at each end of the ground bus for future field connection to the negative bus and drainage board. Routing for these connections shall be provided by the DB Entity via suitably sized conduits installed during the substation construction.
 - c. Ground bus splices shall be made with a minimum of four bolts, two bolts on each side of the splice plate.

E. Power Circuit Breakers

1. Power circuit breakers shall be draw-out type, nominal 13.8 kV class, three pole, employing vacuum interrupters, designed for 60 Hz operation and rated on a symmetrical current basis in accordance with ANSI C37.06 as follows:
 - a. Rated continuous current 1200 A
 - b. Rated maximum voltage 15.0 kV
 - c. Nominal voltage 13.8 kV
 - d. Rated voltage range factor (K) 1.3
 - e. Rated withstand test voltage:

Low frequency (rms)	36 kV
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- | | |
|---|----------|
| Impulse, crest | 95 kV |
| f. Nominal MVA class | 750 MVA |
| g. Rated short circuit current at maximum voltage (rms) | 28 kA |
| h. Maximum symmetrical interrupting capability (rms) | 36 kA |
| i. Rated short time current(3 sec.) | 36 kA |
| j. Closing and latching capability, crest | 97 kA |
| k. Rated interrupting time | 5 cycles |
2. Operating mechanisms shall be of the stored energy type, suitable for operation from a 125 Vdc supply, and electrically and mechanically trip free. Operating circuits shall successfully close the breaker over a voltage range of 90 to 140 Volts and trip the breaker over a voltage range of 70 to 140 Volts. The breakers shall be designed so that they may be tripped manually in an emergency. A removable handle shall be provided for manual closing of the breaker for maintenance and adjustment. An operating mechanism shall be provided with a mechanism charging motor cut-off switch mounted on the breaker removable element and a mechanical breaker contact position indicator visible from the front when the breaker is inserted in its housing.
 3. The stabs of the movable element and the bus will be insulated to the same requirement as Article 2.01.D paragraph 1.a of this Section in so far as practically possible.
 4. In addition to auxiliary switches required for control, interlock, indication, and alarm circuits, provide each circuit breaker with a minimum of four "a" and four "b" spare auxiliary switch contacts wired to outgoing wiring terminal block for MBTA's use. Auxiliary switches mounted on stationary structures are acceptable.
 5. Auxiliary switches and breaker control circuit wiring connected through the secondary disconnecting devices shall be operable when breaker is racked to the test position so that the breaker can be closed and tripped, electrically or mechanically, with primary disconnecting devices open.
 6. Normally closed auxiliary switches mounted on the removable element and used for interlocking shall be shunted with truck operated cell switches to permit operation of interlocked equipment when breaker is in the withdrawn position. A minimum of two "a" and two "b" spare cell switch contracts shall be provided, wired to outgoing wiring terminal block for MBTA's use.
 7. Each circuit breaker shall be mounted on a mobile steel frame equipped with main and secondary circuit disconnecting devices. The frame shall be permanently attached to the circuit breaker and shall be equipped with wheels for rolling the circuit breaker on the floor of the substation. All breakers are required to be a direct roll-in design which allows moving the breaker over the concrete substation floor into the switchgear unit without the need for portable ramps or wedges or cradles. A four-digit register type operations counter shall be mounted on the removable element of each circuit breaker.
 8. Circuit breakers of same rating shall be mechanically and electrically interchangeable.

9. The primary disconnecting devices shall consist of self-aligned assemblies. The female contacts shall be constructed of bridging segments of fatigue-resistant zirconium copper alloy with silver tungsten arching tips or similar approved high quality material, designed to ensure high-pressure contact and guaranteed not to distort or fail under the mechanical stresses and heating due to duties specified for circuit breakers. All contact surfaces shall be heavily silver plated.
10. Secondary disconnecting devices shall provide connections for the control circuits and interlocks between the removable element and the housing. The devices shall be accurately located and securely mounted to maintain alignment.
11. Each switchgear unit housing a circuit breaker shall be equipped with a cranking device for moving the removable breaker element to and from its operating position. The cranking device shall be permanently attached to either the stationary housing or to the removable breaker unit. Suitable guide rails which prevent misalignment shall be provided for centering the breaker in proper position when inserting or withdrawing the removable element. A positive stop shall be provided for the test position and fully disconnected position. Provisions shall be made for padlocking the removable element in the operating and fully disconnected positions. Provisions shall be made to the front of the cubicle's hinged door to provide a sliding shutter to cover the aperture utilized for the cranking device. The circuit breaker shall be able to be racked or cranked from the "test" position to the "operating" position with the breaker compartment door closed. The doors of each cubicle shall have provisions for padlocking.
12. Front ends of guide rails shall be flared and the bottom plate of the enclosure within the guide rails beveled to facilitate the lining-up and insertion of the circuit breaker removable element.
13. Mechanical interlocks shall be provided on each circuit breaker to prevent the withdrawal of the removable element when the breaker is in the closed position and to prevent the insertion of a closed breaker from the test to the operating position. The interlocks shall also discharge the spring of the stored energy operating mechanism before the breaker removable element can be fully withdrawn from its housing.
14. The racking-in mechanism shall be manually operated, threaded shaft type, employing a removable crank. A portable electric racking in device with time delay shall be provided to supplement the manual racking operation. Lever type rack-in mechanism will not be acceptable.

F. Ground and Test Device (GTD)

1. Two types of ground and test devices shall be provided at each substation (except at Ball Square where only the MBTA type ground and test device is required). One for incoming line breaker directly fed by Eversource (Formerly NSTAR) and one for MBTA circuit breakers.
2. MBTA Ground and Test Device
 - a. The DB Entity shall provide Two (2) Ground Test Devices at each substation.
 - b. A ground and test device (GTD) shall be provided for the grounding of primary switchgear circuits during maintenance work, and to provide access to high voltage circuits for high potential (hi-pot) testing and phase checking. The ground and test

device shall be a mobile draw-out element that can be inserted into a switchgear cubicle in place of a circuit breaker. The ground and test device shall be constructed in compliance with all mechanical features and applicable electrical ratings specified for the 15 kV class circuit breaker removable element, in accordance with IEEE Standard C37.20.6, IEEE Standard for 4.76 kV to 38 kV Rated Grounding and Testing Devices Used in Enclosures, and this Section. The GTD is required to be a direct roll-in design which allows moving the breaker over the concrete substation floor into the switchgear unit without the need for portable ramps or wedges or cradles

- c. The ground and test device shall be designed so that it can be racked from the "test" to "operating" position with the breaker compartment door closed. Clearly indexed positive stops shall be provided for the operating, test and disconnected positions.
- d. The ground and test device shall be provided with three primary disconnecting devices for connection to the feeder cable terminals and with three uninstalled primary disconnecting devices for connection to the switchgear bus. The ground and test device will be accepted with all six primary disconnecting devices installed, provided that those for connection to the switchgear bus can be readily removable in the field. The ground and test device shall be provided with a sliding contact assembly, of appropriate ampacity, for connecting to switchgear ground bus; a 15 kV three pole, two position, manually operated air break primary selector switch; and a stored energy operated air break ground switch capable of closing and latching against a live circuit. Windows of non-shatterable material shall be provided for observation of ground switch contact position when the grounding and testing device is racked into the switchgear. Windows on the top and side panels of transparent insulating, non-shatterable material shall also be provided for viewing the position of the selector switch, the ground switch, the bus work and the primary circuit cable from the buses at the primary circuit disconnect devices to the test ports. Viewing mirrors may be added to facilitate easy viewing of the switch position. The mirrors, if used, shall be secured such that once in the necessary position they cannot be easily dislodged or adjusted.
- e. Ground and test devices employing a vacuum interrupter as the ground switch will not be acceptable.
- f. Test port cables shall be firmly supported and installed with phase-to-phase distances based on in-air clearances without the benefit of the cable insulation, unless barriers of insulating material are installed to separate the phases.
- g. The stabs of the movable element and the bus will be insulated to the same requirements as Article 2.01.D, Paragraph 1.a of this Section.
- h. Interlocks shall be provided so the primary circuit selector switch can be operated only while the ground and test device is outside the switchgear. Mechanical interlocks shall be provided to permit the insertion and removal of the ground and test device only when the ground switch is open. A mechanical interlock shall be bolted to the selector switch operator to prevent positioning of the ground switch from cable side to bus side unless the interlock is removed. Means for padlocking the ground switch in open and closed positions shall be provided.
- i. The ground and test device shall have the same voltage, three second current carrying capability, and closing and latching capability as specified in this Section, for the circuit breakers. The ground switch control circuit shall be rated for operation on 125 Volts DC. The control circuit shall be wired to the secondary disconnecting devices matching those furnished with the circuit breaker removable elements. A 20' long control cable, with a

pushbutton station at one end and quick-type disconnecting plug on the opposite end, shall be provided for electrically closing and tripping the ground switch. A timing relay, adjustable between 5 and 50 seconds, shall be provided for the ground switch closing circuit. Interlocks shall be provided to permit the closure of the ground switch only when the ground and test device is racked into the "operating" position. A manual handle shall be provided for closing the ground switch when the ground and test device is inserted in the breaker housing and the cubicle door is closed.

- j. The GTD will normally be operated with the switchgear cubicle door closed. Provide shuttered openings in the substation 15 kV switchgear cubicle doors to accommodate the GTD control cable. The cubicle door openings for the GTD control cable shall be provided with means of securely fastening them in the closed position when GTD is not in use.
- k. Arrangements shall be made to prevent the operation of the structure-mounted circuit breaker auxiliary switches during the racking-in and withdrawal operation of the ground and test device.
- l. Opening and closing of the GTD grounding switch shall occur only as a separate operation independent of the charging of the ground switch mechanism. A ground switch mechanism that charges and then automatically closes or opens will not be acceptable.
- m. Mechanical means of charging the ground switch mechanism shall be provided, enabling the GTD to be opened in the event the charging motor fails.
- n. Primary circuit test terminals shall be recessed, and the access ports furnished with automatic shutters. The DB Entity shall provide the ground and test device with two (2) sets of high voltage test probes for applying an external test voltage (hi-pot) to the incoming feeder cable or switchgear bus. These test probes shall be self-powered, requiring no auxiliary supply for operation. Battery-operated test probes are not acceptable. The DB Entity will request all connector detail requirements to the MBTA.
- o. The primary disconnect devices, test port openings and the selector switch positions shall be identified with permanently attached nameplates engraved "BUS" and "CABLE". Similarly, all references to the primary circuit positions on the schematic and wiring diagrams and in the operating instructions shall be "BUS" and "CABLE".
- p. A nameplate, depicting the primary circuit in single line from shall be permanently attached to the front or side of the ground and test device.
- q. The ground and test device will be used for hi-pot testing of substation 13.8 kV cable circuits. A DC test source up to 45 kV will be applied to the cable through the ground and test device for five minutes while the ground switch is open.
- r. Provide a charging motor cut-off switch mounted on the front of the GTD similar to that provided for the substation 15 kV class circuit breakers.
- s. Provide a white LED lamp as well as a mechanical flag to indicate "mechanism fully charged" status.
- t. Provide a mechanical flag to indicate ground switch open and closed status.
- u. The diameter of the GTD test ports shall accommodate the MBTA standard "shotgun" telescopic high voltage detector stick, which is a Biddle Instruments DETEX Neon Voltage Detector Cat. No. 51440-1 or 51440-2. Provisions shall be made to allow verification of cable de-energized status using the detector stick when the GTD is racked into position and open, in accordance with MBTA standard operating procedures. The

DB Entity shall provide two (2) MBTA standard high voltage detector sticks with the GTD. These two detectors shall be present at the time of factory testing for use in the testing of the equipment.

- v. The construction details, list of components, single line and schematic diagrams and operating procedure of the ground and test device shall be submitted to the MBTA for acceptance. Construction details shall include dimensioned front, side and section views illustrating dimensions of internal and external features. Demonstration of the approved GTD operating procedure shall be considered part of the factory witness testing requirements.
 - w. The GTD shall be tested in accordance with IEEE Standard 1286, with certified test reports provided for MBTA's acceptance.
3. Eversource (Formerly NSTAR) Ground & Test Device (extracted from Eversource (Formerly NSTAR) Specifications)
- a. The DB Entity shall provide One (1) Ground Test Device, at each substation connected to the Eversource (Formerly NSTAR) system, 15kV, suitably designed for transporting between the switchgear and the storage location, to provide means of application of low tension phasing, probe and DC insulation cable testing and application of cable fault location equipment of the incoming line cables and grounding of the incoming line cables.
 - b. The GTD shall be capable of racking into the incoming line positions. Blocking plates are to be used so that this device is incapable of being racked into any other position on the switchgear.
 - c. This test device shall have only three (3) female contacts of similar design of the circuit breaker which when put into position shall make connection to the stationary contacts on the line side of the breaker unit.
 - d. The test device shall be self-aligning in the breaker unit and shall be put into position in the same manner as the circuit breaker.
 - e. Each phase terminal shall extend to the front portion of the device with a 2" x 1/4" flat copper bar for test connections.
 - f. Each copper phase shall have micarta barriers (or equivalent) between each of the other phases and/or ground.
 - g. The device shall have a grounding shoe for grounding the device when in position.
 - h. A grounding terminal with wing nut arrangement shall be provided at the front of the device for connection thereto for test purposes.
 - i. The front of the device shall have a suitably insulated hinged door.
 - j. Three (3) 6' flexible cable jumpers with an equivalent short circuit rating of the switchgear for connection between each phase terminal and ground shall be provided.
 - k. The Ground and Test Device (GTD) will be limited to insertion into the incoming line breaker cubicles ONLY.
 - l. The vendor will install the appropriate blocking plates so that the GTD is incapable of being inserted into a tie breaker or customer feeder position.

- m. Each phase terminal shall be fitted with a nameplate indicating which utility phase is connected to each terminal.
- n. For grounding, there shall be one ball stud fitted per phase and 3 individual ground ball studs fitted to the ground bus.

G. Eversource (Formerly NSTAR) Revenue Metering (extracted from Eversource (Formerly NSTAR) Specifications)

1. The following are the requirements for primary metering equipment that will be installed in separate metal enclosed bays. The DB Entity shall furnish, install the metal clad bay for approved metering current and potential transformers. This will include cubicle heaters and interior connections. The metering transformers will be furnished and installed by the DB Entity's switchgear manufacturer. The metering transformers will become the property of the Eversource (Formerly NSTAR) Electric Company.
2. No instruments, meters, or devices other than the aforementioned current and potential transformers shall be mounted on or inside the metering bay unless specified herein.
3. All ground connections shall be copper to copper connection.
4. The metallic metering instrument transformer bases shall be grounded to their supporting structures by serrated metal mounting washers with screws that penetrate the painted surface, and by #6 AWG bare copper ground connections to the switchgear ground bus. The bases of each of the metering transformers are to be grounded individually to the ground bus. Daisy chain grounding arrangements are not acceptable.
5. Metering Current Transformers
 - a. A separate section, isolated with a solid barrier, shall be provided for the installation of two metering current transformers. Compartment design shall be such that after proper electrical isolation, the transformers can be readily replaced.
 - b. The approved current transformers will be mounted in phases 1 and 3, and the area of the primary connections to the bus shall be treated to inhibit corrosion and oxidation. Current transformers will be mounted on phase 1 and 3 when connected to a delta connected transformer. These current transformers shall be of one of the following or approved equal:

Manufacturer	Type	Accuracy	Burden
General Electric	JKM 5	0.3	B-0.1 to B-1.8
	755X142043 200/400:5		

- c. Current transformers shall not be ordered until consultation with the Meter Technical Central Operations of the Eversource (Formerly NSTAR) Electric Company has occurred.
 - d. The current transformers shall be located in the top section of the metering bay.
6. Metering Potential Transformers

- a. The potential transformers and fuses shall be mounted on a drawout carriage located in the bottom half of the metering bay and shall be completely isolated from the high voltage bus or connections. Phasing shall be 1-2-3 left to right facing the drawout carriage for Boston Edison Territories. Phasing shall be 3-2-1 (C-B-A) left to right facing the draw out carriage for Cambridge Electric territories. Note: MBTA phasing at the front to the switchgear is 1-2-3 or A-B-C. These potential transformers shall be of one of the following or approved equal:

Manufacturer	Type	Primary Voltage	Ratio	Primary Fuses (3 total)
General Electric	JVM	14,400	120:1	½ E
	#765X023026			

- b. Primary connections shall be 4/0 copper equivalent. The primary connections to the potential transformers shall be suitably treated to insure low resistance, eliminate moisture and resist oxidation. A two bolt connection at each end of the PT connection to the drawout/dropout stabs is required.
- c. Two (2) revenue metering potential transformers with primaries connected in an open delta configuration for a delta connected transformer, the high voltage side of the potential transformers shall be connected via three current limiting fuses, type ½ E. The fuses shall indicate when blown.
- d. Primary contacts for the drawout carriage shall be of such design as to ensure continuous positive contact pressure. The design shall ensure the primary contacts are disconnected from the bus connections and grounded before the potential transformers and fuses become accessible for checking and replacement. Sufficient clearance shall be provided so that fuses can be changed while wearing high voltage insulating protective gloves. Preference shall be for braided connections shall be provide in lieu of spring connectors.
- e. Three spare fuses, type ½ E, shall be furnished for each set of metering potential transformers. Provisions shall be provided for fuse storage. The preferred location for the fuse storage is on the inside of the outside bay door.
- f. The front of the potential transformer drawout carriage shall extend up to close the section when the transformers are in the operating position. The section enclosing the fuses shall be so constructed that ionized gases and/or flame resulting from blowing of the fuses will not readily be conducted into other sections.
- g. The manufacturer shall insure that potential transformer fuse clips are held rigid with double bolt connections and cannot pivot when removing fuses.
- h. Mechanical latches shall be provided to allow the drawout carriage to be held in fixed positions when the PT carriage is in either the fully operational position or the fully disconnected position. The fully disconnected position is to mean the position the carriage would be in for fuse removal/insertion.

7. Secondary Wiring

- a. Secondary wiring from the current and potential transformers shall be limited to the following terminal blocks within the switchgear. Current transformer secondary conductors require GE shorting type EB27A6S and potential transformers require EB25B04 terminal blocks or equivalent. The wiring shall consist of thirteen (13) conductors of #12 AWG flameproof switchboard wire with ring type connectors; 3 wires

from each current transformer and 4 wires from the potential transformer (Eversource (Formerly NSTAR) Electric meter drawing will be provided upon request). Secondary wiring beyond the terminal block will be installed by the Meter Technical Central Operations of the Eversource (Formerly NSTAR) Electric Company.

- b. No instruments or meters other than Eversource (Formerly NSTAR) Electric revenue meters shall be connected to the secondaries of the metering current and potential transformers.

8. Meter Panel

- a. A remote outdoor cabinet with a meter panel drilled in accordance with a sketch furnished by Meter Technical Central Operations of the Eversource (Formerly NSTAR) Electric Company. The MBTA and Design-Builder shall consult with John Marcone (339 987 7078) of the Eversource (Formerly NSTAR) Electric Company for the location of the meter panel. The Design-Builder shall provide a run of 1-1/2" conduit from the terminal block location in the switchgear to the remote meter panel for the extension of the secondary wiring.

H. Instrument Transformers – MBTA circuit breakers

1. Instrument transformers shall be dry type. Transformers and associated wiring shall have mechanical strength and thermal rating commensurate with rating of associated equipment.
2. Voltage transformers for relaying and indication shall have ratios as specified in Article 2.01.Q.a of this Section, a minimum thermal rating of 1,000 Volt Amperes with 55 °C rise above a room ambient of 40 °C, and an accuracy of 0.3 with ANSI standard W, X, and Y burdens, 0.6 with Z burdens, and 1.2 with ZZ burdens. Voltage transformers shall be equipped with current limiting primary fuses and shall be mounted on draw-out or tilt-out carriages. The front of the carriages shall be designed to close the section when the transformers are in the operating position. Primary contacts for the draw-out feature shall be of a design which will ensure continuous positive contact pressure. Carriages shall be of sufficiently rigid design to maintain proper alignment of the primary contacts. Visible grounding devices shall be provided to ensure that the draw-out carriage mounted voltage transformer primary terminals are grounded when the carriage is withdrawn. The visible grounding devices shall not be able to be deflected out of position by repeated operations of the carriage. A flexible braided strap shall be provided for bonding the drawout carriage to the switchgear enclosure.
3. All voltage transformer primary circuit connections from bus or line side terminals of circuit breakers to the primary fuses shall be of No. 2/0 AWG minimum, copper wire, fully insulated for 15 kV. Connections from the fuses to the high voltage terminals of the transformers shall be No. 6 AWG minimum, copper wire, fully insulated for 15 kV. Phase-to-phase and phase-to-enclosure distances shall be based on in-air clearances, assuming bare conductors. Insulated wire shall be secured in position by the use of non-conductive cable clamps. The use of ty-wraps type cable ties will not be permitted.
4. Ungrounded conductors of voltage transformer secondary circuits shall be fused. Fuses shall be of the dual element, cartridge type, rated 20 Amperes, 250 Volts, mounted in barrier-type, porcelain base fuse holders.

5. Provisions shall be made for storing a set of three primary current-limiting fuses in each voltage transformer compartment.
 6. Current transformers for relaying and indication shall be of the window-type, with the ratio and accuracy class specified in Article 2.01.Q of this Section, rated 600 Volts, minimum, and designed to withstand full wave impulse test of 10 kV. The primary circuit busbar shall be located at the center of the current transformer window, firmly supported, and fully insulated for 15 kV class. The installation of current transformers shall withstand the dielectric and impulse tests specified for the switchgear assembly. Current transformers shall comply with IEEE Standards C37.20.2 and C57.13. All CT ratios shall be wired to accessible terminal blocks.
 7. Frames and cases of the current and voltage transformers, the secondaries of the current transformers, and the common secondary conductor of the voltage transformers shall be grounded to the switchgear ground bus. Grounding of the voltage transformers and the carriage to the switchgear ground bus shall be made with an extra flexible grounding cable. All grounding conductors shall be made as short as possible, not grouped with other conductors, and shall be No. 6 AWG copper wire or larger. Ground wires shall be continuous without splices or intermediate connections. The current transformer ground wire shall be separate from the voltage transformer ground wire. The case ground wires shall be separate from the ground connections to the instrument transformer secondary wiring.
- I. Instrument Transformers – Eversource (Formerly NSTAR) circuit breakers
1. These requirements apply to Eversource (Formerly NSTAR) Circuit Breakers (52-L1 and 52-L2 at Red Bridge and Pearl Street) and may be incorporated into the requirements of the MBTA instrument transformers.
 2. Instrument transformers shall satisfy the ANSI requirements, for relaying accuracy classification or metering accuracy classification as appropriate for the connected load, under the burdens imposed by the devices specified or implied. Instruments transformers shall be in accordance with the requirements of ANSI C57.13 and NEMA E-12.
 3. Current Transformers:
 - a. Three window type current transformers shall be provided between the incoming line terminations and the circuit breakers.
 - b. Ratings: 600/5 Amperes, 15kV, C200 Relay Accuracy Class. Current transformer ratios are subject to change and confirmation up to the return of shop drawings accepted.
 - c. The secondaries of these current transformers shall be located in an isolated compartment with the incoming line terminals and shall have at least the mechanical and thermal strengths of the circuit breaker.
 - d. All metallic transformer bases and all secondary circuits shall be grounded by connection to switchgear ground bus with a minimum #6 AWG bare conductor.
 - e. The current transformers shall be capable of withstanding high potential tests of 42kV, DC for five minutes.
 - f. Current transformer secondary neutrals shall be grounded to the switchgear bus with a minimum #12 wire.

- g. Current transformers shall be provided with covered secondary terminal blocks. Secondary leads shall be wired to terminal blocks in secondary control compartment, equipped with a device for conveniently shorting the current transformer, and readily identified.
 - h. Current transformer secondary neutrals shall be grounded to the switchgear bus with a minimum #12 AWG bare wire.
 - i. The lengths of these ground connections should be as short as possible and not grouped with other control wires.
4. Potential Transformers
- a. The phase presentation of the primary conductors of the potential transformers shall be 1-2-3 left to right as viewed from the draw-out carriage.
 - b. Potential transformers shall be of the draw-out, disconnecting type insulated for full voltage rating of switchgear. The transformers shall have mechanical rating equal to the momentary rating of the circuit breakers. Potential transformers placed in the upper section of a vertical stack shall be housed in the lower portion of the section to facilitate ease of the operation of the draw-out unit.
 - c. Potential transformer primary leads shall be insulated for full insulation level of main bus and shall be run individually cleated with air separation. Individual insulating bushings shall be provided at barrier penetrations.
 - d. Potential transformers shall be provided with current limiting fuses mounted on the draw-out assembly. Withdrawing a unit shall disconnect and ground the assembly.
 - e. The potential transformer carriage shall be grounded by a two flexible 1/0 AWG bare or clear jacketed copper conductors.
 - f. 15kV connections from the 15kV bus to the potential fuses shall be made with a minimum 4/0 AWG cable with double bolt connections at both ends of each connection.
 - g. The primary fuse clips shall be double bolted to their bases to prevent rotation and movement resulting in misalignment of the clips for fuse removal/insertion. A GPO-3 insulating material may be mounted across an individual fuse clip to prevent movement and rotation of the fuse clip in lieu of the double bolted base arrangement. In either case the fuse clips must be secured so that they do not rotate/move when the primary fuses are either inserted or removed.
 - h. Each transformer case shall have a positive bare copper connection to the ground bus equivalent to a #6 AWG wire. Daisy chain ground connections from one PT frame to another are not acceptable.
 - i. The primary contacts shall be disconnected and isolated from the bus connections and grounded before the fuses become accessible for checking and replacement.
 - j. Mechanical latches shall be provided to allow the draw-out carriage to be held in fixed positions when the PT carriage is in either the fully operational position or the fully disconnected position. The fully disconnected position is to mean the position the carriage would be in for fuse removal/insertion. The fuse clips shall remain positively grounded with the carriage in the disconnected/latched position.

J. Primary Circuit Terminations

1. Switchgear shall be arranged for top or bottom entrance of incoming and outgoing feeder cables, as shown on the Design Documents with exceptions as noted. The DB Entity shall provide necessary terminations for power cables connecting to the breaker load side terminals. Solid dielectric, EPR-insulated cables shall be 15 kV class, 133% insulated and shall have 15 kV class stress cone type terminations. Buses and current transformers in the cable entrance compartments of the switchgear shall be arranged to provide ample space for 15 kV cable termination stress cones.
2. Cable termination supports shall be insulated from the switchgear frame to prevent circulation of current between cable sheath and switchgear structure. The cable shields shall be connected to the insulated ground bus specified in Article 2.01.D.2.a of this Section, by means of an insulated, braided flexible copper connector.
3. 15 kV class stress cone termination kits for the EPR cables shall be provided in accordance with the cable manufacturer's recommendations.
4. The DB Entity shall provide heavy duty, bolted type terminal lugs for power cables in accordance with Section 16203 Article 1.07. For 350 kcmil and smaller cables, the terminal lugs shall have NEMA two-bolt tongues; for 500 kcmil and larger cables, four-bolt tongues shall be provided.
5. The DB Entity shall provide insulated cable supports for power cables, designed to withstand maximum short circuit stresses specified for switchgear assembly. Cable clamps shall be provided to secure the cables to the supports.
6. Each incoming line, ring feeders and feeder circuit breaker units, as indicated on the Design Documents, shall be furnished with two removable neon glow tubes per phase for "feeder alive" indication. The indicators shall be mounted for observation through windows of non-shatterable material located at a convenient viewing height. The neon tubes shall not be connected to switchgear buses, but be arranged for capacitive pickup. Additional capacitive pickup devices shall be provided, if necessary to obtain adequate brilliancy for observing the indicators in well-lit substation. The presence of the neon tube assemblies shall not reduce the impulse withstand level of the equipment.
7. Each circuit breaker that has supply cables connected to aerial AC feeders shall have surge arresters installed within the AC switchgear cable compartment. Refer to Design Documents for circuit breakers connected to aerial feeders. Refer to Section 16203 for description of the surge arrester requirements.

K. Wiring and Terminal Blocks

1. Secondary and control wiring and terminal blocks shall be provided in accordance with Section 16203 Article 1.09, and as follows:
 - a. Wiring and terminal blocks in switchgear housings and on circuit breaker removable elements and on the ground and test device shall be rated for 600 Volts.
 - b. Circuits requiring external connections shall be wired to outgoing wiring terminal blocks readily accessible from the front, with circuit breaker removable element in test or connected position.

- c. External control, indication and SCADA/SAS cabling shall enter and exit each control compartment from the top, front of the switchgear as indicated on the Design Documents. Cable tray above the switchgear shall be used for the routing of these cables.

L. Control Source

1. An ungrounded, two wire, 125 Volt DC control bus shall be provided integral with the switchgear assembly. The control bus shall be No. 4 AWG, stranded switchboard wire insulated for 600 Volts, minimum. An alternative to #4AWG may be proposed by the DB Entity with supporting calculations for acceptance by the MBTA. The supply shall be wired to suitable screw type terminal blocks located at or near the middle of the switchgear lineup for connection to the supply conductors entering from the top.
2. Each breaker control circuit shall be supplied from this bus through a separate set of disconnect switches and main (tripping circuit) fuses. Each circuit breaker closing circuit shall be provided with a secondary set of fuses with pullout disconnects to prevent blowing of main fuses on closing circuit faults.
3. Disconnect switches, fuse holders, and fuses shall be rated 250 Volts. Fuses shall be of the dual-element, cartridge type of appropriate rating. Necessary fuses shall be furnished with the equipment. In addition, a minimum of 15 percent, but not less than two, spare fuses of each rating shall be furnished.

M. Special Requirements

1. Each separate compartment within a switchgear cubicle shall be provided with an electric strip heater of adequate size to prevent condensation within the compartment. Heaters installed in a unit shall be monitored by means of an ammeter, scaled and marked for the heater load. Each cubicle shall be provided with an LED indicating light with blue lens to indicate operation of the heater and an ON-OFF switch. Heaters shall be provided with guards to protect operating personnel against accidental contact with hot surfaces.
2. A fluorescent or LED lamp receptacle, with conveniently located and properly labeled toggle switch or door operated switch, shall be provided in each compartment, accessible from the breaker draw out side of the switchgear. The DB Entity shall also provide a duplex, grounding type receptacle in each switchgear unit, connected for 120 Volt AC service.
3. The DB Entity shall provide a three-phase, four wire, 208/120 Volt AC supply bus, No. 8 AWG minimum, throughout the switchgear assembly. An alternative to #8AWG wire size may be proposed by the DB Entity with supporting calculations for acceptance by the MBTA. The heater, light, and receptacle circuits shall be supplied from this bus through fusible pullout disconnects with dual-element cartridge type fuses located in each switchgear unit. Fuse holders and fuses shall be rated at 250 Volts AC. Fuses shall be furnished with the equipment. A minimum of 15 percent, but not less than two, spare fuses of each rating shall be furnished. As far as practicable, loads shall be balanced between the phases of the supply bus. The supply shall be wired to terminal blocks located at or near the middle of the switchgear lineup for connection to the incoming supply from the substation 208/120 Volt distribution panel.

N. Nameplates

1. In addition to nameplates specified in Section 16203 Article 1.08.C, provide a nameplate on the front of the switchgear assembly, engraved with "DANGER - 13,800 VOLTS". The nameplate shall have white letters, 2 inches high minimum, on red background. Two similar nameplates shall be mounted on the rear of the switchgear assembly. The DB Entity shall furnish and ship loose eight similar nameplates for installation on exterior face of entry and exit doors of the substation.
2. The legends of all equipment nameplates shall be submitted to the MBTA for acceptance.
3. Switchgear identification nameplate shall be engraved "15 kV AC SWITCHGEAR".
4. Additional nameplates for the Eversource (Formerly NSTAR) incoming line breakers shall be provided meeting Eversource (Formerly NSTAR) requirements.

O. Supervisory Control Requirements

1. The 15 kV switchgear assembly shall be provided with supervisory control and indication, measuring and interface devices specified in Article 1.06.C, paragraph 5 of this Section.

P. 15 kV Circuit Breaker Test Cabinet

1. The DB Entity shall provide a wall mounted test cabinet for electrical operation of the 15 kV class circuit breakers as shown on the Design Documents. The test cabinet shall include a control switch, similar to that furnished with the switchgear, to close and trip the breaker; red and green LED breaker position indicating lights; 10' of control cable with a connector at the end for connection to the breaker; a set of properly sized fuses to protect the control circuit; and, screw type terminals for 125 Volt DC control supply No. 8 AWG conductors. An additional indicating LED with white lens shall be provided for monitoring the control supply. The 125 V DC control power shall be provided from a dedicated circuit breaker in the substation DC distribution panel.
2. The control switch and the indicating lights shall be mounted on the door of the test cabinet. The wiring and terminal blocks shall be provided in accordance with Section 16203 Article 1.09, and the nameplates in accordance with Section 16203 Article 1.08.
3. A proper connector shall be provided for protecting the control cable at the point of entry. Provisions shall be made for storing or racking the control cable and the connector at the test cabinet.
4. The test cabinet shall be finished inside and out in accordance with Section 16203 Article 1.15.
5. Switchgear identification nameplate shall be engraved "15 kV AC CIRCUIT BREAKER TEST CABINET".

Q. Protective Relays – MBTA Circuit Breakers

1. All 15 kV substation circuit breakers except for Eversource (Formerly NSTAR) incoming line breakers shall be equipped with identical multifunction intelligent digital relay and metering units. See below for Eversource (Formerly NSTAR) relaying requirement for the incoming line breakers. The specific ANSI device functions to be programmed for these individual

circuit breakers are described in Article 2.01, Paragraph Q of this Section. The multifunction relays shall include the following functions and features.

- a. At least nine time overcurrent relay curve shapes including ANSI, and at least one user-programmable time overcurrent curve shape.
 - b. At least five instantaneous time overcurrent curve shapes including ANSI
 - c. Instantaneous metering functions including circuit Volts, Amps, Watts, VARS and Power Factor.
 - d. Demand metering functions including kW, kVAR, and kVA, with peak demand time stamp.
 - e. Fault location and recording (Up to the ten most recent faults).
 - f. Event recording, date-stamped (up to the 128 most recent events).
 - g. Waveform capture (4 voltages, 3 currents).
 - h. Load profile reporting.
 - i. RS-232 or RS-485 or communication port computer interface on rear of unit, and RS-232 port on front of unit, for relay monitoring and control, downloading and uploading setting and event data, supporting DNP 3.0 protocol.
 - j. Numeric keypad and display to enable the relay to be controlled and programmed without a computer, if necessary.
 - k. Continuous self-checking function with contact closure for relay failure.
 - l. Communications to connect to the substation automation system.
 - m. Programmable to include software based interlocking from voltage inputs and breaker status indications.
 - n. Breaker operations counter and summary.
 - o. Breaker failure detection (adjustable) and relay health to be provided over the SAS system.
 - p. Draw-out unit with automatic CT shorting.
 - q. Front-mounted status indication.
 - r. Sufficient 30A make outputs contacts for specified control and indications, plus 25 % spares.
 - s. Manufacturer-supplied Windows®-based software for relay control and programming, including software operation training, running on a laptop computer to be provided with the relays (see Article 2.10, Technical Support Equipment)
 - t. Ten (10) year warrantee, minimum.
 - u. Model Nos.: Schweitzer 351, GE Multilin 750, ABB Power T&D DPU 2000, or approved equal.
2. The AC switchgear shall include protective devices to protect substation personnel and equipment from the incident energy that can develop in an arc fault in the AC switchgear which is directly proportional to the fault clearing time. Early detection and disruption of the energy being supplied to the fault limits the amount of damage to the switchgear, possible

revenue service delays and more importantly injury to substation personnel. Protective relays and fiber optic cables capable of detecting the development of an arcing fault in the early stages is to be included in the AC switchgear. High speed solid state relays / microprocessors designed to detect the development of an arcing fault are capable of sending tripping signals in as little as 2 to 4 msec. The total clearing time shall not exceed 100msec. Fault detection shall be sent to the substation HMI annunciator and to SCADA. The ARC Flash Assessment may be performed using "Power Analysis Software designed for this purpose.

R. Protective Relays – Eversource (Formerly NSTAR) Supply Circuit Breakers 52-L1 and 52-L2

1. Relays shall be of the electronic type, and shall be designed, constructed, and tested in accordance with the applicable provisions of ANSI C37.2 Manual and Automatic Station Control, Supervisory, and Associated Telemetering Equipment; ANSI C37.90, Relays and Relay Systems associated with Electric Power Apparatus; and C37.90a Guide for Surge Withstand Capability (SWC) Tests. Relays shall have built-in test facilities. Specific relay type and model numbers will be provided if specified by Eversource (Formerly NSTAR) Electric. The relays shall communication with substation automation system equipment.
2. Switchgear shall be furnished with all relays and accessories necessary to provide a complete and coordinated protective relay system for the circuits and switchgear as shown or as required to provide proper interlocks and sequence of operation as specified. Device function numbers shall be the standard device numbers for automatic switchgear as listed in ANSI C37.2. The relays for circuit breaker operation shall have an adjustment range suitable for coordinated tripping with other breakers in the switchgear. Relays shall provide all contacts shown. Where more contacts are required than are available on relays of the types specified, approved types of auxiliary relays shall be provided to supply the required additional contacts.
3. Protective relays shall be semi-flush, drawout type mounted on the front doors of the switchgear. Auxiliary relays of the semi-flush mounted type may also be mounted on the front doors of the switchgear. Other auxiliary relays shall be mounted inside the switchgear on the side sheets and/or on the internal swinging panels designed for this purpose. All relays, except certain auxiliary relays, shall be of a type that can be withdrawn by means of approved sliding contacts from the front of the panels without opening the current transformer secondary circuits or disturbing the external circuits, or requiring disconnection of leads on rear of the panels. Relays instruments and controls for individual feeders shall be located on the respective feeder panel, relays, indicating lamps, instruments and controls for mains [that have the suffix 'M'] shall be located on the associated incoming main and bus relays, indicating lamps, instruments and controls will be located on the bus tie panels. The trip circuits of the mains and ties shall be un-fused.
4. The relay cases shall be rectangular steel, zinc-chromate primed and painted black, back connected, dust tight switchboard type. The case shall be provided with removable covers with windows and with means of sealing against tampering.
5. Stability: Each protective relay shall be free from errors due to normal variations in frequency, waveform, power factor, and ambient temperature. All current coils shall be able to withstand currents caused by short circuits on the system. All potential coils shall be able

to withstand 110 percent of normal voltage continuously without damage to the coils or equipment.

6. Test Devices: The necessary test devices shall be accessible from the panels and shall be arranged to isolate the relays completely from the instrument transformers and other external circuits so that no other device will be affected during tests. Multiple test plugs shall be provided for testing either by an external source of energy or from the instrument transformers and other external circuits so that no other device will be affected.
7. Voltage and Vibration Tolerance: - Relays shall operate successfully at voltages ranging from 80 percent to 110 percent of rated voltage without overheating, chattering, or other malfunction. Protective and auxiliary relays shall not operate falsely due to vibration that may occur in closing or tripping operations of the circuit breaker or adjacent circuit breakers.
8. Other Relay Features: Each protective relay shall be provided with an operation indicator and an external target reset device. Relays shall be complete with all operating auxiliaries, including auxiliary transformers as required to adjust currents and potentials for amplitude and phase angle for proper operation of all relays supplied. Relays shall be suitable for use on 5 Ampere current transformer secondaries and 120 Volt potential transformer secondaries, 125V DC minimum tripping and closing circuits. The relay contacts shall have silver tips and shall be rated 5 Amperes continuous and 25 Amperes for one second at 250 Volts DC. The relay coils shall be rated for continuous duty at rated operating voltage.
9. Lock Out Relays: Lockout relays shall be electric trip reset type as shown on the drawings suitable for appropriate DC control and tripping power. Contacts shall be rated for 10,000 operations and made of silver overlaid bronze alloy. Single contact ratings shall be 30 Amperes continuous 60 Amperes for one minute and interrupting; 3 Amperes resistive, 1 ampere inductive. Each lockout relay shall have an associated white light that is lit when the lockout relay is reset. Provide a "t" operating handle and nameplate engraved "trip-reset".
10. All protective relays on the 52-L1 and 52-L2 circuit breakers are subject to the approval of Eversource (Formerly NSTAR) Electric Relay and Protection Group. The shop drawings are to clearly identify all protective relays proposed for the switchgear.
11. Eversource (Formerly NSTAR) requires fail-safe relay schemes. The incoming lines over-current relaying shall offer one of the following arrangements:
 - a. Three electromechanical phase relays with a ground relay.
 - b. Two microprocessor relays with phase and ground over-current in each relay. In this case one relay is to serve as the primary relay and one as the back-up relay. It is recommended each of these relays be from different vendors to attempt to make the system immune from defeat should a particular vendors relays be problematic.
 - c. One microprocessor relay with phase and ground over-current protection within the relay. An additional electromechanical ground over-current relay shall be provided with this arrangement.

In any case where microprocessor relays are used it is required that the relay health be monitored over the SAS system.

An FT-1 test switch shall be provided for each breaker position offering four current shorting poles and two tripping poles.

All relaying arrangements are subject to the approval of the Eversource (Formerly NSTAR) Protection Group.

12. Bus Differential Relaying Controls shall offer the following:

- a. Bus differential relaying shall be integrated with the relaying provided under the MBTA requirements.

13. Stuck Breaker/Breaker Fail Relaying Controls shall offer the following:

- a. Breaker failure protection shall be provided integral to the multifunction relay on each circuit breaker and shall trip all breaker on eth associated bus via the bus lockout relay.
- b. If an integral protection element is not acceptable to Eversource (Formerly NSTAR) then:
 - (i) Each feeder relay trip signal shall activate a 62 timing relay through an 'a' contact of the breaker to be tripped.
 - (ii) The 62 timing relay will, at the expiration of the time delay trip a lock-out relay that will trip all the breakers on the bus associated with the feeder breaker calling for the original trip signal.
 - (iii) The 62 timing relay will be set for 9 cycles.
 - (iv) Should the feeder breaker trip and the 'a' contact change logical state before the 62 times out, the 62 timer will automatically reset and will not trip the stuck breaker lock-out relay.
 - (v) Each 62 timing relay shall be equipped with a target to indicate the relay has timed out and called to trip the stuck breaker lock-out relay. Or
 - (vi) Each feeder breaker shall be equipped with a dedicated stuck breaker lock-out relay. In this case the stuck breaker lock-out relay will serve as the relay target.

S. Accessories

1. Per Substation, the DB Entity shall furnish two sets of special tools and equipment handling devices as recommended by the manufacturer for installation, assembly, adjustment and maintenance of the furnished 15 kV switchgear and associated circuit breakers. Special tools are defined as tools not readily available on the open market. All items shall be furnished as part of the initial delivery of the switchgear equipment.
2. Per Substation, the DB Entity shall also furnish and ship with the switchgear auxiliary equipment and accessories necessary for operation, maintenance, testing and handling of removable components outside the switchgear assembly. These shall include, but not be limited to, the following:
 - One - Floor-mounting steel cabinet with hinged doors with three point latching mechanism and key-locking handle and shelves for storing tools and accessories. Cabinet shall be fully rustproofed and finished in light gray enamel.
 - Two - MBTA Ground and test devices, rated 750 MVA nominal, as specified in this Section.

- One - Eversource (Formerly NSTAR) Ground and test device, rated 750 MVA nominal, as specified in this Section.
- One - Circuit breaker test cabinet, as specified in Article 2.01.P, this section.
- One - "Fifth-wheel" device for moving/handling the breaker removable element. A breaker lifting device and portable crane for moving the 15 kV AC breakers in and around the substation may be proposed in lieu of the fifth wheel device.
- Two - Racking-in cranks (if not already included as part of Article 2.01.S.1 above).
- Two - Manual spring charging handles (if not already included as part of Article 2.01.S.1 above).
- Two - Sets of tools required for breaker maintenance (if not already included as part of Article 2.01.S.1 above).
- Two - Sets of test plugs for drawout relays (if applicable).
- Two - One-quart cans of matching switchgear touch-up paint.
- One - Set of switchgear base channels for mounting the stationary units. These channels shall be shipped in advance of the switchgear for installation in the floor slab.
- Two - 15 kV circuit breaker guide floor plate for aligning the breaker for insertion into the cubicle. In addition to aligning the AC breaker for insertion, this plate shall maintain the cubicle door open at an angle of 95 degrees minimum, while the circuit breaker is being inserted or withdrawn.

T. Detailed Equipment Requirements

1. The DB Entity shall furnish and deliver to the substation the 15 kV switchgear assembly consisting of switchgear units of the type and quantity specified below. The individual units in the assembly shall be arranged to form a lineup as shown on Design Documents.
2. Individual switchgear units shall consist of the equipment, devices and appurtenances of the types and quantities detailed in the Design Documents.

- a. Incoming Line Breakers, Devices 52-L (also must comply with or exceed the requirements of Eversource (Formerly NSTAR))

Each 52-L circuit breaker unit includes, but not be limited to, the following.

- 1 - Metal-clad stationary unit, nominal 750 MVA class with 1,200 Ampere insulated bus and 1,200 Ampere tap.
- 1 - 1,200 Ampere circuit breaker removable element, as specified, nominal 750 MVA class.
- 3 - Current transformers, 600:5 Ampere for relaying and indication, ANSI accuracy class C-100.
- 3 - Current transformers, 1200:5 Ampere, for bus differential protection, ANSI accuracy class C-200.
- 1 set – Metering CT's and PT's per Eversource (Formerly NSTAR) requirements located in adjacent switchgear cubicle

- 1 - IED Microprocessor-based multifunction relay and metering unit with the following minimum functions (for additional required features see Article 2.01, Paragraph O of this Section):
 - Phase overcurrent relay with instantaneous function for each phase, Devices 50/51, initially programmed with very inverse time coordination curve (TCC).
 - Residually-connected ground overcurrent relay with instantaneous function, Devices 50N/51N, initially programmed with very inverse TCC.
 - Phase overcurrent relay, Device 51C, for cable overload alarm, providing annunciation and supervisory indication (provide same functionality as a Device 51CX auxiliary relay with 125Vdc coil and 3 single pole, double throw contacts). Relay initially programmed with inverse long time TCC.
 - Watt-hour demand metering with 15 minute demand interval. Outputs for the 52-L & 52-RF circuits shall be totalized for telemetry via supervisory system. Totalizing shall be provided by software within the SAS PLC.
 - Breaker failure detection contact closure which trips bus tie breaker when line breaker fails to trip after a user-selectable time delay.
- 2 - Interposing relays to close and trip the circuit breaker via supervisory, Devices 201C and 201T (if applicable).
 - 1 - Control switch, TRIP-CLOSE, with green, white, and red indicating LEDs, Device CS.
 - 1 - Indicating voltmeter, transformer rated, 0-18 kV scale.
 - 1 - Voltmeter switch, 4-position OFF-AB-BC-CA.
 - 1 - Indicating ammeter, transformer rated, 0-600 Ampere scale.
 - 1 - Ammeter switch, 4-position OFF-A-B-C, center-of-circuit type.
 - 1 - Current transducer, as specified, for telemetering phase B current, Device A-XD.
 - 1 - Test switch, 10-pole, for 4 potential and 6 current circuits.
 - 6 - Neon tube-type high voltage indicators installed on line side of circuit breaker, two per phase, type RS with antennae.
 - 2 - Potential transformers, 14400:120 Volts, draw-out mounted with primary current limiting fuses, connected to line side of circuit breaker, open delta primary, grounded open delta secondary.
 - 3 - 15kV class stress cone termination kit (see specification Section 16120).
 - 1 - Set of space heaters with Blue LED ON-OFF switch, and ammeter.
 - 1 - Set of DC and AC control and auxiliary power disconnect devices with fuses.
 - 3 - Surge Arresters, if required by switching surge study.
- b. MBTA Ring Feeders 52-RF

Each 52-RF circuit breaker unit includes but is not be limited to the following.

 - 1 - Metal-clad stationary unit, nominal 750 MVA class with 1,200 Ampere insulated bus and 1,200 Ampere tap.

- 1 - 1,200 Ampere circuit breaker removable element, as specified, nominal 750 MVA class.
- 3 - Current transformers, 600:5 Ampere for relaying and indication, ANSI accuracy class C-100.
- 3 - Current transformers, 1200:5 Ampere, for bus differential protection, ANSI accuracy class C-200.
- 1 - IED Microprocessor-based multifunction relay and metering unit with the following minimum functions (for additional required features see Article 2.01, Paragraph O of this Section):
 - Phase overcurrent relay with instantaneous function for each phase, Devices 50/51, initially programmed with very inverse time coordination curve (TCC). Bi-directional.
 - Residually-connected ground overcurrent relay with instantaneous function, Devices 50N/51N, initially programmed with very inverse TCC.
 - Phase overcurrent relay, Device 51C, for cable overload alarm, providing annunciation and supervisory indication (provide same functionality as a Device 51CX auxiliary relay with 125Vdc coil and 3 single pole, double throw contacts). Relay initially programmed with inverse long time TCC.
 - Watt-hour demand metering with 15 minute demand interval. Outputs for the 52-L & 52-RF circuits shall be totalized for telemetry via supervisory system. Totalizing shall be provided by software within the SAS PLC.
 - Breaker failure detection contact closure which trips bus tie breaker when line breaker fails to trip after a user-selectable time delay.
- 2 - Interposing relays to close and trip the circuit breaker via supervisory, Devices 201C and 201T (if applicable).
- 1 - Control switch, TRIP-CLOSE, with green, white, and red indicating LEDs, Device CS.
- 1 - Indicating voltmeter, transformer rated, 0-18 kV scale.
- 1 - Voltmeter switch, 4-position OFF-AB-BC-CA.
- 1 - Indicating ammeter, transformer rated, 0-600 Ampere scale.
- 1 - Ammeter switch, 4-position OFF-A-B-C, center-of-circuit type.
- 1 - Current transducer, as specified, for telemetering phase B current, Device A-XD.
- 1 - Test switch, 10-pole, for 4 potential and 6 current circuits.
- 6 - Neon tube-type high voltage indicators installed on line side of circuit breaker, two per phase, type RS with antennae.
- 2 - Potential transformers, 14400:120 Volts, draw-out mounted with primary current limiting fuses, connected to line side of circuit breaker, open delta primary, grounded open delta secondary.
- 3 - 15kV class stress cone termination kit (see Section 16120).
- 1 - Set of space heaters with Blue LED ON-OFF switch, and ammeter.

- 1 - Set of DC and AC control and auxiliary power disconnect devices with fuses.
 - 3 - Surge Arresters, if required by switching surge study or if circuit is connected to aerial feeder cables.
- c. Unit Substation Feeder Breakers, Devices 52-F
- Each 52-F Circuit breaker unit includes but is not limited to, the following.
- 1 - Metal-clad stationary unit, nominal 750 MVA class, with 1,200 Ampere insulated bus and 1,200 Ampere tap.
 - 1 - 1,200 Ampere circuit breaker removable element, as specified, nominal 750 MVA class.
 - 3 - Current transformers, 600:5 Ampere multi-ratio, connected for 150:5 Ampere for relaying and indication, ANSI accuracy class C-100.
 - 3 - Current transformers, 1200:5 Ampere for bus differential protection, ANSI accuracy class C-200.
 - 1 - IED Microprocessor-based multifunction relay and metering unit with the following minimum functions (for additional required features see Article 2.01, Paragraph O of this Section):
 - Phase overcurrent relay with instantaneous function for each phase, Devices 50/51, initially programmed with very inverse time coordination curve (TCC).
 - Residually-connected ground overcurrent relay with instantaneous function, Devices 50N/51N, initially programmed with very inverse TCC.
 - Phase overcurrent relay, Device 51C, for cable overload alarm, providing annunciation and supervisory indication (provide same functionality as a Device 51CX auxiliary relay with 125 Vdc coil and 3 single pole, double throw contacts). Relay initially programmed with inverse long time TCC.
 - Watt-hour demand metering with 15 minute demand interval, with outputs telemetered via supervisory.
 - Breaker failure detection contact closure which trips associated line breaker and bus tie breaker when feeder breaker fails to trip after a user-selectable time delay.
 - 2 - Interposing relays to close and trip the circuit breaker via supervisory, Devices 201C and 201T (if applicable).
 - 1 - Control switch TRIP-CLOSE, with green, white, and red indicating LEDs, Device 01.
 - 1 - Indicating voltmeter, transformer rated, 0-18 kV scale.
 - 1 - Voltmeter switch, 4-position OFF-AB-BC-CA.
 - 1 - Indicating ammeter, transformer rated, 0-150 Ampere scale, connected to phase B.
 - 1 - Ammeter switch, 4-position OFF-A-B-C, center-of-circuit type.
 - 1 - Current transducer, as specified, for telemetering phase B current, Device A-XD.
 - 1 - Key interlock system as specified in Section 16203 Article 1.13.
 - 1 - Test switch, 10 pole for 4 potential and 6 current circuits.

- 6 - Neon tube-type high voltage indicators installed on line side of circuit breaker, two per phase, type RS with antennae.
 - 2 - Potential transformers, 14400:120 Volts, draw-out mounted with primary current limiting fuses, connected to line side of circuit breaker, open delta primary, grounded open delta secondary.
 - 3 - 15kV class stress cone termination kits (see Section 16120).
 - 1 - Set of space heaters with Blue LED ON-OFF switch and ammeter.
 - 1 - Set of DC and AC control and auxiliary power disconnect devices with fuses.
 - 3 - Surge Arresters, if required by switching surge study or if circuit is connected to aerial feeder cables.
- d. Bus Tie Breaker Unit, Device 52-BT
- Each 52-BT circuit breaker unit includes but is not be limited to, the following.
- 1 - Metal-clad stationary unit, nominal 750 MVA class, with 1,200 Ampere insulated bus and 1,200 ampere taps.
 - 1 - 1,200 Ampere circuit breaker removable element, as specified, nominal 750 MVA class.
 - 6 - Current transformers, 1200:5 Ampere for bus differential protection, ANSI accuracy class C-200.
 - 1 - IED Microprocessor-based bus differential relays, Device 87B (3 phase).
 - 1 - Bus lockout relay, manually reset type, rated for operation on 125 Volts DC, Device 86B.
 - 1 - Bus voltage secondary undervoltage relays, Device 27B.
 - 1 - Bus undervoltage/phase sequence relay, solid state, three-phase, 120V, 60 Hz, connected to bus PT secondaries, Device 47.
 - 1 - Time delay relay for bus under-voltage alarm, Device 47-X
 - 1 - Indicating voltmeters, transformer rated, 0-18 kV scale.
 - 1 - Voltmeter switches, 4-position OFF-AB-BC-CA.
 - 1 - Voltage transducers, as specified, for telemetering, 13.8 kV bus potential, Device V-XD.
 - 1 - Interposing relays to close and trip the circuit breaker via supervisory, Devices 201C and 201T (if applicable).
 - 1 - Control switch, TRIP-CLOSE, with green, white, and red indicating LEDs, Device CS.
 - 1 - Set of space heaters with Blue LED, ON-OFF switch and ammeter.
 - 1 - Set of DC and AC control and auxiliary power disconnect devices with fuses.
 - 1 - 120 Vac grounded duplex receptacle.
 - 3 - Bus 2 potential transformers, 14400:120 Volts, draw-out mounted, with primary current limiting fuses, connected to the main bus, grounded wye primary, grounded wye secondary (mount in enclosure above bus tie breaker cubicle).

- 1 - Totalizer for Watthour metering, equipped for telemetering to SCADA.
- 3 - Surge Arresters, if required by switching surge study.
- e. Rectifier Transformer Feeder Breaker Units, Device 52-T

Each 52-T rectifier transformer circuit breaker unit includes but is not be limited to the following.

 - 1 - Metal-clad stationary unit, nominal 750 MVA class with 1,200 Ampere insulated bus and 1,200 Ampere tap.
 - 1 - 1,200 ampere circuit breaker removable element, as specified, 750 MVA class.
 - 3 - Current transformers, 600:5 Ampere multi ratio, connected for 300:5 Ampere for relaying and indication, ANSI accuracy class C-100.
 - 3 - Current transformers, 1200:5 Ampere for bus differential protection, ANSI accuracy class C-200.
 - 1 - IED Microprocessor-based multifunction relay and metering unit with the following minimum functions (for additional required features see Article 2.01, Paragraph O of this Section):
 - Phase overcurrent relay with instantaneous function for each phase, Devices 50/51, initially programmed with very inverse time coordination curve (TCC).
 - Residually-connected ground overcurrent relay with instantaneous function, Devices 50N/51N, initially programmed with very inverse TCC.
 - Phase overcurrent relay, three-phase, Device 51R, for rectifier overload detection. Relay initially programmed with inverse long time TCC.
 - Watt-hour demand metering with 15 minute demand interval, with output telemetered to supervisory.
 - Breaker failure detection contact closure which trips associated line breaker and bus tie breaker when rectifier breaker fails to trip after a user-selectable time delay.
 - 2 - Interposing relays to close and trip the circuit breaker via supervisory, Devices 201C and 201T (if applicable).
 - 1 - Control switch TRIP-CLOSE with green, white, and red indicating LEDs, Device CS.
 - 1 - Indicating ammeter, transformer rated, 0-300 Ampere scale, connected to phase B.
 - 1 - Ammeter switch, 4-position OFF-A-B-C, center-of-circuit type.
 - 3 - Bus 1 potential transformers, 14400:120 Volts, draw-out mounted, with primary current limiting fuses, connected to the main bus, grounded wye primary, grounded wye secondary (mount in enclosure above rectifier transformer breaker cubicle).
 - 3 - Bus 3 potential transformers, 14400:120 Volts, draw-out mounted, with primary current limiting fuses, connected to the main bus, grounded wye primary, grounded wye secondary (mount in enclosure above rectifier transformer breaker cubicle).
 - 1 - Test switch, 10 pole, with 4 potential and 6 current circuits.
 - 3 - 15kV class stress cone termination kits (see specification Section 16120).

- 1 - Set of space heaters with blue LED, ON-OFF switch and ammeter.
- 1 - Set of DC and AC control and auxiliary power disconnect devices with fuses.
- 1 - 120 Vac duplex grounded receptacle.
- 3 - Surge Arresters, if required by switching surge study.

2.2 RECTIFIER TRANSFORMERS

2.2.1 RECTIFIER TRANSFORMERS – OIL FILLED

A. General

1. Rectifier transformers shall be oil immersed, three phase, 60 Hz, three-winding, delta-delta/wye configured as a Circuit 31 per IEEE C.57.18.10, using ambient air for cooling under ambient conditions as specified in Article 1.03 of this Section.
2. Transformers shall be capable of withstanding short circuit forces in accordance with ANSI C57.12.00 and C57.12.90. Certified short circuit test data for a transformer of similar design, voltages and MVA capacity showing no evidence of failure during the short circuit test shall be provided to document the capability of the transformer plant and design. A description of the test code under which the transformer was tested shall be provided.
3. The transformer and its accessories shall be qualified in accordance with IEEE Standard 693, IEEE Recommended Practice for Seismic Design of Substations. The seismic qualification level shall be “MODERATE”.
4. The transformer shall be designed to meet the requirements of ANSI C57.18.10, IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers, and NEMA RI-9, for extra heavy traction service, with sequentially-applied loads as follows:
 - a. 100% load continuously;
 - b. 150 percent current for 2 hours following 100 percent load;
 - c. 300 percent current for five equally spaced periods of 1 minute during 150 percent load; and
 - d. 450 percent current for the final 15 seconds.
5. Transformers shall fully coordinate with and operate in conjunction with their associated rectifiers specified under Article 2.03 of this Section.
6. The DB Entity shall submit for MBTA's acceptance, 21 days prior to the Design Conference, design calculations for the transformer rated for use with the specified rectifier, which shall include, but not be limited to, the following. If computer simulations are submitted in lieu of calculations, all program input data, technical assumptions, and results must be clearly documented to the MBTA's satisfaction.
 - a. Resistance
 - b. Impedance

- c. X/R Ratio
 - d. Temperature Rise Curve
 - e. Power Loss Curve
 - f. Efficiency vs. Load Curve
 - g. Power Factor vs. Load Curve
7. The number of rectifier transformers to be furnished and shipped to the substation shall be as indicated on the Design Documents.
 8. Provision shall be made by the DB Entity for the clearances necessary for the removal of the equipment without the need to dismantle or remove other operating equipment located within the substation.

B. Ratings

1. The rms kVA rating of each rectifier transformer shall be based on the load requirements its associated rectifier as detailed in Article 2.03 of this Section, in accordance with the referenced standards.
2. Cooling class: ONAN.
3. Average winding temperature rise by resistance for the specified extra heavy traction overload cycle shall not exceed 65°C with an average ambient temperature of 30°C and a maximum ambient temperature of 40°C during a 24-hour period. Maximum temperature by hot spot shall not exceed 80°C.
4. High voltage windings shall be three phase 60 Hz, 13.8 kV nominal, delta connected, copper conductor. High voltage winding insulation class shall be 15 kV, rated for a basic impulse level (BIL) of 110 kV.
5. Transformer shall have two three phase low voltage copper windings: one delta connected, the second wye connected, arranged in accordance with ANSI Circuit No. 31, as defined in ANSI Standards C57.18.10 and C34.2, to provide six-phase (for connection to a twelve-pulse rectifier), multiple delta-wye, double-way supply to the rectifiers. Voltage and related characteristics shall be commensurate with the rectifier specified under Article 2.03 of this Section. Low voltage winding insulation class shall be 1.5 kV, rated for a BIL of 45 kV, minimum.
6. The transformer winding current rating at any tap position shall be based on rectifier rated current for the nominal full load operating voltage of 590 Vdc.

C. Impedance

1. The transformer impedance shall be as low as possible, consistent with good design and shall be determined by the overall requirements of the transformer, rectifier, AC and DC buses, particularly with respect to the DC output voltage regulation specified in Article 2.03 of this Section, and the limitation of fault current magnitudes in accordance with rectifier diode capabilities and the interrupting ratings of the DC circuit breakers. The specified maximum

and minimum short circuit capacity of the incoming 13.8 kV service at the substation shall be used for determining the total voltage regulation of each transformer-rectifier unit (Article 1.06.B of this Section).

D. Taps

1. Ten 2-1/2 percent no load, full capacity taps shall be provided in the high voltage windings, as tabulated below, for adjustment of sustained departures in AC supply voltage and for adjustment of output voltage as required for initial and future operation of the rectifiers.

	HV Winding	LV Winding	Rectifier Light Load
<u>Tap Position</u>	<u>Voltage Rating</u>	<u>Voltage Rating</u>	<u>Output Voltage</u>
0	14,835 Vac	466 Vac (Note 1)	563 Vdc (Note 1)
1	14,490 Vac	466 Vac	563 Vdc
2	14,145 Vac	466 Vac	577 Vdc
3	13,800 Vac	466 Vac	592 Vdc
4	13,455 Vac	466 Vac	607 Vdc
5	13,110 Vac	466 Vac	623 Vdc
6	12,765 Vac	466 Vac	640 Vdc
7	12,420 Vac	466 Vac	657 Vdc
8	12,075 Vac	466 Vac	676 Vdc
9	11,730 Vac	466 Vac	696 Vdc

Note 1: A 466 Vac rectifier transformer low voltage winding rating is typical, not mandatory, and is provided herein for illustrative purposes only.

2. In addition, application of 13,800 Vac to the rectifier transformer with the tap changer at position seven shall result in future rectifier operation in the range of 650 to 661 Vdc at rated full (100%) load. For future operation, the taps above and below tap seven shall be suitable for adjustments, in 2½ percent increments, for the deviations in the nominal 13,800 Vac supply system voltage.

E. Power Circuit Terminations

1. Transformer high voltage terminals shall be provided with bolted-type terminal lugs with NEMA four bolt tongue, in accordance with Section 16203 Article 1.07, for terminating one 350kcmil stranded copper cable per phase. Terminals shall be located to provide ample space and support for stress-coning the three 15kV class, single conductor, EPR-insulated, jacketed cables.

Terminals H1, H2, H3, R1, R2, R3, R4, R5, R6 shall be clearly and indelibly marked on the transformer.

F. Wiring and Terminal Blocks

1. All devices furnished with the transformer shall be factory wired to the maximum extent practicable. Circuits requiring external connections shall be wired to the terminal blocks in the instrument compartment for connection of the field wiring entering from the top.
2. Wiring for control and auxiliary circuits and terminal blocks shall be rated for 600 Volts, provided in accordance with Section 16203 Article 1.09. Minimum wire size shall be No. 12 AWG, except low voltage, low energy connections between components and alarm device pigtails may be No. 16 AWG.

G. Audible Sound Level

1. Audible sound level shall not exceed NEMA TR-1 limits at no load with excitation on the transformer, when measured in accordance with conditions outlined in ANSI Standard C57.12.90.
2. Major sound-producing components and the transformer enclosure shall be acoustically treated, if required, to meet this criterion.

H. Transformer Tank Construction

1. Transformers shall be of the sealed tank, welded steel plate and cover construction, outdoor type, liquid tight, with bolted and gasketed manhole(s) on top of tank. Mounted on steel skid base, suitable for skidding in any direction. Use care to avoid tank or component distortion during welding operations. Assembled transformer base shall be sufficiently flat to be installed on a flat concrete foundation without supplemental shims. Adequately designed and braced to allow full vacuum filling and vacuum drying operations in the field.
2. Provide jacking lugs and pulling eyes for lifting or moving along either axis when completely assembled and oil-filled. Lifting lugs to be mounted near the top of the tank. Jacking lugs shall be installed with approximately 13" of clearance to the bottom of the base plate.
3. Provide two NEMA 2-hole copper faced or stainless steel ground pads at diagonally opposite corners of transformer tank near base, with two-bolt terminal connectors for 4/0 AWG copper conductors.
4. Maintain positive pressure continually to prevent ingress of moisture during shipping.
5. Provide an adequately braced domed or sloped top on all major surfaces. Design tank and fittings to prevent water puddling on surfaces or in cavities.
6. Provide raised flanges with thru-bolts for all removable cover penetrations, including bushings, manhole/handhole covers and removable equipment. Welded studs are not acceptable.
7. All gasketed joints shall have machined surfaces on both sides, and shall be provided with gasket retainers and metal-to-metal stops to assure even the effective pressure and to avoid

over-stressing the gasket. Gaskets shall maintain oil-tight joints under all service and fault conditions.

8. The transformer manufacturer shall supply all necessary support devices and mechanisms required to “hold” the unit in place on the structural steel grillage if applicable. Details of these devices should be provided as part of the equipment product information submittal.

I. Transformer Core Construction

1. Provide highest quality, non-aging, cold-rolled, grain-oriented, stress free, thin silicon steel laminations, having high permeability and low hysteresis loss and properly annealed with smooth surfaces at edges.
2. Provide each sheet with an insulated surface treatment which is impervious to hot transformer oil.
3. Core shall be carefully assembled, rigidly clamped and blocked to prevent deteriorating vibrations, interference with oil circulation, objectionable noise conditions and short circuit and shipment distortions.
4. Provide a core ground lead connected to an external bushing for each core. Provide a flexible ground strap to connect the terminal of the bushing to the transformer tank, thereby grounding the transformer core. Provide a suitable cover or deflector to protect the core ground bushing from damage from falling objects. Provide an engraved nameplate clearly indicating the function of the bushing. Provide a separate core ground bushing and ground strap for each separate core, if more than one core is used.
5. Serial number shall be stamped on core or core clamp in conspicuous place, and shall be visible without the necessity for untanking or otherwise removing entire enclosure.
6. Provide means for properly handling core assembly when core assembly is untanked.

J. Transformer Windings

1. Comprised of electrolytic copper with high conductivity characteristics
2. Provided with insulation system of high dielectric and mechanical strength, arranged to permit free circulation of oil.
3. Made up, shaped and braced to provide for expansion and contraction due to temperature changes and avoid abrasion of insulation.
4. Adequately braced to prevent distortion due to any abnormal operating condition. Designed to withstand short circuit conditions in accordance with IEEE C57.12.90.
5. Brazed joints and pressure connectors are acceptable. No soldered connections will be allowed. No more than one connection shall be made in a single lead.
6. Each lead for connection to tap changers and bushings, shall be permanently identified.
7. The core and coil assembly shall be dried using a vapor phase process.

K. Transformer Cooling Equipment

1. Type: ONAN conforming to ratings previously specified.
2. Radiators:
 - a. Of nominal dimensions and interchangeable.
 - b. Galvanized steel, welded construction, with flanged connection and provisions for draining and venting, and without external cavities that would collect moisture.
 - c. Provided with lifting eyes or lugs.
 - d. Provided with oil-tight valves at all connections to main tank that will allow removal of radiators without taking transformer out of service.

L. Transformer Oil and Preservation System

1. FM Global approved less flammable insulating oil with characteristics similar to EnviroTemp FR3 Fluid or approved equal.
2. Dielectric strength not less than 30,000 Volts between one inch discs spaced 1/10" apart.
3. Transformer shall be provided with maintenance-free sealed tank type oil preservation system which does not require external nitrogen supply for normal operation. All other methods of oil preservation will be subjected to Engineers approval.

M. De-Energized Tap Changers (DETC):

1. Externally operated when transformer is de-energized
2. Provided with indicating pointer, dial, and means for locking in any tap position. Include provisions for MBTA supplied padlock.
3. Mounted at a convenient operating height.
4. Capable of withstanding full transformer short circuit current without damage.
5. Configured to prevent leaving a winding open or short circuited when operating handle is in locked position.
6. Provided with full capacity taps as specified herein.

N. Air Terminal Chambers

1. Transformer high voltage bushings shall be side-wall mounted and enclosed in a weather proof air-insulated terminal chamber. The DB Entity shall provide for each bushing a heavy duty bolted type terminal lug suitable for a 15 kV class, three-single conductor, EPR-insulated (133%), jacketed cables entering from below. Ample space and support shall be provided in the terminal chamber for stress-coning the 15 kV cables. The DB Entity shall

provide suitable insulating material and tape to properly insulate all exposed current carrying members of terminators and bushing studs.

2. Transformer low voltage bushings shall be either cover mounted or sidewall mounted, enclosed by a weatherproof flanged throat. The bushings and throat shall be provided with necessary connectors and hardware for direct bolted connection to the weather-proof bus duct or set of low voltage cables as accepted by the MBTA and shown in the Design Documents. Bolted, readily removable links shall be provided for connecting the bus bars/cables to the transformer terminals. The flanged throat and bus enclosure shall be joined by bolted and gasketed weatherproof connection providing ready means of separating the bus duct from transformer. A weatherproof access opening shall be provided for connecting the transformer to the bus duct/cables.
3. Terminals H1, H2, H3, R1, R2, R3, R4, R5 and R6 shall be clearly and indelibly marked on the transformer.
4. Chambers shall have gland plates for conduit entrances. They shall be removable, gasketed, bottom plates, ready for field drilling as needed.
5. High voltage cabinet shall have a hinge. Final cabinet dimension to be submitted and accepted by the MBTA.

O. Transformer Bushings

1. Bushing studs: Threaded, stud type, silver plated.
2. Provide stud connectors with NEMA standard 4-hole (minimum) pad drilling sized to accommodate the full rating of the bushing.
3. Color: ANSI 61, Light Gray (to match transformer)
4. High Voltage Bushings
 - a. Type: Interchangeable
 - b. BIL rating: 110 kV minimum
 - c. Current rating: To match transformer primary kVA rating
 - d. Creepage distance: Standard
 - e. Mounting: In high voltage air terminal chamber
 - f. Material: Porcelain manufactured by the wet process.
5. Low Voltage Phase Bushings
 - a. Type: Interchangeable
 - b. BIL rating: 45 kV minimum
 - c. Current rating: To match transformer secondary kVA rating.

- d. Creepage distance: Standard
 - e. Mounting: In low air voltage terminal chamber.
 - f. Material: Porcelain manufactured by the wet process.
6. Low Voltage Neutral Bushing
- a. Type: Interchangeable
 - b. BIL rating: 45 kV minimum
 - c. Current rating: To match transformer secondary kVA rating.
 - d. Creepage distance: Standard.
 - e. Mounting: In low voltage air terminal chamber.
 - f. Material: Porcelain manufactured by the wet process.

P. Wiring and Terminal Blocks

- 1. All devices furnished with the transformer shall be factory wired as far as practicable. Circuits requiring external connections shall be wired to the terminal in the instrument compartment for connection of the field wiring entering from the bottom.
- 2. All secondary and control wiring shall be ICEA type SIS, or approved equal, stranded tinned copper switchboard wire, No. 12 AWG or larger, rated for a minimum conductor temperature of 90 °C, insulated for 600 Volts AC minimum. Wire shall comply with Underwriters Laboratories, Inc. Flame Retardant Properties Test, in accordance with standard UL-44 thermoplastic insulated wire.
- 3. Wiring shall be provided with ring type compression terminals with insulated sleeves at each termination. All wiring shall be identified at each termination by printing on wire jacket or on an insulating sleeve. Adhesive wire markers are not acceptable.
- 4. Terminal blocks shall be heavy duty, washer-head screw type with insulating barriers between circuits, rated 600 Volts, General Electric Company type EB-25 or approved equal, complete with marking strips and plastic covers. A sufficient number of terminals to satisfy all external connection requirements and 20 percent additional unassigned terminals shall be provided. Able to accommodate up to No. 10 AWG wire.

Q. Main Transformer Control Cabinet

- 1. Weatherproof and fastened securely to transformer tank.
- 2. Doors: Vertically hinged with padlocks.
- 3. Conduit entrance: Removable, gasketed bottom plate, field drilled.
- 4. Mount terminal blocks and equipment at least 6" above bottom plate.

5. Provide anti-condensation space heaters powered from transformer auxiliary supply complete with a thermostat adjustable from 40 °F to 90 °F, and a by-pass switch wired in parallel with the thermostat. Heaters shall be rated at 240 V AC, operated at 120 V AC, and properly sized for reduced output. Provide an ammeter to measure heater current. Provide a nameplate indicating "Control Compartment Heater Ammeter - Normal = ____ A". Fill in normal amp reading.
6. Provide one set of incandescent lamp receptacle(s) with conveniently located toggle switch or door, operated switch to provide adequate light within the terminal cabinet and a grounding type receptacle, mounted inside the terminal cabinet.
7. Provide one 15A convenience outlet.

R. Protective Devices and Accessories

1. Protect all gauges and instruments with protective guards and mount at eye level when operator is standing on ground level.
2. Each rectifier transformers shall be furnished with suitable, factory-installed protective and maintenance devices. Devices shall be rated for operation on 125Vdc, unless otherwise noted.
3. All devices, valves, pipes and other projections from the sides of the transformer that may be used as a step shall be provided with a guard strong enough to support the weight of a 300 pound man. Any item located on the top of the transformer that may be inadvertently stepped on shall also be provided with a guard.
4. All electrical devices shall be provided with weatherproof enclosures. All temperature devices shall be installed in wells to permit removal of the sensing element without draining the transformer.
5. All control and alarm devices shall be wired to terminal blocks located in a single terminal cabinet accessible from ground level. The terminal cabinet shall be weatherproof and shall have a full access, hinged and gasketed door arranged for pad-locking. Wiring shall be in rigid, hot-dip galvanized steel conduit, except for short flexible connections to devices which shall be in Sealtite, or approved equal, liquid tight flexible conduit.
 - a. Alarms: Provide two auxiliary alarm contacts (form C) for each alarm point. Wire all outputs to transformer control cabinet terminal block for MBTA use.
6. Circuits requiring external connections shall be factory-wired to readily accessible terminal blocks within the terminal cabinet, for connection to field wiring entering from below.
7. The protective devices shall interface with the substation automation system within the substation to remotely provide the alarms and controls.
8. Each transformer shall be furnished with accessories in accordance with ANSI C57.12.10, including, but not limited to, the following:
 - a. 1 – Liquid level gauge and relay complete with two (2) sets of alarm and tripping contacts (Device 71T).

- b. 1 – Dial thermometer with two (2) two-step electrically independent high liquid temperature alarm contacts which close on rising liquid temperature for alarm (first step) and for tripping and self resetting conditional lockout relay (second step). Scale shall be in degrees Celsius. An additional red marker shall be provided to indicate maximum allowable oil temperature (Device 26T and 26TH).
- c. 1 – Winding hot spot temperature indicator, complete with a current transformer, top oil temperature device and relay with two (2) two-step electrically independent contacts which close on rising temperature for alarm (first step) and for tripping and self resetting conditional lockout relay (second step). Scale shall be in degrees Celsius (Device 49WT and 49WTH).
- d. 1 – Sudden Pressure Relay with two (2) sets of contacts for indication and control designed to respond to sudden increase of pressure caused by an internal arc. The relay shall not operate on pressure changes due to changes in transformer temperature, loading or through faults and shall be designed to safeguard against false tripping due to mechanical vibrations and shock. The relay shall be of the manually reset-able type (Device 63P).
- e. 1 – Pressure/vacuum gauge.
- f. 1 – Pressure relief device with self-resealing cover and hand-reset two electrically independent normally open contacts for lockout alarm. Relief device shall function to protect the tank, radiators, gaskets and all other appurtenances from damage. The pressure relief valve discharge shall be piped to a point adjacent to the base of the transformer and 12” above the base of the transformer. Discharge shall be located away from areas that are commonly accessed by personnel while the transformer is energized, including but not limited to the control cabinet. Device shall include mechanical target visible from ground level (Device 63MR).
- g. 1 – Combination drain and lower filter valve with two inch NPT thread complete with sampling valve. The drain/filter valve and the sampling valve shall be provided with means for padlocking in valve closed position.
 - i) 1 – Upper filter valve with two inch NPT thread.
 - ii) 1 – Lower valve with two inch NPT thread for removal of sludge, arranged for padlocking in closed position.
- h. 2 – Grounding pads on diametrically opposite corners, each provided with a bolted type terminal lug with two bolt tongue for stranded copper ground cable within range of No. 4/0 AWG through 500 kcmil.
- i. 1 – Complete set of spare gaskets, cut to size and drilled for all holes, for all covers, radiators, devices and fittings and sufficient amount of gasket cement. The gaskets shall be tagged to indicate their use.
- j. Equipment as necessary to interface the rectifier equipment with the substation automation system i.e. the Transformer IED / DIO will be located within the control compartment

- k. Spaces heater for terminal cabinet/control compartment with light and 120V AC receptacle. 120V AC supply will provide power to the AC busduct heater via this cabinet.

S. Nameplates

1. In addition to nameplates specified above and in Section 16203 Article 1.08, provide a nameplate on front and rear of the transformer enclosure, engraved "DANGER -13,800 VOLTS". The nameplate shall have white letters, two inches high, minimum, on red background.
2. Inscription of nameplate shall be in accordance with IEEE Std. C57.18.10, and shall be submitted to the MBTA for acceptance.
3. Equipment identification nameplates shall be engraved "RECTIFIER TRANSFORMER NO.1" and "RECTIFIER TRANSFORMER NO.2" (typical).

T. Finish

1. Prepare all surfaces of the transformer and the base in accordance with Section 16203 Article 1.15, and finish exterior surfaces with two coats of semi-gloss ANSI-61 light gray paint. Ensure that all surfaces are coated, including areas partially blocked by conduits, equipment and accessories.
2. Paint interior of transformer tank white.
3. Top surface of the transformer tank shall be coated with a non-skid paint.
4. Paint interior of cabinets white.
5. One quart of matching touch-up paint shall be shipped with the transformer.

2.3 RECTIFIERS AND ACCESSORIES

A. General

1. Rectifier shall be indoor, metal enclosed, natural convection cooled, using building air for cooling under ambient conditions as specified in Article 1.03 of this Section, for 12-phase multiple double way rectification.
2. The number of rectifiers to be furnished and shipped to the substation by the DB Entity shall be as indicated on the Design Documents.
3. The rectifier shall be supplied with AC traction power directly from the rectifier transformer specified in Article 2.02 of this Section, to serve as the source of supply for the DC switchgear specified in Article 2.04 of this Section. The rectifier shall be operated with enclosure high-resistance grounded. Rectifier shall be designed to meet the requirements of ANSI C34.2 and NEMA RI-9 for extra heavy duty traction service as noted in Article 2.02 of this Section.
4. Rectifier shall be designed for non-attended operation. Rectifier shall function as an integrated unit with associated transformer and DC switchgear. Rectifiers and accessories

shall also be capable of parallel operation with existing rectification equipment at adjacent MBTA traction power substations. Details about the MBTA's existing equipment can be supplied upon request.

5. The DB Entity shall submit for MBTA's acceptance, 21 days prior to the Design Conference, a set of complete design calculations for each type and/or rating of rectifier to be provided under this Contract, which shall include but not be limited to, the following. If computer simulations are submitted in lieu of calculations, all program input data, technical assumptions, and results must be clearly documented to the MBTA's satisfaction.
 - a. Voltage Regulation Curve
 - b. No Load Voltage
 - c. Power factor vs. Load Curve
 - d. Efficiency vs. Load Curve
 - e. Harmonic Amplitude vs. Load Curve for 11th, 13th, 23rd and 25th harmonics
 - f. Commutation Reactance for $X/R = 8$
 - g. Momentary Peak and Sustained Short Circuit Current for a single rectifier, and for all substation rectifiers in operation
 - h. Commutation Factor
 - i. Calculations to show compliance with Specification on number of parallel diodes furnished
 - j. Interphase transformer design criteria

B. Structures

1. Rectifier units shall be metal enclosed, provided with self-supported, electrically welded steel structures. The rectifier assembly shall consist of a power rectifier section and a control/auxiliary section, arranged to form a continuous, free-standing unit. The enclosures shall be constructed of structural members of sufficient strength to support the bus duct which interconnects the rectifier to the rectifier transformer, DC switchgear and negative equalizer bus and drainage board.
2. Rectifier section shall be provided with hinged front and rear doors for easy access to diodes, fuses, surge protection devices, heat sinks and buses for inspection, maintenance and cleaning. Each door shall be provided with safety glass windows, arranged to permit inspection of all indicating fuses and fuse failure indicating lights of surge protection devices. All doors shall be securely fastened in the closed position by vibration-resistant fasteners with provision for padlocking, and easily opened without the use of tools. Doors shall be provided with stops to hold them securely open at 90 degrees.
3. The control/auxiliary section shall be completely isolated from the rectifier section by suitable sheet steel barriers. The Auxiliary section shall extend the full height of the rectifier to facilitate top and bottom control wire entry. It shall contain the instruments and devices

required for control and monitoring of the rectifier transformer, rectifier and the rectifier DC main breaker. The control/auxiliary section shall be provided with hinged front and rear doors, for access to devices and terminal blocks and for mounting of relays, instruments and control devices. The doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges or stiffening members. The door shall be securely fastened in the closed position and easily opened without the use of tools.

4. All control and supervisory circuit devices located in the control/auxiliary section are operated on 125 Volts DC or 120 Volts AC. Where the use of higher voltage is unavoidable, such circuits shall be connected with red-colored wire.
5. All doors of the rectifier section and the doors of control/auxiliary section compartments containing exposed buses or devices operated on 600 Volt nominal DC positive potential shall be provided with interlocks designed to prevent energization of the rectifier while any of the doors are open, and to de-energize and lockout the rectifier when any of the doors are opened while the rectifier is in operation. Control devices and wiring operated on 600 Volts DC nominal shall be grouped in separate compartments as far as possible so that the devices operated at lower voltage are accessible for maintenance without the need for de-energizing the rectifier.
6. All components within the control/auxiliary section shall be located for easy access for maintenance and inspection. The arrangement of devices will be subject to the acceptance of the MBTA.
7. Openings in doors or fixed panels on the rectifier section which are utilized for circulation of air through the rectifier, shall be screened for personnel safety. Screens shall be expanded metal of gage accepted by the MBTA, with openings approximately 1/4" x 1". Cooling air shall enter the rectifier enclosure no less than 6" above floor level.
8. All surfaces of the enclosure shall be finished in accordance with Section 16203 Article 1.15. One quart of matching touch-up paint shall be shipped with each rectifier.
9. As necessary, provide a raised flange for the busduct connections to accommodate an insulating busduct collar.

C. Buses and Power Connections

1. Rectifier internal buses shall be copper, provided in accordance with Section 16203, Article 1.06. Aluminum may be used for diode heat sinks, and for certain current carrying sub-assemblies as accepted by the MBTA. Appropriate barriers shall be provided to separate the positive and negative buses within the rectifier. Suitable means, accepted by the MBTA, shall be employed to prevent corrosion at connections of dissimilar metals.
2. Permanent corrosion inhibiting coatings shall be provided for all bolted connections to reduce maintenance.
3. Rectifier anode (AC) and positive and negative cathode (DC) terminals shall be copper, located at the top of the enclosure, in an air-filled terminal chamber or in a flanged throat, arranged for direct, bolted connection to the anode and cathode bus ducts specified in Article 2.05 of this Section and as accepted by the MBTA. Bolted, readily removable flexible links covered with insulating boots shall be provided, in accordance with Section 16203 Article

1.07, for connecting the bus conductors to rectifier terminals. The terminal enclosure and bus enclosure shall be joined by an approved bolted-on insulating collar, providing electrical insulation and a ready means for separating the bus duct from the rectifier. Openings with bolted-on covers shall be provided for access to the connecting links.

D. Ratings

1. Each rectifier shall have a continuous full load output rating of 3,000 kW at a maximum ambient room temperature of 40°C during initial operation, and 3,300 kW during future operation. Rated full load output voltage for determining the continuous current rating of the rectifier shall be taken as 590 Vdc for initial operation, and 650 Vdc for future operation. After constant temperature rise is reached following continuous full load, it shall be capable of operating at an overload equal to 150 percent of full load current for two hours and superimposed cyclic overload consisting of five periods of 300% full load current for one minute, equally spaced throughout the 2-hour period, followed by one period of 450% full load current for fifteen seconds at the end of the two hour period. The rectifiers shall be designed for two two-hour overload cycles within a 24 hour period, spaced 6 hours apart.
2. Each rectifier shall be capable of carrying the specified overload with one diode removed from service in each phase leg of the rectifier without exceeding the safe junction temperature of the remaining diodes.
3. Loss of one diode in each phase leg shall not adversely affect the ability of the rectifier to withstand a short circuit.
4. Each rectifier shall be capable of withstanding a bolted short circuit on the rectifier output terminals immediately following (within one second or less) the two hour overload period specified above until fault is cleared by the rectifier AC circuit breaker, without damage to any component, including protective fuses and rectifier elements.
5. Each rectifier shall have a full load overall efficiency of not less than 94 percent with a displacement power factor above 95 percent, lagging. The voltage regulation characteristic, based on the minimum short circuit supply MVA and the X/R ratio of the incoming 13.8 kV services specified in Article 1.06.B of this Section, shall be such as to provide output voltage within the limits set forth below when the AC system voltage at no load corresponds to transformer tap voltage. These limits shall be met on all transformer taps. All DC values shall be based on use of averaging type meters.

Output Voltage-Direct Current

	<u>Output Voltage</u>	<u>Output Voltage</u>
<u>Output Current</u>	<u>Initial Operation</u>	<u>Future Operation</u>
0.5% Full load.....	636 to 626.....	700 to 689
100% Full load.....	600 to 590.....	661 to 650
150% Full load.....	582 to 572.....	641 to 630
300% Full load.....	527 to 507.....	582 to 558

450% Full Load..... 474 to 425.....522 to 468

6. The rectifier transformers, AC and DC buses and the DC switchgear assemblies specified herein shall be capable of continuous operation under the voltages specified above.

E. Number of Diodes Required

1. The manufacturer shall provide a sufficient number of diodes per phase leg to fulfill all the requirements of this Specification (“N + 1” design). The DB Entity shall submit detailed calculations to MBTA demonstrating the adequacy of the number of diodes proposed.
2. Each rectifier shall not have less than four diodes per phase leg.
3. A single series fuse shall protect each diode. A fuse assembly comprising multiple diodes will not be accepted.

F. Rectifier Protection

1. Rectifiers shall be designed so that the diodes and other rectifier elements are protected against overcurrents and fault currents by the phase and ground instantaneous and time overcurrent relays, Devices 50/51, 50N/51N, and 51R (where present). The overcurrent relays shall be selective with the individual diode fuses so that the fuses will not blow on a through fault. Diode fuses shall blow on a diode shorting failure only.
2. Rectifier heat sinks shall be provided with thermal devices, Device 26RH, which shall take the rectifier out of service and prevent rectifier operation under any conditions where the rectifier elements and fuses are no longer afforded complete protection by the overcurrent relays. These thermal devices shall be mounted and wired to permit easy removal.
3. Provide rectifier diode fuse failure detection and monitoring system (two-stage). Device 58A/58T. The first stage shall be an alarm condition indicating a single diode fuse failure via the rectifier annunciator. The second stage shall activate upon failure of a second diode fuse on the same phase leg. The second stage shall trip the associated AC and DC circuit breakers via the rectifier lockout 86-T device.
4. Each rectifier unit shall be adequately protected against transient surge voltages caused by lightning, faults or switching operations and the DC spikes caused by operation of rolling stock. The DB Entity shall submit the proposed surge protection method and devices proposed to be used to the MBTA for acceptance.
5. These devices shall interface with the substation automation system within the substation.

G. Wiring and Terminal Blocks

1. Wiring for control and auxiliary circuits and terminal blocks shall be rated for 1000 Volts DC service, minimum, provided in accordance with Section 16203m Article 1.09.
2. Minimum size of wiring shall be No 12 AWG, except internal wiring of devices and device pigtails may be No. 16 AWG.

3. Circuits requiring external connections shall be wired to outgoing wiring terminal blocks in the control/auxiliary section for connection of field wiring entering from above via cable tray, unless otherwise indicated on the Design Documents. Minimum wire size of outgoing wiring shall be No 12 AWG in accordance with Section 16203, Article 1.09.
4. All elements of control devices operated on 600 Volts DC nominal shall be connected with red-colored wire.

H. Control Sources

1. Rectifier control and alarm circuits will receive the 125 Vdc supply from the station battery. Rectifier lockout relay and annunciator circuits shall be connected to this supply through a separate set of disconnect switches and properly sized fuses, rated for 1000 Vdc service, minimum. The DB Entity shall furnish an undervoltage relay, Device 27RA, for the rectifier DC control circuits to provide local alarm.
2. Terminal blocks, rated for 1000 Vdc service, minimum, shall be provided in the control/auxiliary section in accordance with Section 16203, Article 1.09.
3. Any control and indication wiring routed through the main DC power circuit compartment to the control compartment shall be sleeved or ran in conduit rated for a minimum of 1kV DC. Communications cables shall be run in orange innerduct or equal.
4. An independent isolating transformer shall be utilized for all 120 VAC requirements within the equipment. Isolating transformer shall not be located within the equipment.

I. Special Requirements

1. The control/auxiliary compartment of the rectifier shall be provided with electric strip heaters to prevent condensation within the compartment during shutdown periods. An ammeter shall be provided to monitor the heater circuit. The ammeter shall be properly scaled and marked for the heater load. In addition, an indicating blue LED light shall be provided to indicate operation of the heaters, and an ON-OFF switch.
2. Fluorescent lighting fixtures with conveniently located and properly labeled external toggle switch shall be provided in the rectifier section and in each compartment which contains relays, control devices and outgoing wiring terminal blocks. The light switch for the rectifier section shall be mounted on the control compartment door and switch for the relay compartment shall be mounted inside the compartment itself. The lighting fixtures in the rectifier section shall be located so that adequate lighting is provided for normal maintenance and observation, and to permit inspection of all indicating fuses, nameplates and other devices within the unit.
3. The heater and lighting circuits shall be rated for operation on a single phase, three wire, 120 Volt circuit. All devices shall be completely wired by the DB Entity and the circuit extended to a suitable terminal blocks for top connection to supply conductors, unless otherwise indicated on the Design Documents. The lighting fixtures, light switches, space heater devices and terminal blocks shall be insulated from rectifier enclosure for a minimum of 1000 Vdc.

4. Function to be incorporated into the Substation Automation System: A non-reset type elapsed time meter shall be provided in front of the control/auxiliary section, wired through series-connected "a" contacts of the rectifier AC circuit breaker, Device 52-T and rectifier DC circuit breaker, Device 72-R, to record the in-service time of the rectifier unit. The instrument shall be wired to outgoing wiring terminal blocks for top connection to supply conductors, unless otherwise indicated on the Design Documents. The elapsed time meter shall be rated 120 Volts, 60 Hz and shall have a six-digit display to record hours and tenths of hours. Instrument shall be connected to the 120 Volt, 60 Hz reliable supply.
5. The rectifiers shall be secured to the insulated epoxy floor with approved insulated anchors (see Design Documents). The insulated anchors shall be tested in accordance with Section 09671. The rectifier supplier shall recognize that MBTA preference is to insulate the anchor bolts in the floor in order to achieve the 40kV insulation level per the Section 09671. The standard MBTA anchor arrangement is shown in the Design Documents. Alternative floor anchoring arrangements may be proposed but the 40kV anchor insulation requirement shall be maintained.

J. Audible Sound Level

1. The maximum average audible sound level produced by the entire rectifier unit under no-load condition shall not exceed 60 decibels (A). Major sound-producing components, their supports and rectifier enclosure shall be acoustically treated, if required, to meet this criterion.
2. The rectifier unit shall be tested in accordance with NEMA Standard TR1, treating the rectifier (instead of the transformer) as the sound source.

K. Nameplates

1. In addition to nameplates specified in Section 16203, Article 1.08, the DB Entity shall provide nameplates, mounted in the front and rear of each rectifier assembly, engraved "650 VOLTS DC PRESENT IN RECTIFIER COMPARTMENT". The nameplate shall have white letters, two inches high minimum, on red background. Similar nameplates, engraved with one-inch high letters "650 VOLTS DC PRESENT IN THIS COMPARTMENT" shall be provided on the door of each compartment which contains control devices operated on nominal 600 Volts DC.
2. The legend of nameplates shall be submitted to the MBTA for acceptance.
3. Equipment identification nameplates shall be engraved "RECTIFIER No. 1 - 3000 kW" and "RECTIFIER No. 2 - 3000kW".

L. Supervisory Indication

1. Two normally open contacts for each of the following devices or functions, wired to outgoing wiring terminal blocks, shall be provided within each rectifier for remote indication via MBTA's supervisory systems:
 - a. Device 86-T (rectifier lockout). This feature shall be integrated into the substation automation system and the lockout reset be operated via the HMI screen.

M. Detailed Equipment Requirements

1. Each rectifier assembly shall include, but not be limited to, the following:
 - a. Lot of air-filled terminal chambers or flanged throats, connectors and hardware for direct bolted connections to AC anode bus and DC positive and negative cathode buses.
 - b. Silicon diode and heat sink assembly. Single diodes shall be connected in series for each leg and shall have a minimum repetitive peak reverse voltage rating of 2,200 Volts. Each individual silicon diode shall be hermetically sealed and mounted on air-cooled heat sink adequate for maximum heat dissipation. A current balancing arrangement employing reactors, or other equivalent means, shall be provided to ensure constant current balance between paralleled diodes of each individual phase and to maintain each individual diode current within guaranteed capability under all load conditions up to and including the current peaks specified in Article 2.03.D of this section, with one fuse per phase leg open. With any diode fuse open at any and all rated loads, the current in any other parallel diode in the same phase leg shall not exceed its pro-rated share by an amount greater than one percent times the number of paralleled diodes in that phase leg, or by an amount not greater than 20 percent, whichever is greater. Pro-rated share is defined as the total rated phase leg current divided by the number of paralleled diodes in that phase leg. The current balancing method is subject to acceptance by the MBTA. Reliance upon matched diodes for current balancing purpose will not be acceptable, unless the Design-Builder can prove to the satisfaction of the MBTA that each diode selected at random from a production run of diodes of the type to be installed in the rectifier has a tolerance sufficiently close to ensure the specified current balance between the paralleled diodes.
 - c. Set of current limiting fuses: One fuse shall be connected in series with each diode, complete with fuse monitoring system.
 - d. Set of heat sink over-temperature devices. Quantity of devices shall be as necessary with minimum of one device per top diode in each leg. The devices shall be circuit opening on rising temperature, bi-metallic thermal devices shall be furnished and mounted on diode heat sinks. A minimum of sixteen devices, eight on positive and eight on negative heat sinks, shall be connected to provide first-step high temperature alarm, Device 26R. A minimum of sixteen devices, eight on positive and eight on negative heat sinks shall be connected to provide second-step high temperature trip and lockout, Device 26RH. The devices shall be selected to allow for overloads specified in Article 2.03.D of this Section. Circuit shall be self-monitoring with provisions to actuate the alarm or trip circuits, after a time delay of approximately one second, in the event of detection of high temperature, device or circuit failure or loss of AC auxiliary power to Devices 26RX and 26RHX. Provide a white light for Device 26RHX, 120 Volt, AC control source and mount on the rectifier control compartment door with suitable identifying nameplate. Suitable isolating transformers shall be provided to isolate thermal switches from control circuits and from other thermal switches on heat sinks not rigidly at the same potential.
 - e. Resettable counter mounted in front of the control/auxiliary section, to count the number of trips due to heat sink overtemperature.
 - f. Set of surge protective devices. The surge protective devices shall limit the repetitive reverse voltage surges, induced during lightning, faults and switching or by operation of trains, across the diode to within 75 percent of the peak reverse voltage (PRV) rating of

the diodes. The transient surge voltage is assumed to have a crest of 3,000 Volts and 1.5 x 40 microsecond wave shape of either polarity, applied to all rectifier terminals, while operating at rated current and full rated temperature. In addition, the rectifier shall withstand lightning surges of 75 kV crest and 1.5 x 40 microsecond wave shape, applied to rectifier output terminals. Where surge protective devices are protected by a circuit interrupting component, a monitoring circuit employing a neon lamp shall be provided to indicate an inoperative circuit. The monitoring circuits shall be provided with a relay, Device 99Y, to actuate alarm in the event of fuse or surge protective device failure.

- g. Interphase transformer or a set of mutually coupled reactors, for interconnecting the negative side of the two three-phase double-way rectifier circuits. Interphase transformer shall have the voltage and current ratings and the ability to withstand short circuits equal to those specified in Article 2.03.D of this Section, for the rectifier.
- h. Set of interlock switches designed to de-energize the rectifier when any one rectifier access door is opened exposing 600 Volt nominal "live" parts. The interlocks shall trip Device 86-T and actuate alarm, Device 33R. Activation of Device 33R shall be transmitted to the annunciator. A door interlock shall not be provided on the control/auxiliary compartment if this compartment is completely isolated from the rectifier section by suitable sheet steel barriers per Article 2.03.B of this section.
- i. Lot of electric strip heaters, lights and accessories.
- j. Control/auxiliary compartment, completely wired, with all relays, controls and auxiliary devices, including but not limited to the following equipment and quantities:
 - 1 - Master control relay, electrically reset type. Device 4.
 - 1 - The substation HMI system shall replace the below identified annunciator. Functionality and associated requirements shall be provided within the automation system and shown on the HMI.

Annunciator, solid state type, with back-lit nameplates consisting of 30 alarm positions, arranged five high and six wide (see Section 16203, Article 1.12). Annunciator shall be rated for operation on 125 Vdc and shall be provided with three push buttons for acknowledge, reset and test functions. Annunciator cabinets shall be insulated from rectifier enclosure for a minimum of 1,000 Vdc. List of nameplate inscriptions shall be provided for review by the MBTA. All alarm points for which the actuating contacts are remote from rectifier unit and all retransmitting contacts shall be wired to outgoing wiring terminal blocks for connection to field wiring entering from top. Device 30.
 - 1 - Rectifier transformer auxiliary DC circuit undervoltage relay, Device 27RA.
 - 1 - Rectifier and transformer auxiliary AC circuit undervoltage relay, Device 27RB.
 - 1 - Two stage diode fuse failure monitoring relay, Device 58A/58T.
 - 1 - Set of 125 Vdc control power disconnect devices with overload protection, all rated at 1,000 Vdc and wired to terminal blocks for supply conductors entering from top.

- 1 - Set of ground detector circuit components, including relays, Devices 64R and 64RX, DC power supply and related devices, as detailed in Article 1.06.C of this Section.
- 1 - Lockout relay, manually reset type. Device 86-T.
- 1 - Lockout relay circuit undervoltage relay. Device 27R.
- 1 - Conditional lockout relay, electrically reset type. Device 86X-T.
- 1 - Set of auxiliary relays for heat sink overtemperature devices. Devices 26RX and 26RHX.
- 1 - Temperature indicator to show the air temperature within the rectifier enclosure.
- 1 - Resettable counter mounted in front of the control/auxiliary section, to count the number of trips due to heat sink overtemperature.
- 1 - One set of insulated anchor blocks for rectifier assembly, as required. These shall be shipped in advance of equipment.
- 1 - One set of equipment as necessary to interface the rectifier equipment with the substation automation system including IED's.

2.4 DC SWITCHGEAR ASSEMBLY

A. General

- 1. The switchgear assembly shall consist of indoor metal-enclosed, self-supporting structures rated for 750 Volt DC class traction service.
- 2. The switchgear assembly will be directly supplied from the power rectifiers specified in Article 2.03 of this Section, and shall serve as the DC traction power supply to the traction feeders as outlined in this Section. Switchgear shall be suitable for operation with switchgear structure high-resistance grounded.
- 3. Provisions shall be included to accommodate future extension from aisle end of the switchgear assembly.

B. Switchgear Assembly and Circuit Breaker Units

- 1. The metal-enclosed switchgear assembly shall consist of rigid self-supporting and self-contained electrically welded steel structures. The individual breaker units shall be enclosed with not less than 12 gauge formed steel sheets. The individual units shall be bolted to each other to form a continuous, free-standing switchgear assembly, divided into shipping sections as specified in Article 1.06.A of this Section.
- 2. Hinged doors shall be provided at front and rear of each circuit breaker unit, suitable for mounting relays, meters, instruments and control devices. Doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be heavy duty of a type accepted by the MBTA. Full height doors shall be securely fastened in the closed position with a minimum of three latches easily

opened without the use of tools. For doors less than the full height of the equipment, a minimum of two latches will be acceptable. Doors shall be provided with automatic self-stopping capabilities, with the automatic stops at 90 degrees and at 120 degrees. Manual defeating mechanism shall be provided for moving the door from one stop to another. At each stop, the door shall be held securely in the open position. With the front door of any compartment open at 90 degree position, it shall not prevent the adjacent compartment door from being opened and its breaker completely removed from its housing.

3. Separate, steel-enclosed compartments shall be provided for the circuit breaker, main bus, outgoing buses, feeder cables, and for relays, instruments and control devices. All compartments shall be sufficiently gas tight to assure that no ionized gas will pass from one compartment to the other.
4. Compartments for circuit breaker, outgoing cables, and for relays and control devices, shall be provided with a separate hinged door for servicing without exposing circuits in adjacent compartment. In lieu of the hinged doors, circuit breaker compartments may be provided with hinged closure panels attached to breaker removable element. Cable compartments shall be accessible for connection of power cables from the rear of the unit.
5. The bus compartment shall contain the main (positive) bus and bus taps and shall be isolated from all rear cubicle compartments by an insulated barrier, and shall be provided with either a separate hinged door or a removable bolted-on cover for complete access to the bus and the taps.
6. Barriers shall be provided at the side of cubicles to insulate the bus compartment of adjacent units. A similar, completely isolated compartment shall be provided for termination of outgoing power cables. The cable compartment of each circuit breaker unit shall be isolated from the cable compartment of adjacent unit.
7. The breaker compartment shall be completely enclosed except for the insulated vent opening at the top, designed for rapid exhaust and deionization of ionized gases. The design shall prevent striking an arc to conductive members of the switchgear during and after fault interruption. Screws made of non-conducting material and insulating barriers shall be provided for all surfaces exposed to ionized gases. Metal screws covered with insulating caps are not acceptable. Insulation of circuit breaker compartment and its vent openings are not required if the DB Entity can prove to the satisfaction of the MBTA that the gases exhausted from the circuit breaker removable element during fault interruption are completely de-ionized.
8. Vent openings shall be designed to prevent damage to or malfunctioning of the circuit breaker, control circuits and other components from foreign objects and shall be so located that hot gasses or other materials cannot be discharged through them in a manner which might be injurious to operating personnel. Each circuit breaker housing shall be provided with protective shutters which close and block access to the positive bus and breaker load terminals as the removable element of circuit breaker is racked from the cubicle. Protective shutter mechanism shall be designed and installed in a manner that it can be removed for repair without necessitating de-energization of the main bus.
9. Rectifier main DC breaker housing and bus entry unit housing shall be of sufficient strength to support the DC cathode bus which interconnects the DC switchgear with the rectifier. Flexible connections between buses shall be provided as necessary.

10. The DC switchgear enclosure shall be arranged for insulated fastening to the DC cathode busduct enclosures connecting to the associated rectifiers specified in Article 2.03 of this Section. The insulation shall take the form of a glastic-type bolted on collar providing electrical insulation between the DC busduct enclosure and the DC switchgear enclosure. The collar shall also provide a ready means of disconnecting the bus duct from the switchgear. At the DC switchgear a removable jumper providing electrical continuity between the switchgear and the bus duct enclosures shall be provided. The material shall be 1/8" thick, minimum, and shall be flame-retardant, track resistant and have high mechanical impact strength. The electrical and mechanical properties of the material and the method of attachment will be subject to the MBTA's acceptance. As necessary, provide a raised flange for the busduct connections to accommodate the insulating busduct collar.
11. Unless otherwise indicated on the Design Documents, the width of individual switchgear units shall not exceed 24". Any proposed variation by the DB Entity shall be subject to acceptance by the MBTA but due to the existing space limitations may not be acceptable. Any such proposal shall be accompanied with a fully dimensions substation layout drawing. Equipment at all substations under the contract shall be identical.
12. The switchgear shall be secured to the insulated epoxy floor with approved insulated anchors (see Design Documents). The insulated anchors shall be tested in accordance with Section 09671. The switchgear supplier shall recognize that MBTA preference is to insulate the anchor bolts in the floor in order to achieve the 40kV insulation level per Section 09671. The standard MBTA anchor arrangement is shown in the Design Documents. Alternative floor anchoring arrangements may be proposed but the 40kV anchor insulation requirement shall be maintained.
13. Finish of inside and outside of switchgear assembly, including all steel panels and subpanels inside the cubicles, shall be in accordance with Section 16203 Article 1.15. Galvanized, unpainted steel panels are not acceptable.
14. The switchgear shall be designed with a minimum of 3/4" clearance between the removable breaker element and the control cabinet overhang to ensure there is no interference due to floor irregularities when racking the breakers in and out.
15. The base plate of each circuit breaker compartment shall be beveled to ease rolling the circuit breaker truck in and out of the compartment.

C. Buses and Bus Connections

1. Switchgear main bus and bus taps shall be copper and shall be provided in accordance with Section 16203 Article 1.06. Continuous current carrying capacity of buses and bus taps shall be as specified in Article 2.04 of this Section.
2. Main bus and bus taps shall be supported and braced to withstand short circuit stresses at least as great as those for which circuit breakers are designed.
3. The buses shall be supported on approved high-strength flame retardant polyester glass, epoxy, or porcelain insulators designed to ensure adequate electrical clearances and to withstand the specified short circuit stresses.

D. DC Power Circuit Breakers

1. Circuit breakers shall be 750 Volt DC class minimum, single pole, air break, draw-out type without negative disconnecting device, capable of withstanding a continuous no load or light load voltage of 750 Volts DC. The breakers shall be of high-speed classification as per ANSI Standard C37.14 and C37.16, suitable for operating on a substation DC bus supplied directly by all substation power rectifiers operated in parallel at 590 Vdc as specified below. The DB Entity is hereby informed that application of reactors between the rectifiers and DC switchgear or between the rectifiers and negative equalizer bus, to limit the short circuit current to be interrupted by the circuit breakers, will not be acceptable.
2. The DC circuit breakers shall have peak current, momentary current, short time current and short circuit current ratings required for operation in a substation with the number, type and rating of the power rectifiers specified in this Section and shown on the Design Documents, when operating under the service conditions specified in Article 1.06, Paragraph B of this Section. For selecting the rectifier and traction feeder circuit breaker ratings, The DB Entity shall add 50 percent to the peak current and sustained current values thus obtained. Short circuits specified herein are those that are applied between the load terminals of either traction feeder circuit breaker or rectifier main DC circuit breaker, and the negative load terminals of the rectifiers.
3. High speed DC circuit breakers which limit peak value of short circuit current shall have short circuit interrupting capability equal to or greater than the maximum available rate of rise of short circuit current under the short circuit conditions specified. The short circuit interrupting rating of the circuit breaker with delayed tripping shall not be less than 100,000 Amperes.
4. The rectifier main DC circuit breaker shall either be capable of withstanding a fault on the 600 Volt nominal DC bus until AC relays trip the rectifier transformer feeder breaker in the AC switchgear, or a tripping device which fully coordinates with all other specified coordination requirements may be supplied, if accepted by the MBTA, which shall protect the circuit breaker from damage under bus fault conditions.
5. The rectifier main DC circuit breaker shall have momentary current rating equal to or greater than the maximum available peak current due to a short circuit at the load terminals of the rectifier main circuit breaker.
6. The rectifier main DC circuit breaker shall have short time current rating which is equal to or greater than the maximum rms value of available current during a period of 250 milliseconds following application of short circuit to the load terminals of the circuit breaker. The rated short time current is defined as the designated limit of available rms current which the circuit breaker can carry for a period of 250 milliseconds, without impairing the circuit breaker's ability to meet all other ratings.
7. High speed DC feeder circuit breakers which limit peak value of short circuit current with a fast-acting tripping arrangement provided shall have a momentary rating no less than 125,000 Amperes.
8. All DC circuit breakers shall be rated to successfully dissipate the maximum value of energy stored in the system inductance during circuit breaker arcing under the short circuit conditions specified. Breaker maximum arc voltage shall not exceed 75 percent of the peak reverse voltage (PRV) of diodes furnished with the rectifiers and the limits dictated by DC power and control equipment.

9. Circuit breaker operating mechanism shall be of the mechanically latched or the magnetically latched type, solenoid operated, as specified below, and shall be electrically and mechanically trip free. The control circuits of all breakers shall be provided with anti-pumping protection.
10. The closing coil of solenoid operated circuit breakers shall be rated for operation on 125 Vdc supplied from the substation battery. Circuit shall be provided with a timing relay for closing coil cut-off. The closing coil shall successfully close the breaker over a voltage range of 90 to 140 Vdc.
11. All solenoid operated circuit breakers shall have trip circuit rated 125 Vdc supplied from the station battery and shall be capable of tripping the breaker over a voltage range of 70 to 140 Volts.
12. DC circuit breakers shall be designed so that they may be safely closed and tripped manually in the operating position with the enclosure door closed during an emergency. Removable, fully insulated handles shall be provided for manual closing. Mechanical interlocks shall be provided which will disable the manual closing mechanism if the breaker compartment door is open. Manual trip shall be from an approved mechanical trip device.
13. The operating mechanism of each circuit breaker shall be provided with a mechanical breaker contact position indicator.
14. Breaker tripping devices shall be furnished as required to provide reliable coordinated protection for the system. They shall have operating characteristics and adjustable ranges as outlined in Article 1.06.D of this Section. Range of trip settings shall be as specified and calibration scales shall be calibrated covering full range of adjustable settings.
15. Mechanically latched DC circuit breakers shall be provided with an undervoltage trip device which is magnetically held by flux produced by control power current and which mechanically trips the circuit breaker upon reduction of control power voltage to any level which does not allow reliable operation.
16. Mechanically latched DC circuit breakers which require control power for any part of an instantaneous overcurrent or reverse current trip arrangement shall be provided with a second overcurrent or reverse current trip arrangement. The redundant instantaneous overcurrent or reverse current trip arrangements shall independently sense magnitude of the circuit breaker current and may utilize control power for their tripping but shall have their own separate electrical components and not share any common electrical components with the first overcurrent or reverse current arrangement. One of the two tripping arrangements may utilize the undervoltage trip device to affect circuit breaker tripping. The discriminating rate-of-rise trip equipment will not be acceptable as the second tripping arrangement specified above. However, the discriminating rate-of-rise trip equipment may utilize a current sensor and trip coil in common with either of the required redundant instantaneous overcurrent or reverse current trip arrangements and may utilize the undervoltage trip device to affect circuit breaker tripping. Each of the redundant instantaneous overcurrent or reverse current trip arrangements shall provide the overall coordination specified in Article 1.06.D of this Section.
 - a. For the rectifier main DC circuit breaker, the second reverse current tripping arrangement may be a polarized electro-mechanical trip device, a current sensing polarized relay

which shunt trips or undervoltage trips the circuit breaker, or other arrangement in conformance with this Specification which is accepted by the MBTA.

- b. For the DC feeder circuit breaker, the required second overcurrent tripping arrangement may be an electro-mechanical trip device, a current magnitude sensing non-polarized relay which shunt trips or undervoltage trips the circuit breaker, or other arrangement which is accepted by the MBTA. Tripping for the redundant overcurrent arrangement shall be adjustable within the limits of 100 percent and 400 percent of the rating of direct acting instantaneous series trip device specified for the feeder circuit breakers.
17. Circuit breakers which are magnetically latched shall be latched by flux produced from control power and tripped by interaction between this flux and flux produced by circuit breaker primary current. No undervoltage trip device is required.
- a. For the rectifier main DC circuit breaker, the magnitude of latch flux shall be at least 200 percent of the minimum value required for successful closing of the circuit breaker without primary current. The circuit breaker tripping arrangement may be responsive to rate-of-rise of reverse current by use of inductive shunts or other means. Control power current for the magnetic latch shall not exceed 500 milliamperes.
 - b. For the DC feeder circuit breakers, the magnitude of latch flux shall be such that at least 30,000 Amperes of primary current are required to cause tripping by shift of flux. The circuit breaker tripping arrangement shall not be responsive to rate-of-rise of primary current. Control power current for the magnetic latch shall not exceed 500 milliamperes. DC feeder circuit breakers shall be provided with a second tripping arrangement which is easily adjustable to cause tripping between the limits of 100 percent and 400 percent of the rating of direct acting instantaneous series trip device specified for the breaker. This second tripping arrangement may be an electro-mechanical trip device which mechanically or electrically trips the circuit breaker, a current magnitude sensing non-polarized relay which shunt trips the circuit breaker, or other arrangement in conformance with this Section which is accepted by the MBTA. The rate-of-rise discrimination equipment will not be acceptable as the second tripping arrangement specified above, but may utilize a common trip coil.
18. Each circuit breaker shall be mounted on a mobile steel frame equipped with power and control circuit disconnecting devices, to make the circuit breaker and the operating mechanism a removable element. The frame shall be permanently attached to the circuit breaker and shall be equipped with rugged, non-metallic wheels for rolling the breaker on the floor of the substation. A “fifth wheel” device shall be installed on the breaker carriage to assist with moving the breaker. The supplier may request the requirement for a “fifth wheel” device be removed but must provide evidence, or a practical demonstration that this device is unnecessary for the type of breaker proposed, for acceptance by the MBTA. A four digit register type operations counter shall be mounted on the removable element of each circuit breaker.
19. The power disconnecting devices shall consist of self-aligned assemblies. Female contacts shall be constructed of bridging segments designed to ensure high pressure contact guaranteed not to distort or fail under the mechanical stresses and heating due to duties specified for the circuit breakers.

20. The control disconnecting devices shall provide rugged, heavy-duty connections for the control circuits and interlocks between the removable element and the housing. The devices shall be precisely located and securely mounted to maintain alignment.
21. Circuit breaker components requiring periodic maintenance and replacement and those which may require replacement due to deterioration shall be easily accessible without removal of major breaker assemblies.
22. Frames of relays and other devices mounted on energized breaker frame and operated on 125 Vdc shall be insulated for 1,000 Vdc from the frame of the circuit breaker. Relays, switches, terminal blocks and other components of the control circuitry on the breaker shall be labeled as identified on DB Entity's prepared and MBTA's accepted shop drawings.
23. In addition to auxiliary switches required for control, interlock, indication and alarm circuits, each circuit breaker shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts, wired to outgoing wiring terminal block for MBTA's use.
24. Normally-closed auxiliary switches mounted on the removable element and used for interlocking shall be shunted with truck-operated cell switches to permit operation of interlocked equipment when breaker is in the withdrawn position. A minimum of two "a" and two "b" spare cell switch contacts shall be provided, wired to outgoing wiring terminal blocks for MBTA's use.
25. All auxiliary switches, whether cell-mounted or mounted on removable element, and breaker control circuit wiring connected through control disconnecting devices, shall be made up and operable when breaker is racked to the test position so the breaker may be closed and tripped electrically or mechanically.
26. DC traction feeder circuit breakers shall be mechanically and electrically interchangeable with all other traction feeder breakers of the same ratings.
27. Main rectifier DC circuit breakers shall not be interchangeable with DC traction feeder circuit breakers, but the main DC breakers shall be interchangeable with each other.
28. A mechanical or electrical indicator shall be provided on the front of the breaker compartment to show that the breaker is in the "test" or "connected" position. An electrical breaker position indicator is acceptable.
29. Each circuit breaker unit shall be equipped with a cranking device for moving the removable breaker element to and from its operating position. The mechanism shall be mechanically operated by a hand crank, arranged to rack the breaker from test to operating position, also from disconnect to test position. Suitable guide rails shall be provided for centering the breaker in proper position when inserting or withdrawing the removable element. Front ends of guide rails shall be flared and the bottom plate of the enclosure within the guide rails beveled to facilitate the lining-up and insertion of the circuit breaker removable element. A positive stop shall be provided to prevent over-travel of the removable element when moving it into operating position. A similar positive stop shall be provided for the test position. The design of the circuit breaker unit having the access door mounted on the stationary structure of the switchgear, shall permit closing of the compartment door with the circuit breaker in test position.

30. Mechanical interlocks shall be provided on each circuit breaker to prevent the withdrawal of the removable element when the breaker is in the closed position and to prevent the insertion of a closed breaker from the test to the operating position. For circuit breakers with stored energy type operating mechanism, the interlocks shall also discharge the springs before the breaker removable element can be fully withdrawn from its housing. Breaker must be arranged so that personnel are guarded from contact with energized parts while racking the circuit breaker into or out of the connected position.
31. Rectifier main DC circuit breakers shall be key-interlocked with the negative disconnect switch of the respective rectifier, arranged to prevent closing or opening of the disconnect switch unless the main DC circuit breaker is in fully disconnected position, as specified in Section 16203 Article 1.13. The key interlock shall be mounted on the cubicle, not on the breaker.
32. Electrical breaker components such as relays, resistors, auxiliary switches, and terminal strips shall all have nameplates.

E. Arrangement of Control Devices

1. Normal control, indicating and protective devices associated with the circuit breaker operation shall be mounted in their respective DC breaker switchgear compartments, except as otherwise specified. All devices, whether mounted on the compartment door or other portion of the stationary unit structure, must be physically accessible and so connected as to permit testing and maintenance of relays and control circuitry in de-energized condition while the circuit breaker is in normal operating position. The arrangement of devices will be subject to acceptance of the MBTA. Insulated panels attached to cutouts in the doors for mounting of relays, switches and devices, are not acceptable. Individual cutouts shall be provided for mounting each relay, switch and device.
2. Current shunts, transducers and other such equipment shall be accessible for testing and maintenance with the switchgear bus energized.
3. Care shall be taken in arrangement of relays, control and key-operated switches, indicating lights and instruments so as not to violate the provision for the removal of an adjacent breaker when the door of adjacent unit is opened to 90 degrees. Refer to Article 2.04.B of this Section.

F. Power Circuit Terminations

1. Rectifier main DC circuit breaker unit shall be arranged for direct bolted connections to incoming DC positive cathode bus specified in Article 2.05 of this Section, using copper bus bars. All contact surfaces shall be silver plated. Buses and connections shall conform to Section 16203, Article 1.06. The bus connections shall be arranged for bottom cable entrance unless otherwise indicated on the Design Documents. Arrangement of buses will be determined at the Design Conference.
2. For each DC traction feeder, the DB Entity shall furnish four bolted type NEMA heavy duty terminal lugs suitable for stranded copper feeder cables of sizes shown on the Design Documents, entering from below, unless otherwise indicated on the Design Documents. All DC feeder breakers shall have provision for four DC feeder cables. Provision shall include holes, grommet/clamp hardware, such that future cable installations will match existing. All

unused openings shall be sealed with steel screw-on type plugs. Terminal lugs shall be provided in accordance with Section 16203 Article 1.07, and shall have NEMA four-bolt tongue. Provisions shall be made for quick disconnection and isolation of each cable from the terminal during an emergency without disturbing the remaining cables. This requires access to the terminals through an easily-opened hinged panel and sturdy, individual support for each cable close to the connection point. Back-to-back arrangement of terminal lugs will not be acceptable.

G. Wiring and Terminal Blocks

1. Secondary and control wiring in each unit, including that on removable element, shall be No. 12 AWG or larger, stranded tinned copper in accordance with Section 16203, Article 1.09, and insulated for 1,000 Vdc service.
2. Circuits requiring external connections shall be factory-wired to readily accessible terminal blocks within the control compartments for connection to field wiring entering from above. Provide terminal blocks rated for 1,000 Vdc and in accordance with Section 16203 Article 1.09. The field cabling shall have a minimum insulation rating of 1000 Vdc.
3. All elements of control devices operated on 600 Volts DC nominal shall be connected with red-colored or red-striped wire and terminals both rated for 2000 Volts. Associated terminals at equipment and devices shall be insulated for 1,000 Volts from adjacent terminals and from the frame of switchgear. Exposed terminals shall be capped or provided with insulating covers to prevent accidental contact by operating and maintenance personnel.
4. All supply, control and indication wiring shall enter the DC switchgear via a suitable opening in the front control compartment of Unit #1 and be routed along the switchgear as necessary. Externally, the wiring shall be routed via cable trunking on the end of the switchgear through a floor opening to the cable tray below as indicated in the Design Documents. Routing to all other equipment in the substation shall be via this route.

H. Control Sources

1. An ungrounded, two wire, 125 Vdc control bus shall be provided integral with the DC switchgear assembly. The control bus shall be not less than No. 4 AWG consisting of stranded copper switchboard wire (SIS), wired to suitable screw type terminal blocks in the auxiliary compartment for connection to No. 2 AWG supply conductors. Where smaller supply conductors are proposed, the DB Entity shall submit evidence in the form of calculations, showing circuit loading and wire current capacities, supporting the use of the smaller conductors for review and acceptance by the MBTA. Each circuit breaker control circuit shall be supplied from this bus through individual switches and fuses. In addition, the closing circuit and spring loading motor circuit of each stored energy operated circuit breaker shall be protected by a secondary set of fuses to prevent opening of main fuses and thus loss of trip supply on closing circuit or motor circuit faults. All fuses, fuse holders and switches shall be rated for 1,000 Vdc service. This supply shall be monitored, Device 27SA, and in the event of low voltage or voltage failure.
2. As required based on vendors design, a two wire, 120 Volt, 60 Hz control bus shall be provided for load measuring circuit timers, Device 102; rectifier and DC switchgear ground detection relays, Devices 64R, 64RX, 164S and 164SX; rectifier heat sink overtemperature device circuits; and, transducers and other control devices requiring AC supply. The 120 Vac control bus shall be no smaller than No. 10 AWG stranded switchboard wire. Both legs of

each take-off from this bus shall be separately fused. If required, this supply shall be monitored, Device 27SB, and indicate in the event of low voltage or voltage failure. An independent isolating transformer shall be utilized for all 120 VAC requirements within the equipment. Isolating transformer shall not be located within the equipment.

3. All fuses used for control shall be of the cartridge type of appropriate rating, conforming to Section 16203 Article 1.10, Paragraph F. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10 percent, but not less than two fuses of each rating shall be furnished with the switchgear assembly.

I. Special Requirements

1. Each separate compartment within a switchgear cubicle shall be provided with an electric strip heater of adequate size to prevent condensation within the compartment. All heaters installed in a switchgear cubicle shall be monitored by means of an ammeter scaled and marked for the heater load. Each individual heater circuit shall be provided with blue LED indicating lamp to indicate operation of the heater, and an ON-OFF switch. Heaters shall be provided with properly designed guards to protect operating personnel against accidental contact with hot surfaces.
2. A fluorescent lighting fixture with conveniently located and properly labeled toggle switch or a door operated switch, rated 250 Volts minimum, shall be provided in each compartment of the switchgear which contains relays, control devices and outgoing wiring terminal blocks. Incandescent lighting will be acceptable only for compartments where, in the opinion of the MBTA, the installation of fluorescent lighting fixtures would be impractical. In addition, a duplex receptacle, rated 250 Volts, 20 amperes minimum, shall be provided in each switchgear unit, connected for 120 Volt service. The outlet boxes of light receptacles, light switches and plug receptacle shall be insulated from switchgear enclosure for a minimum of 1,000 Vdc.
3. Two single phase, two wire, 120Volt, 60 Hz supply bus shall be provided throughout switchgear lineup. The AC supply buses shall be not less than No. 10 AWG, stranded copper switchboard wire (SIS). One supply shall provide power to the heaters, the other shall provide power to the light and receptacle circuits. Each supply bus shall be connected at each cubicle through fusible pull-out disconnects with cartridge-type fuses located in each switchgear unit. The fuse holders shall be insulated from switchgear enclosure for 1,000 Vdc. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10 percent, but not less than two, spare fuses of each rating shall be furnished. The supplies shall be wired to screw type terminal blocks, insulated from the switchgear enclosure for 1,000 Vdc, located in the auxiliary compartment of the switchgear lineup for connection of up to No. 6 AWG supply conductors from adjacent cubicles. DB Entity shall verify that the proposed wires sizes used are adequately sized and may propose alternative sizes to those specified above for acceptance by the MBTA.

J. Nameplates

1. Nameplates shall be provided in accordance with Section 16203 Article 1.08. The legend of nameplates shall be submitted to the MBTA for acceptance.
2. Switchgear identification nameplate shall be engraved: "750 VOLT DC SWITCHGEAR".

K. Supervisory Control Requirements

1. The DC switchgear assembly shall be provided with supervisory control, indication, measuring and interface devices as specified in Article 1.06.C.5 of this Section.

L. Circuit Breaker Test Cabinet

1. The DB Entity shall provide a wall-mounted test cabinet for electrical operation of circuit breakers at the location indicated on the Design Documents. The test cabinet shall include: a control switch, similar to that furnished with the switchgear, to close and trip the breaker; red and green breaker position LED indicating lamps; 10' of control cable with a connector at the end for connection to the breaker; a set of properly sized fuses to protect the control circuit; and, screw-type terminals for 125 Vdc control supply No. 8 AWG conductors which shall be connected to a dedicated circuit breaker in the DC distribution panel. An additional white LED indicating lamp shall be provided for monitoring the control supply.
2. The control switch and indicating lamps shall be mounted on the door of the test cabinet. The wiring and terminal blocks shall be provided in accordance with Article 1.09, and the nameplates with Article 1.08 of Section 16203.
3. An approved connector shall be provided for adequately protecting the control cable at the point of entry. Provisions shall be made for storing or racking the control cable and the connector at the test cabinet.
4. The test cabinet shall be finished inside and out in accordance with Article 1.15 of Section 16203.

M. Auxiliary Equipment and Accessories

1. The DB Entity shall furnish special tools and equipment handling devices as recommended by the manufacturer for installation, assembly, adjustment and maintenance of the DC switchgear and circuit breakers furnished. Special tools are defined as tools not readily available on the open market. All items shall be furnished as part of the initial delivery of the switchgear equipment.
2. The DB Entity shall also furnish and ship with the switchgear any auxiliary equipment and accessories necessary for operation, maintenance, testing and handling of removable components outside the switchgear assembly. One complete set of auxiliary equipment and accessories shall be provided at each substation. Auxiliary equipment and accessories shall include, but not be limited to, the following and shall be provided in addition to the items specified in Article 2.09 Technical Support Equipment.

One - Circuit breaker test cabinet, as specified in Article 2.04.L of this Section.

One - Floor-mounted steel cabinet with hinged doors, three-point latching mechanism and key-locking handle and shelves, for storing tools and accessories. Cabinet shall be fully rustproofed and finished in light gray enamel.

Two - "Fifth-wheel" device for handling breaker outside its housing, preferably as part of each breaker drawout element.

Two - Racking-in cranks.

Two - Manual spring charging handle (if required).

Two - Insulated lever for manual closing of the breaker.

Two - Arc chute lifting device.

One - Set of tools required for breaker maintenance.

One - Set of insulated anchor blocks for the DC switchgear assembly. These shall be shipped in advance of equipment.

Two - One-quart cans of matching touch-up paint.

N. Detailed Equipment Requirements

1. DB Entity shall furnish and deliver to the substation the 750 Volt DC switchgear assembly consisting of switchgear units of the type specified below; switchgear unit quantities shall be as shown on the Design Documents. The individual units in the assembly shall be arranged to form lineups as shown on the Design Documents.
2. Individual switchgear units shall consist of the equipment, devices and appurtenances of the types detailed below. The ratings provided are for used with 3,000 kW rectifiers. Refer to the Design Documents for switchgear unit quantities.

a. Rectifier DC Main Circuit Breaker, Device 72-R

750 Volt rectifier DC main circuit breaker unit(s), including, but not be limited to, the following:

- 1 - Metal-enclosed stationary unit with 10,000 Ampere bus and 8,000 Ampere tap, equipped with provisions for connection to 8,000 Ampere DC positive cathode bus entering the side.
- 1 - 8,000 ampere air circuit breaker removable element with direct acting series reverse current instantaneous trip device, Device 32, as specified in Article 2.04.D, this Section, set at the minimum value consistent with overall coordination of rectifier circuit protective devices. The reverse current device shall be provided with auxiliary contacts for operation of auxiliary relay, Device 32X, which shall be used for remote indication and lockout relay operation.
- 1 - Removable element position switch with a minimum of four convertible contacts.
- 1 - 8,000 Ampere, 50 millivolt shunt with indicating ammeter, 0-15 kA scale, and calibrated leads, Device AM.
- 1 - Isolation amplifier or isolation type transducer, input from 8,000 ampere, 50 millivolt shunt, for telemetering rectifier current, Device IA.

- 1 - DC indicating voltmeter, 0-750 Volt scale, connected to rectifier side of breaker, Device VM.
 - 1 - Control switch "TRIP-CLOSE" for closing and tripping the main DC breaker, with green, white (if breaker has stored energy type operating mechanism) and red LEDs, Device 101.
 - 1 - Control switch "TRIP-CLOSE" for closing and tripping the rectifier AC breaker, with green and red LEDs, Device 01-R.
 - 1 - Breaker control mode selection switch "LOCAL-OFF-HMI-SUPV" for rectifier AC circuit breaker, Device 43.
 - 1 - Set of space heaters with "ON-OFF" switch (Device HS), blue LED and ammeter (Device HAM) as specified.
 - 1 - Set of DC and AC control power disconnect devices with fuses.
 - 1 - Key interlock system as described in Article 1.13 of Section 16203.
 - 1 - Lot of nameplates as specified.
 - 1 - DC Watt-hour demand meter for telemetering power, Device WXD.
 - 1 - Two position voltmeter switch (Device VS) labeled "ON-OFF".
 - 1 - One set of equipment as necessary to interface the rectifier equipment with the substation automation system.
- b. DC Traction Feeder Breakers Device 172

750 Volt DC nominal automatic reclosing traction feeder circuit breaker units, each including, but not be limited to, the following:

- 1 - Metal-enclosed stationary unit with 10,000 Ampere bus and 4,000 Ampere tap.
- 1 - 4000 Ampere air circuit breaker removable element with direct acting series bi-directional instantaneous trip device, Device 176. The continuous current rating of the series trip device shall be 4000 amperes; the instantaneous trip device shall be adjustable between 100 percent and 400 percent of the continuous rating, with calibration marks at suitable intervals.
- 2 - Interposing relays with 125 Volt DC coils, to close and trip the circuit breaker via supervisory, Devices 201C and 201T.
- 1 - Removable element position switch with a minimum of four convertible contacts.
- 1 - 4,000 Ampere, 50 millivolt shunt with calibrated leads for providing input to: multifunction DC feeder protection relay, Device 150M/176F; and, ammeter and isolation amplifier, Device IA. Device 150M shall include the following protection channels:

- Bi-directional instantaneous overcurrent relay channel with an adjustable range of at least 4,000-0-12,000 Amperes.
 - Polarized discriminating overcurrent trip with short time and long-time protection channels.
 - Rate-of-rise overcurrent trip channel capable of discriminating between remote short circuits and inrush current of starting trains.
- 1 - Zero-center scale ammeter for operation with 4,000 Ampere, 50 millivolt shunt as specified. Ammeter scale shall be 4,000-0-12,000 Amperes or as shown on the Design Documents, Device AM.
- 1 - Isolation amplifier as specified, with input from 4,000 Ampere, 50 millivolt shunt for telemetering DC feeder current. Device IA.
- 1 - DC indicating voltmeter, 0-750 Volt scale, connected to cable side of the breaker, and a voltmeter switch wired to enable reading the DC bus voltage also, Device VM.
- 1 - Transducer for telemetering DC feeder voltage, Device V-XD.
- 1 - Permissive setup relay, electrically reset type, to start the closing/reclosing cycle of the DC traction feeder circuit breaker; operating coil and closing coil both rated 125 Vdc, Device 169.
- 1 - Set of load measuring, voltage measuring and automatic reclosing equipment, as specified in Article 1.06.C.4. of this Section, to prevent closing of the circuit breaker into a faulted circuit. The equipment shall include: a load measuring relay, Device 182; a voltage measuring relay, Device 183; load measuring resistor (LMR) and contactor, Device 129; a cycle timer, Device 102; and, all necessary accessories. The cycle timer shall be synchronous motor driven, cam-operated type for operation on 120 Volt, 60 Hz reliable AC supply. Load measuring resistor shall be located on top of feeder breaker stationary unit and shall be provided with ventilated enclosure. The DB Entity shall provide the interconnecting wiring and insulated resistor supports.
- The load measuring control circuitry may be combined into a single electronic control relay. If this is proposed by the DB Entity, relay details shall be submitted for acceptance by the MBTA. The DB Entity shall specifically state the limits of operation of the relay and any operational differences from the equipment described above.
- 1 - Control switch "TRIP-CLOSE" for closing and tripping the DC traction feeder breaker, with green, white (if breaker has stored energy type operating mechanism) and red indicating lamps, Device 101.
- 1 - Breaker control mode selector switch "LOCAL-OFF-HMI-SUPV", Device 143.
- 1 - Set of four heavy duty NEMA terminal lugs suitable for 2,000 kcmil stranded copper feeder conductor mounted on the load terminals for the DC traction feeder breaker, for traction feeder cables entering as shown on the Design Documents.

- 1 - Load measuring system bypass switch and associated timing relay, Device LMBP.
 - 1 - MOV type surge arrester with polymer housing rated for 750 Volt nominal DC service, 970 MCOV, connected to load side of circuit breaker. Arrester shall be located outside of the breaker cubicle in a wall-mounted cage-type enclosure as shown on the Design Documents.
 - 1 - Set of space heaters with blue indicating LED, ON-OFF switch (Device HS) and ammeter (Device HAM).
 - 1 - Set of DC and AC control power disconnect devices with fuses.
 - 1 - Lot of nameplates as specified.
 - 1 - "Cable alive" meter, 0-750 Vdc, complete with dropping resistor and two setpoints, Device 197X.
 - 1 - Three position voltmeter switch (Device VS) labeled "FEEDER-OFF-BUS".
 - 1 - One set of equipment as necessary to interface the rectifier equipment with the substation automation system.
- c. 750 Vdc Switchgear Auxiliary Equipment

750 Volt DC switchgear auxiliary equipment shall be integrated into the DC switchgear lineup and shall include, but not limited to the following items.

- 1 - Lot of alarm bell, timing relay, Device 74 and illuminated warning sign "SWITCHGEAR FRAME ALIVE" as specified in Article 1.06.C.7 of this Section, rated for operation on 120 Volt, 60 Hz.
- 1 - 120 Volt DC supply undervoltage relay, for operation on 125 Volts DC, Device 27SA.
- 1 - 120 Volt supply undervoltage relay, for operation on 120 Volts, 60 Hz, Device 27SB (if used for protection devices).
- 1 - DC Switchgear Structure grounded/hot relay, Devices 164S/164SX.
- 1 - DC power supply with adjustable 15-25 Volt output, as specified, for isolation amplifiers, Device IA (if used).
- 1 - 1 - Voltage transducer, as specified, for telemetering 750 Vdc switchgear bus potential, Device V-XD.
- 1 - Set of space heaters with ON-OFF switch (HS), blue indicating LED and ammeter (HAM) as specified.
- 1 - Lot nameplates as specified.

2.5 ANODE AND CATHODE BUSES

A. General

1. AC anode bus duct and DC positive and negative cathode buses shall be furnished for interconnection of the rectifier transformer, rectifier, the DC switchgear, and the negative bus. The Design Documents indicate the desired arrangement of AC and DC bus duct. A 15kV AC busduct shall also be provided to interconnect the two AC switchgear lineups at Red Bridge Substation. At the Design Conference, the DB Entity shall bring to MBTA's attention and approval any deviations the DB Entity proposes to make from the arrangement shown.
2. The following types of bus duct shall be furnished:
 - a. 15kV AC 1200A three phase busduct.
 - b. 600 Volt AC non-segregated phase anode bus duct assembly for connecting the rectifier transformer to the rectifier. Bus duct shall be complete with AC heaters for the outdoor sections of the equipment.
 - c. 750 Volt DC positive cathode bus duct assembly for connecting the rectifier positive terminal to the DC switchgear.
 - d. 750 Volt DC negative cathode bus duct assembly for connecting the rectifier negative terminal to the negative equalizer bus and drainage board.

B. Assembly Requirements

1. Metal Enclosure
 - a. Each bus duct assembly shall be metal enclosed, ventilated, non-segregated phase type, conforming to ANSI C37.20, except that an approved low impedance type bus duct may be applied as the anode bus, providing such requirement is dictated by the design of the transformer and rectifier package. The enclosure shall be fabricated from steel or aluminum as specified. Removable covers shall be provided to allow access to bolted bus connections and insulators for cleaning and inspection. Removable covers shall be secured with bolts to the frame.
 - b. Metal enclosures shall be finished in accordance with Article 1.15 of Section 16203. Two quarts of matching touch-up paint shall be shipped with the bus duct assemblies.
2. Copper Bus Bars
 - a. Bus bars shall be of high conductivity rectangular copper with round edges finished to required size by cold rolling or drawing. Bus bars shall have uniform shape and dimensions, free from defects in material and workmanship. All bus bars shall be individually insulated, properly supported and braced to each other and to the enclosure with approved, high quality, high strength, non-tracking insulators to withstand short circuit stresses to be encountered in use. AC and 750V DC positive bus bars shall be individually insulated. All bus taps and connections shall be tightly bolted. Contact surfaces of bolted joints shall be factory silver plated. The DB Entity may propose the use of non-insulated DC bus bars for acceptance by the MBTA. Busbars, joints and hardware shall conform to Article 1.06 of Section 16203.

- b. Bus bars shall be rated for the current and voltages specified. They shall be amply designed for continuous operation under the specified load conditions.
 - c. The temperature rise of bus bars at the hottest spot for the specified duty shall not exceed 65°C over an ambient of 40°C, thus limiting the maximum operating temperature of bus conductor to 105°C.
3. Lengths and Fittings
- a. Bus duct assemblies shall be supplied complete with connection flanges, taps, elbows, insulated housing sections, offsets, splicing plates, terminal connectors, and associated accessories. Bus duct assemblies shall be furnished in accordance with the arrangement, dimensions and details depicted on final, MBTA-accepted shop drawings.
 - b. The shipping sections shall be pre-assembled in the factory so that minimum installation is required at site. It is the responsibility of the DB Entity to furnish the equipment as specified here and shown on the Design Documents so that they can be installed as a complete, integrated system without any modifications or requiring additional materials and labor at site, except to carry out the manufacturer's installation instructions.
4. Hardware and Supports
- a. All hardware required to make the field connections between sections and terminations to the equipment shall be furnished in sufficient quantity.
 - b. Supports required for bus ducts between equipment enclosures shall be hanger type. Location of supports, arrangements of each support, anchoring details, and the support components shall be shown on DB Entity's equipment arrangement drawings and are subject to MBTA's acceptance. Supports for the positive cathode bus and the negative anode bus shall be provided with approved insulators to insulate the bus enclosure from building structure for a minimum of 1,000 Vdc. Insulation in hangers shall be installed a minimum of 6' from the ceiling.
 - c. The DB Entity shall provide calculations to demonstrate that the proposed hangers will support the weight of the equipment and also withstand the additional mechanical and thermal forces experienced during a short circuit condition.
5. Expansion Joints
- a. Expansion joints shall be provided by the DB Entity wherever required for proper operation of the equipment.
6. Induced Heating
- a. Bus ducts are intended for operation at high values of current. The design of bus ducts shall be such as to minimize the induced magnetic heating and induced circulating currents in the metallic enclosure of the bus duct, adjacent enclosures and supporting structures.
7. Insulated Sections

- a. Insulated sections of bus duct housing, where shown on the Design Documents, shall be designed for phase-to-ground potential existing in these sections. The material and detailed design of insulated sections are subject to MBTA's acceptance.

C. 15kV AC Bus Duct Assembly

- 1. The 15Kv AC bus duct assemblies shall meet all the applicable requirements of Article 2.05.B of this Section, conform to ANSI C37.20 and meet the following additional requirements:

Rated maximum voltage: 15kV, maximum
 13.8kV nominal

Rated insulation level (BIL): 95kV
power frequency withstand: 36kV (for one minute, dry)

- 2. Buses shall be rated to carry continuously 1200A. The temperature of the bus bars shall not exceed maximum limit of 105°C over a 40°C ambient under these loading conditions. The bus duct assembly shall be compatible in design and construction with the provisions made at the 15kV AC Switchgear and shall operate as an integral unit when assembled.
- 3. Enclosure of bus duct assemblies shall be ventilated, made of high strength, corrosion-resistant aluminum. AC bus with steel enclosure may be acceptable if the DB Entity can prove to the satisfaction of the MBTA that the induced magnetic heating will not increase the temperature of the enclosure above safe limits.
- 4. A single bus duct assembly shall be provided as shown on the Design Documents.
- 5. Bus enclosure(s) shall be grounded.
- 6. Suitable support of bus enclosures shall be provided as may be required to ensure a rigid structure and workmanlike installation of the system.
- 7. At both ends of the busduct, flexible bus conductor terminations shall be provided. The termination details shall be fully coordinated with the 15kV AC Switchgear specified in this Section. These connections shall be provided with an easily removable insulating boot.

D. 600 Volt AC Anode Bus Duct Assemblies

- 8. The 600 volt AC anode bus duct assemblies shall meet all the applicable requirements of Article 2.05.B of this Section, conform to ANSI C37.20 and meet the following additional requirements:

Rated maximum voltage: 635 Volts, maximum
 600 Volts, nominal

Rated insulation level
power frequency withstand: 2.2 kV (for one minute, dry)

- 9. Buses shall be rated to carry continuously the current of the rectifier transformer and rectifier operated at 160 percent of rated full load. The temperature of the bus bars shall not exceed

maximum limit of 105°C over a 40°C ambient under these loading conditions. The bus duct assembly shall be compatible in design and construction with the provisions made at the transformer and rectifier and shall operate as an integral unit when assembled.

10. Enclosure of bus duct assemblies shall be ventilated, made of high strength, corrosion-resistant aluminum. Anode bus with steel enclosure may be acceptable if the DB Entity can prove to the satisfaction of the MBTA that the induced magnetic heating will not increase the temperature of the enclosure above safe limits during the two hour overload cycle specified in Article 2.03.D of this Section, for the rectifier.
11. A single bus duct assembly containing the conductors from both secondary windings of transformer shall be provided as shown on the Design Documents. The DB Entity may furnish two separate anode bus ducts, one from each secondary windings of the transformer, only upon the acceptance of the MBTA.
12. Each anode bus duct assembly shall be provided with bus taps, rated not less than 1/3 of the continuous current rating of the main bus to enable connection of future bus ducts for harmonic suppression filters with minimum of labor and without involving drilling of main bus bars.
13. Grounded bus enclosure(s) shall be insulated from the high-resistance grounded rectifier enclosure by installation of boxed glastic or approved fiberglass sections in the vertical portion at the rectifier, providing a minimum of 6" clearance between the metal enclosure of bus duct and nearest metal on the rectifier. An acceptable alternate arrangement is an insulated section in horizontal bus run near the rectifier, providing a minimum 2' clearance between the metal bus enclosure and the nearest metal connected to the rectifier enclosure.
14. Suitable support of bus enclosures shall be provided as may be required to ensure a rigid structure and workmanlike installation of the system.
15. The bus conductors, because of the inherent characteristics of the circuit, remain at a DC potential relative to the bus enclosure while energized. Construction of the bus duct and the materials used shall be proper for this type of service.
16. At both transformer and rectifier, flexible bus conductor terminations shall be provided. The termination details shall be fully coordinated with the rectifier transformer specified in Article 2.02 and rectifier in Article 2.03 of this Section. These connections shall be provided with an easily removable insulating boot.
17. Space heaters rated 240 Vac, operating at 120 Vac, shall be provided in all outdoor bus duct sections to prevent condensation. The space heaters shall be completely factory wired with no exposed wiring inside the bus housing. Heaters shall be thermostatically controlled. The entire circuit shall be wired to an accessible terminal block providing for a single connection to the 120 Vac power source. Space heaters shall be accessible from the outside of the bus duct. A drip shield will be provided over the space heater opening to prevent entry of water into the enclosure. The bus duct heater power supply shall be provided from the rectifier transformer control compartment.
18. A fire resistant divider or barrier shall be provided at all points where the bus duct extends through the building wall. The barrier shall have a minimum rating of (3) three hours. The DB Entity shall propose suitable material for this purpose.

E. DC Positive and Negative Cathode Bus Assemblies

1. DC cathode bus assemblies shall meet all the applicable requirements of Article 2.05 of this Section, and conform to ANSI C37.20 and shall meet the following additional requirements. Current ratings shown are applicable for use with 3,000 kW rectifiers:

Rated maximum voltage: 750 Volts

Rated continuous current: 8000 Amperes

2. Cathode bus assemblies shall be rated to carry continuously the current of their associated rectifier operating at 160 percent of full load. The temperature of the bus shall not exceed a maximum limit of 105°C over a 40°C ambient under these loading conditions. The bus duct assembly shall be compatible in design and construction with the rectifier and DC switchgear and shall operate as an integral unit when assembled.
3. Enclosure of bus duct assemblies shall be ventilated, made of high strength, corrosion-resistant aluminum.
4. DC cathode bus enclosures and supports shall be insulated from building structure for 1000 Volts. In addition, the bus enclosures shall be insulated from the high-resistance grounded rectifier enclosure and the high-resistance grounded dc switchgear enclosures by installation of boxed glastic or fiberglass sections in the vertical portions at the rectifier and DC switchgear. This insulation shall provide a minimum of 6" clearance between the metal enclosure of bus duct and nearest metal on rectifier or DC switchgear. An acceptable alternate arrangement is an insulated section in horizontal bus run near the rectifier and DC switchgear, providing a minimum two foot clearance between the metal bus enclosure and the nearest metal connected to the rectifier enclosure or DC switchgear enclosure. A suitably sized jumper across the insulating collar at the DC switchgear shall be provided in accordance with Article 2.04.B.10 of this Section.
5. Suitable support of bus enclosures shall be provided as required to ensure a rigid structure and workmanlike installation of the system.
6. To enable connection of future harmonic suppression filters, the cathode bus assembly shall be provided with bus taps, rated not less than 1/3 of the continuous current rating of the main bus. The exact location where the tap will be provided in the bus shall be furnished by the DB Entity for acceptance of the MBTA. Taps provided shall enable connection of future bus connection with minimum of labor and without involving drilling of main bus bars.
7. Flexible terminations shall be provided at each end of positive and negative cathode buses for connecting the bus conductors to equipment. Positive and negative bus termination details shall be fully coordinated with the rectifier specified in Article 2.03, the DC switchgear specified in Article 2.04 and the negative equalizer bus and drainage board in Article 2.06 of this Section. All flexible connections shall be provided with an easily removable insulating boot.

2.6 NEGATIVE EQUALIZER BUS AND DRAINAGE BOARD

A. General

1. Negative drainage boards shall be provided, located as shown on the Design Documents. The negative drainage board shall contain the negative equalizer bus. Negative leads of the rectifiers shall be connected to the negative equalizer bus through a negative lead disconnect switch. The negative drainage board shall have provisions to accommodate future negative drainage board equipment to include three bonding cables from the AC switchgear insulated ground bus each connected to the negative equalizer bus through an assembly of one blocking diode and one drainage contactor. The diode shall be rated 600 A, 400 V for each of the three bonding cables.

B. Structure

1. The negative drainage board shall consist of a freestanding panel containing the negative equalizer bus, rectifier negative lead disconnect switches, Device 89N, and connectors for the negative return cables. The negative drainage board shall be equipped with nine units each comprising a contactor, blocking diode, shunt and isolation amplifier.
2. The drainage contactors shall be of the latched-in type, open rear connected, single pole rated 600 Vdc, 600 Ampere, having high contact pressure and rapid arc quenching properties. Operating and reset coils shall be rated for operation on 125 Vdc. A minimum quantity of six (6) contactors shall be provided as shown on the Design Documents. The DB Entity may propose using three 3-pole contactors for this purpose subject to acceptance by the MBTA.
3. Contactors shall be mounted on the panel as shown on the Design Documents and shall be factory wired to the negative equalizer bus. Contactors shall be provided with a four digit register type operations counter. The negative panel shall be fitted with doors containing viewing windows.
4. All contactors shall be electrically interlocked with the rectifier main DC breakers so that all the contactors will be in the closed position as long as at least one DC main breaker is closed. All the contactors shall automatically trip open when both the rectifier main DC breakers are open. All circuits requiring external connections shall be factory wired to an easily accessible terminal box for connection to field wiring.
5. A blocking diode rated 600 A, 400 V and a shunt rated 600 A, 50mV shall be provided, connected in series with each drainage contactor.
6. An isolation type transducer, as specified in Article 1.11.B of Section 16203, shall be provided for each drainage circuit connected to shunt leads for telemetering drainage current. These indications shall be available at the drainage board ready and provided through the SAS system for future use by SCADA.
7. The DB Entity shall provide a nameplate, mounted above the operating handle of each switch engraved "DO NOT OPEN UNDER LOAD". The nameplate shall have white letters. ½" high, minimum, on red background. The legend for the nameplates shall be submitted to the MBTA for acceptance.
8. Panel frame shall be fabricated from steel members of sufficient strength to provide rigid support for the negative equalizer bus and all devices. A 2" thick, minimum, insulating board shall be provided for mounting the negative disconnect switches and the drainage

contactors. The front face below the insulating board and the sides of the structure shall be enclosed with sheet steel plates.

9. The insulating board shall be 2" thick and shall have high mechanical and dielectric strength, be impervious to moisture, be non-tracking and be able to withstand high temperatures without disintegration. The front surface shall be smooth and true. The edges shall be beveled for ¼". Material for the insulating board shall be subject to acceptance by the MBTA. DB Entity shall submit material data sheets for the proposed insulation material.
10. The negative bus and drainage board panel shall be sufficiently sized to accommodate the incoming negative bus ducts, negative disconnect switches (Device 89N), outgoing negative return cables, control cables, outgoing drainage feeder cables and other specified accessories. The negative buses and negative control cables, negative return cables and drainage cables shall enter from above or below as shown in the Design Documents.
11. All metal surfaces shall be finished in accordance with Article 1.15 of Section 16203. One quart of matching touch-up paint shall be shipped with the board.

C. Negative Bus and Power Terminations

1. The negative bus shall run the full length of the panel. The negative equalizer bus shall have the same continuous current rating as the DC switchgear main bus. The bus shall be supported on insulators with bus clamps mounted on the back of the panel. Taps shall be provided for connecting to the negative disconnect switches. Negative equalizer bus and bus taps shall be of copper, provided in accordance with Article 1.06 of Section 16203. All bus taps and connections shall be tightly bolted. Contact surfaces of bolted joints shall be factory silver-plated.
2. Heavy duty bolted type terminal lugs having NEMA four-bolt cable clamp and four-bolt tongue shall be provided in accordance with Article 1.07 of Section 16203 for up to twelve (12) 2000 kcmil copper conductor negative return cables. Terminal lugs shall be arranged for disconnecting any cable without disturbing the remaining cables. Back-to-back mounting of terminal lugs is not acceptable. Individual supports for each cable shall be provided near the cable terminal. The use of nylon ty-wrap type cable ties for individual cable supports will not be acceptable.

D. Negative Bus Disconnect Switch

1. The negative bus disconnect switch shall be single pole, open type, rated for operation on 750 Vdc. The switch shall have the continuous current rating of 8,000 Amperes. The switch shall be mounted in the rear of the panel. One switch terminal shall be directly connected to the negative equalizer bus, the second shall be arranged for connection to the negative cathode bus from its associated rectifier. All connections shall be made with a minimum of four ½"bolts. Switch shall be operable by an insulated handle from the front.
2. Switch shall be equipped with a mechanical lock or catch to hold it firmly in either open or closed position. Nameplates shall be provided to indicate the open and closed position of switch. Nameplates shall also be provided to indicate the rectifier number to which the negative disconnect switch is connected to.

3. Switch shall be provided with a key interlock, as described in Article 1.13 of Section 16203, to prevent closing or opening of the switch unless the associated rectifier main DC circuit breaker is open. An auxiliary switch shall also be provided, having at least eight independent contacts with four open when the switch is closed and four closed when the switch is open, for remote trip and alarm. Switch shall be of the bolted pressure contact type with a proven record and verifiable references for similar application.
4. Auxiliary switch shall be wired to the negative bus and drainage board IED for use in the substation automation system.

E. Surge Arrester

1. An approved surge arrester shall be provided, rated for 750 Volt DC nominal service, factory wired from negative bus to equipment ground terminal.

F. Control Sources

1. Each separate compartment within the negative drainage board shall be provided with an electric strip heater of adequate size to prevent condensation within the compartment. All heaters installed shall be monitored by means of an ammeter scaled and marked for the heater load. Each individual heater circuit shall be provided with blue LED indicating lamp to indicate operation of the heater, and an ON-OFF switch. Heaters shall be provided with properly designed guards to protect operating personnel against accidental contact with hot surfaces.
2. A fluorescent lighting fixture with conveniently located and properly labeled toggle switch, rated 250 Volts minimum, shall be provided in each compartment of the switchgear which contains disconnect switches, relays, control devices and outgoing wiring terminal blocks. Incandescent lighting will be acceptable only for compartments where, in the opinion of the MBTA, the installation of fluorescent lighting fixtures would be impractical. The lighting toggle switch shall be located on the exterior of the negative drainage board enclosure. In addition, a duplex receptacle, rated 250 Volts, 20 amperes minimum, shall be provided on the exterior of the enclosure connected for 120 Volt service. The outlet boxes of light receptacles, light switches and plug receptacle shall be insulated from switchgear enclosure for a minimum of 1,000 Vdc.
3. One single phase, two wire, 120Volt, 60 Hz supply bus shall be provided to provide power to the heaters, lighting and receptacle circuits. The supply bus shall be connected at each cubicle through fusible pull-out disconnects with cartridge-type fuses located in inside the control area. The fuse holders shall be insulated from enclosure for 1,000 Vdc. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10 percent, but not less than two, spare fuses of each rating shall be furnished. The supplies shall be wired to screw type terminal blocks, insulated from the enclosure for 1,000 Vdc

G. Nameplates

1. Equipment identification nameplates shall be engraved "NEGATIVE EQUALIZER BUS AND DRAINAGE BOARD".
2. In addition to nameplates specified for equipment and devices in Article 1.08 of Section 16203, the DB Entity shall provide a nameplate, mounted above the operating handle of the

switch, engraved "DO NOT OPEN UNDER LOAD". The nameplate shall have white letters, ½" high, minimum, on red background.

3. Nameplates shall be submitted to the MBTA for acceptance.

2.7 15 kV BREAKER CONTROL AND INSTRUMENT PANEL (ACCP)

- A. The 15 kV breaker control and instrument panel (also called the AC common control panel) is intended to be used in conjunction with the substation HMI, for the local and remote control of all substation 15 kV circuit breakers except for the rectifier transformer breakers.
- B. Structure
 1. The panel shall be finished inside and outside in accordance with Article 1.15 of Section 16203.
 2. The control and instrument panel shall be a rigid, self-supporting, electrically welded steel structure fabricated from not less than 12 gauge formed sheet steel. The panel shall have the configuration and dimensions shown on the Design Documents and shall be fully insulated from the DC switchgear to ensure integrity of the high resistance grounding requirement.
 3. Hinged, full access single doors shall be provided in at the front of the enclosure. If necessary, an interior swing out panel may be proposed. Doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be heavy duty of type to be accepted by the MBTA. If double doors are proposed, the doors shall be of the overlapping design. The doors shall be furnished with 3-point latching mechanism and key-locking handle. Doors shall be provided with stops to hold them securely in the open position. A single rear access door meeting the above requirements may be proposed by the DB Entity for acceptance by the MBTA where the door proposed will be less than 30" wide.
 4. The control panel enclosure shall be provided with electric space heaters of adequate size to prevent condensation within the panel. The heaters shall be monitored by means of an ammeter, marked for heater normal load. The heater circuit shall be provided with a blue LED indicating lamp to indicate operation of the heater and an ON-OFF switch. Heaters shall be provided with properly designed guards to protect operating personnel against accidental contact with hot surfaces. The space heaters shall be rated for operation on 120V, 60 Hz supply.
 5. The cabinet shall be provided with vent louvers to allow ventilations and ensure that heat buildup is not excessive for the electronic equipment. The louvers that shall be fitted with internal vent filters to protect from entry of dust and dirt. Filters shall be removable for cleaning and/or replacement.
- C. Arrangement of Devices
 1. Control and selector switches Devices 01 and 43 and indicating instruments shall be arranged to mimic the layout of the 15kV switchgear as shown on the Design Documents. Breaker control switches and breaker control mode selector switches are specified in Article 2.04 of this Section.

2. The ACCP shall house a SAS IED to integrate the AC switchgear controls and analog indications into the substation automation system.

D. Wiring and Terminal Blocks

1. All wiring shall be No. 12 AWG, stranded tinned copper, in accordance with Article 1.09 of Section 16203 unless otherwise specified.
2. Circuits requiring external connections shall be factory-wired to readily accessible terminal blocks rated 600 Volts as specified in Article 1.09 of Section 16203.
3. All necessary cable supports shall be provided with the ACCP for supporting the incoming control, indication and communication cables.

E. Meters, Switches, Indicating Lights

1. Indicating instruments, control and selector switches and indicating LEDs shall be provided in accordance with Article 1.10 of Section 16203 and as shown in the Design Documents.

F. Control Sources

1. A fluorescent lighting fixture with conveniently located and properly labeled toggle switch or door operated switch, rated 250 Volts minimum, shall be provided in each compartment which contains disconnect switches, relays, control devices and outgoing wiring terminal blocks. Incandescent lighting will be acceptable only for compartments where, in the opinion of the MBTA, the installation of fluorescent lighting fixtures would be impractical. In addition, a duplex receptacle, rated 250 Volts, 20 amperes minimum, shall be provided connected for 120 Volt service.
2. One single phase, two wire, 120Volt, 60 Hz supply bus shall be provided to provide power to the heaters, lighting and receptacle circuits. The supply bus shall be connected at each cubicle through fusible pull-out disconnects with cartridge-type fuses located in inside the control area. The fuse holders shall be insulated from enclosure for 1,000 Vdc. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10 percent, but not less than two, spare fuses of each rating shall be furnished. The supplies shall be wired to screw type terminal blocks, insulated from the enclosure for 1,000 Vdc

G. Nameplates

1. Nameplates shall be provided in accordance with Article 1.08 of Section 16203.
2. Panel identification nameplates shall be provided in front and rear of the panel, engraved "15 kV BREAKER CONTROL AND INSTRUMENT PANEL".

H. Detailed Equipment Requirement

1. Panel shall contain, but not be limited to, the following equipment and devices; Quantities shall be as shown on the Design Documents.
 - Control switches, TRIP-CLOSE with green and red indicating LEDs, Device 01

- Breaker control mode selector switches LOCAL-HMI-OFF-SUPV, Device 43
- Indicating bus voltmeters, transformer rated, 0-18 kV scale
- Indicating feeder voltmeters, transformer rated, 0-18 kV scale
- Ammeters (digital multifunction meters may be provided as shown in the Design Documents)

One - Lot of terminal blocks and wiring

One - Lot of nameplates

One - Set of space heaters with ON-OFF switch, blue LED light and ammeter

One - AC Watt-hour demand totalizer for totalizing the KWHr demand of 52-L1 and 52-L2. Meters shall interface with the substation automation system to provide output to SCADA.

One - One set of equipment as necessary to interface the ACCP equipment with the substation automation system i.e. IED / DIO for integrating all devices into the SAS

2.8 STATION BATTERY, CHARGER AND ACCESSORIES

A. General

1. The station battery will serve as the primary source of ungrounded 125 Vdc control power for AC and DC circuit breakers, rectifiers, and station auxiliary systems located in the substation.
2. One complete station battery system shall be furnished, including rack, charger, on-line battery monitoring system, distribution panel and accessories. The station battery shall be connected to the main circuit breaker of the 125 Vdc distribution panel and the charger to the DC distribution panel through a branch circuit breaker. Thus connected, the equipment can be used to supply the 125 Vdc control power system from the station battery and charger operating in parallel, or from the station battery alone, or from the charger alone. See Figure 1 below.

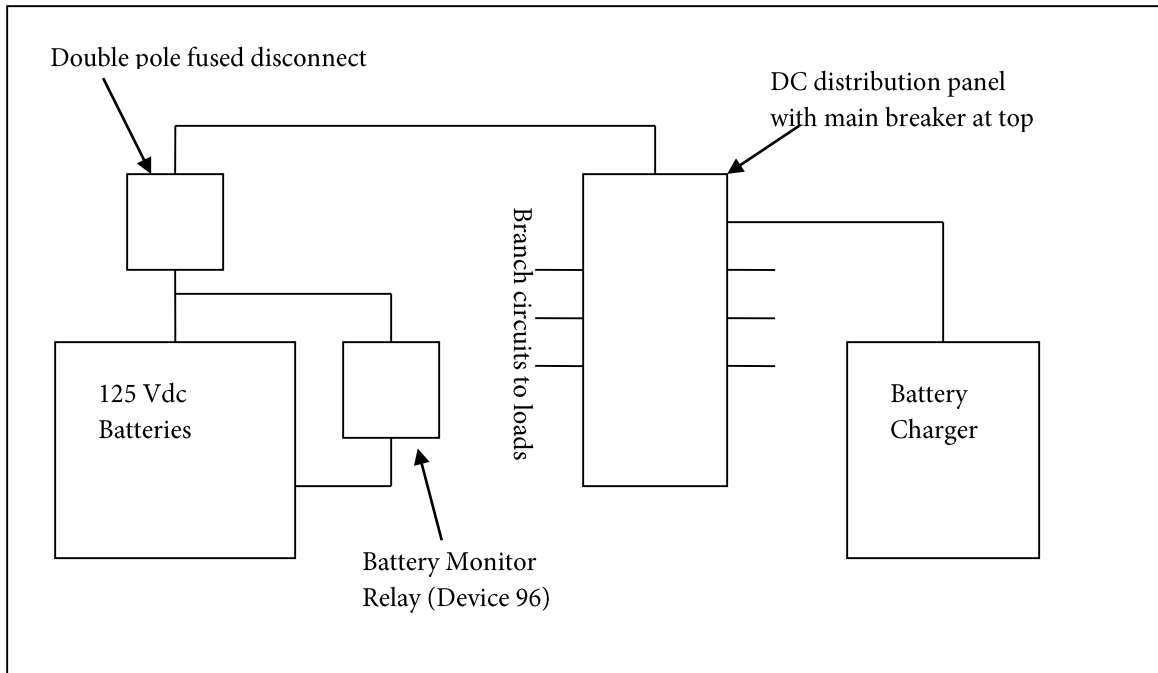


Figure 1

3. Provide a spill containment and absorption system for MBTA's acceptance.
4. All equipment shall be suitable for indoor installation as shown on the Design Documents.

B. Station Battery

1. Station battery shall be of an approved pasted plate type, designed for switchgear service. Battery, as applied, shall give a minimum of 20 years of satisfactory service with a minimum amount of maintenance. Under normal operation the station batteries will be operated in the steady float mode of charging with periodic equalizing and cycling as required by the manufacturer's operation and maintenance guidelines. The station batteries will not be deep-cycled under normal circumstances.
2. Each station battery shall consist of 60 cells connected in series for a nominal 125 Volt, ungrounded, control power system. Each cell or group of cells shall be housed in a heat resistant, shock absorbing clear plastic container (jar) of extra strength which will not deteriorate or become cloudy upon exposure to the electrolyte. Covers shall be cemented in place to form a permanent, leak proof seal. Each cell shall be provided with a filler opening fitted with a safety cap to prevent explosion of internal cell gases due to an external spark or flame. Sufficient sediment space shall be provided for the normal life of the battery.
3. Each cell jar shall be legibly and permanently marked with the manufacturer's name or trademark, cell type, eight hour discharge rate, ampere-hour capacity, electrolyte level and month and year of manufacture.
4. Cell terminal posts shall be of lead-alloy (with or without solid copper insert), clearly and permanently marked for polarity. Cell posts shall be equipped with approved lead covered or stainless steel terminal bolts and nuts. Lead covered solid copper intercell connection straps

shall be provided as required for interconnection of the individual cells. Interconnections shall be arranged to allow the removal of each cell from the battery. Battery terminals shall be furnished with approved lead covered, bolted type terminal lugs for external wiring. Cell posts, connection bolts, straps and terminal lugs shall have ample current carrying capacity and sufficient contact surface to provide for maximum discharge current of the battery. All hardware shall be sized to be compatible with the ratings required per Paragraph 7 below.

5. The terminals through the cell cover shall be sealed against seepage of electrolyte by burned-on seal rings, to ensure a clean, dry battery.
6. The batteries shall be of required ampere-hour capacity to supply the high discharge rates necessary to close and trip the specified number of 15 kV AC circuit breakers and 750 Vdc circuit breakers consecutively after the battery has supplied, without assistance from a charging source, the lower rate continuous load for 12 hours.
7. It shall be the responsibility of the DB Entity to determine the required battery rating, and to fit the battery into the space shown on the Design Documents. The DB Entity's proposed battery rating will be subject to acceptance by the MBTA. Battery rating shall be based on IEEE Standard 485 calculations, *IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications*, and the equipment loads shown on the following table. The voltage of the battery, when supplying the specified loads, shall at no time drop below 105 Volts or 1.75 Volts per cell, including the IR drop of inter-cell connections. Calculations shall be performed at an ambient temperature of 50°F.

	<u>Amperes</u>	<u>Assumed Load Duration</u>	<u>Interval of Load Application</u>
MBTA's Load	3.0A	12 hours	Continuous
Substation Automation System – including HMI	*	Continuous	Continuous
Control circuit load	*	12 hours	Continuous
Closing 8 – 15 kV breakers consecutively	*	30 sec.	30 sec. Apart
Closing 8 - DC breakers consecutively	*	30 sec.	30 sec. Apart
Tripping 8 - 15 kV breakers by Device 86B	*	30 sec.	Simultaneously
Tripping 8 - DC breakers	*	30 sec.	Simultaneously

*- Load to be determined by the DB Entity

8. Battery shall be delivered wet, fully charged (over 90% of rated battery capacity), ready for service, suitable for storage at site for at least three months from shipping date without deterioration.
9. The battery shall be lead-acid type, with flat pasted plates and lead-calcium alloy grid, Enersys type CC, EC or approved equal. Calcium alloy grids drastically reduce the frequency of watering when the battery is float charged and seldom cycled, and is therefore a mandatory

requirement of the specification. C&D Technologies KCR Lead-Calcium batteries meeting all specification requirements will also be acceptable.

10. Battery shall be furnished with accessories for normal operation and maintenance, including the following:
 - a. Two portable thermometers of adequate size to be read easily and accurately.
 - b. Two syringe type portable hydrometers of adequate size to be read easily and accurately.
 - c. A cell lifter.
 - d. An electrically insulated torque wrench for battery terminal connections.
 - e. A container of protective coating for battery terminals as recommended by the manufacturer.
 - f. An approved corrosive resistant wooden or metal cabinet suitable for wall mounting to house accessories. Drip-proof containers shall be provided for the portable thermometers and hydrometers.

11. The DB Entity shall furnish the MBTA with the following information for the provided battery. The DB Entity shall complete the table below and provide it with the design submittal for acceptance.

No.	Description	Equipment Information:
a.	Manufacture and type of battery	
b.	Ratings (to final voltage of 1.75 volts per cell, at 25°C):	
	Ampere rating for 8 hour discharge	
	Ampere rating for 1 hour discharge	
	Ampere rating for 1 minute discharge	
c.	Number of plates per cell	
d.	A complete description of separators and plate separation	
e.	Number of cells per jar	
f.	Overall dimensions of jar	
g.	Weight of complete jar with electrolyte	
h.	Type of connectors	
i.	Quantity of electrolyte per cell	
j.	Specific gravity of electrolyte when battery is fully charge at 25°C	
k.	Material used for covers and jars	
l.	Description of cell posts and terminals	
m.	Station battery loads used in sizing batteries. Calculations to be performed at an ambient temperature of 50°F.	

C. Combination Power Supply and Battery Charger

1. The combination power supply (“battery eliminator”) and battery charger furnished will be utilized for supplying nominal 125 Vdc to control and relay circuitry and for float charging the station battery. It shall be rated for operation on a 208 Volt, three-phase, 60 Hz supply.
2. The charger shall be convection cooled, solid state, full wave rectifier type. No internal cooling fans will be permitted. The rectifier shall consist of hermetically sealed units of silicon controlled rectifiers of adequate voltage and current rating for this service. The diodes shall be mounted on heat dissipating fins of proper size to limit the junction temperature of the diodes to a safe value.
3. The power supply shall consist of a three-phase isolation transformer and a rectifier with an adjustable regulated voltage and current limiting feature. Regulation shall vary less than plus or minus one percent at any control setting. It shall be adjustable between 127 and 140 Vdc and shall be capable of sharing the load with the battery when the load current exceeds a preset value. The preset current setpoint value shall be adjustable between 90 and 120 percent of the power supply continuous rating.
4. To function as a battery charger, the power supply shall have two separate voltage adjustments: one for float charge, adjustable between 115 and 140 Volts; the second for equalizing charge, adjustable between 124 and 150 Volts. A manually adjustable 0-72 hour timer shall be provided to control the charging and equalizing cycle. All of these adjustable functions shall be enabled with control knobs on the front of the charger panel.
5. The charger shall be provided with current limiting circuitry to keep the output of the charger within the safe operating limits under all loading conditions and during severe overloads. The circuit shall continuously monitor the load current and when the current begins to exceed charger rating (as may be the case of recharging depleted battery while supplying other DC loads in the substation), a feed-back feature provided as part of the circuit shall keep the output current within 110 percent of rated. The charger shall be designed to operate continuously at this rating without damage to any circuit components. The current-limiting mode of operation shall not cause the tripping of input (AC) or output (DC) circuit breakers. The input circuit breaker shall trip only in case of component failure and high DC output voltage; the output circuit breaker shall trip in the case of an external fault.
6. A blocking diode shall be provided in the output circuit, to prevent battery discharge through the charger in the event of AC power failure.
7. The power supply shall be capable of concurrently carrying the constant load of the associated battery and fully charging the battery within six hours after the batteries have been discharged to 1.75 Volts per cell, and shall be able to carry the entire battery load in the event of a battery failure. The power supply shall be capable of operating safely at building ambient temperatures from zero °C (32°F) to plus 50 °C (122°F).
8. The battery charger shall also be capable of functioning as a “filtered battery eliminator” to operate as a DC power supply without batteries. Filtered silicon controlled rectifiers shall be provided for this purpose to minimize output ripple voltage to 30mV rms or 0.06% of nominal output voltage, whichever is higher.

Since the associated battery is not considered to be part of the output filtering network, electrolytic capacitors may be used to smooth-out the high magnitude output ripple voltage, provided such capacitors have protective circuitry and are 50 percent in excess of the

capacitance value required for 0.06% ripple and are rated for operation at 100°C. In such case, three capacitors shall be used of such value that two will limit the ripple to 0.06%. The third capacitor is to be considered a spare which must be kept energized to prevent deterioration.

9. The battery charger shall include a “temperature compensation” feature to automatically adjust charger output voltage based on changes in ambient temperature.
10. All solid state electronic circuit components shall be provided with surge and transient voltage protection.
11. The power supply circuit components and control devices shall be mounted in a free-standing, floor mounting cabinet, with the base fabricated from not less than 12 gauge sheet steel and the enclosure sides and top fabricated from not less than 16 gauge sheet steel. The internal equipment shall be mounted on a panel of insulating material, supported on a swinging steel frame. The frame shall form a component part of a self-supporting steel cubicle. Heavy components such as reactors, transformers and other iron core devices shall be supported by bracing to the swinging steel frame. A swing-out panel may be omitted in the power supply and battery charger unit only if all components are accessible from the front for easy maintenance, removal and inspection and the arrangement meets MBTA's acceptance. Conduit knockouts shall be provided at appropriate locations.
12. Each resistor, capacitor, transformer and similar device shall be inscribed with an approved lettered identification corresponding to the apparatus or device with which it functions and as identified on the schematic and wiring diagrams. The proposed inscriptions should be identified on the equipment nameplate list which shall be provided with the design submission.
13. The cabinet shall have hinged full-access front door. Door shall be securely fastened in the closed position with a minimum of two latches easily opened without the use of tools. Arrangements shall be made to hold door securely in the open position.
14. Control wiring of circuits operated on 60 Volts AC or DC, or higher, shall be No. 14 AWG or larger, stranded tinned copper switchboard wire in accordance with Article 2.01.D of Section 16203. No. 18 AWG wire will be acceptable for low-voltage, low-energy control circuits only.
15. Circuits requiring external connections shall be factory-wired to terminal blocks, readily accessible for connection to field wiring.
16. Finish of equipment, inside and out, shall be thoroughly cleaned and rust-proofed, painted with one coat of approved rust inhibiting primer and a minimum of two coats of acid resistant ANSI No. 61 gray paint.
17. Battery chargers with microprocessor controls and associated extensive use of printed circuit boards are not considered to be an acceptable "equal" to the above specification. Any charger submittal with microprocessor controls shall be rejected.
18. The equipment for the power supply and battery charger shall include, but not be limited to, the following:

- (a). One - Three-phase isolation transformer in accordance with paragraph C.3 above.
 - (b). One - Charger rectifier unit and associated control equipment.
 - (c). One - Large scale DC switchboard type ammeter for charger DC output with suitable scale. Minimum face dimensions shall be 2" x 3".
 - (d). One - Large scale DC switchboard type voltmeter, 0-150 Volt scale. Minimum face dimensions shall be 2" x 3".
 - (e). One - 250 Volt, 3-pole alternating current molded case circuit breaker on the AC input.
 - (f). One - 250 Volt, 2-pole direct current molded case circuit breaker on the DC output.
 - (g). One - Set of alarms/status indications monitoring AC input undervoltage (Device 27BA), AC input overvoltage, DC output overvoltage (Device 59), DC output undervoltage (27BB), charger failure, ground fault detection and a common alarm relay providing a summary alarm for any one or all of the alarms stated above. Each alarm shall be provided with a red indication LED mounted on the front of the charger, appropriate time delays on alarm and shall be auto reset. Two sets of isolated, dry, form C contacts shall be provided for each alarm point with all contacts being wired to suitable terminal blocks for field wiring interconnections.
 - (h). One - Indicating LED test switch to verify correct operation of the indication lights.
 - (i). One - Large-scale 72-hour manually operated timer with sufficient contacts to switch the regulatory section of the power supply between float charge and equalization charge settings.
 - (j). One - Battery Fused disconnect switch to facilitate isolating the batteries from the DC distribution panel and charger. The fused disconnect switch shall be suitably located adjacent to the battery rack. The DB Entity can request instructions to the MBTA (see Figure 1).
 - (k). One - AC voltmeter for monitoring the incoming supply. Minimum face dimensions shall be 2" x 3".
19. In addition to nameplates specified in Article 1.08 of Section 16203, furnish a nameplate on the door of the cabinet engraved: "125 VOLTS DC POWER SUPPLY". Nameplate shall have white letters, 1/2" high on red background. In addition, the battery charger shall be provided with a permanently attached equipment rating plate stating the manufacturer's name, equipment model number, serial number, and electrical ratings.
20. Each battery charger/eliminator shall be shipped with a maintenance manual, which shall include a troubleshooting guide and schematic drawings for all component systems.

D. Battery Rack

- 1. The DB Entity shall provide a two-step rack for mounting the individual jars of the station battery.
- 2. Battery racks shall be constructed of galvanized steel rails, frames and braces, bolted together to form rigid, free-standing structures. Racks shall be furnished with plastic channels with a 1000 V minimum dielectric strength for mounting the battery cells. The rack assembly shall

be designed to withstand Uniform Building Code Zone 2A seismic forces for the Boston, Massachusetts metro area.

3. All steel members shall be thoroughly cleaned and rust-proofed, painted with one coat of approved rust inhibiting primer and a minimum of two coats of acid resistant ANSI No. 61 gray paint.
4. All assembly hardware shall be provided, including a battery rack frame ground connection point.

E. On-Line Battery Monitoring System

1. Provide an on-line battery monitoring system that can monitor the performance of each battery cell at each of the MBTA traction power substations, store the performance data locally, and distribute this information to two central PCs. Each monitor shall be supplied complete with all required battery cell wiring for connecting each battery post to the monitor, associated connection hardware, current transducers, temperature transducers, fuses, and any other hardware needed to complete the assembly of the battery monitoring system at each substation.

The system shall also include the necessary software to be installed at the two central PCs that are capable of managing the remote battery monitors and able to auto poll each system on a programmed schedule from a modem connection, Ethernet connection, or a combination thereof. This software shall be capable of receiving and archiving the measured data from each monitor, recalling and sorting it, printing and/or plotting it, and facilitating the observance of trends in the data which signify deteriorating conditions in a proactive manner. The software shall have a real time monitoring mode to allow a graphic presentation of real time voltage, temperature, and discharge data during a discharge test or live discharge event.

Each substation battery monitor shall have the capability of sending an alarm automatically to the central PCs when an alarm condition has been detected.

OR

Each substation battery monitor system shall also be capable of integrating with the substation automation system to provide all status, polling, archiving data as described above and shall be capable of integrating fully with the battery monitoring software.

2. Detailed specifications for each battery monitors are summarized as follows and shall equal or exceed the product specifications of Albercorp's MPM-100 Multi-Purpose Monitor:
 - (a). String Capacity: Each monitor shall have the capacity to monitor 60, 2-volt cells connected in series to provide a string voltage of 120 volts.
 - (b). Input Power: The monitor shall be DC powered from the 120 volt station battery system.
 - (c). Operating Temperature Range: 41 to 104 degrees Fahrenheit.
 - (d). Humidity: 0 to 80% RH (non-condensing) at 5 to 31 degrees Celsius; 0 to 50% RH (non-condensing) at 32 to 40 degrees Celsius.

- (e). Cell Voltage:
 - a. 0 to 4.000 volts; 0.1% of reading +_1mV.
 - b. 0 to 16.0 volts; +-20mV.
- (f). Cell Voltage Channel:
 - a. 2V range: (0-4V), 0.1%+_1mV
 - b. 4V range: (0-8V), 0.1%+-2mV.
 - c. 6V range: (0-8.5V), 0.1%+-2mV.
 - d. 8V range: (0-10V), 0.1%+-10mV.
 - e. 12V range: (0-16V), 0.1%+-10mV.
- (g). Cell Resistance: 0 to 32,000microOhms, 5% of reading +-1micro-ohm.
- (h). Inter-tier Resistance: 0 to 5milliOhms, 5% of reading +-5 micro-ohms.
- (i). String Voltage: 0 to 150 volts, 0.1% of reading +-0.1V.
- (j). Discharge Current: 0 to 4000Amps, +-5% of full scale using current transformer.
- (k). Temperature: 0 to 80 degrees Celsius, +-1 degree Celsius.
- (l). Float Current: 0 to 5000mA, +-50mA.
- (m). Communication:
 - a. One USB port
 - b. One modem serial port
 - c. One RJ-45 connection port or RS-232 connection port.
 - d. Protocols: MODBUS and SNMP
- (n). Local Data Storage:
 - a. E2 nonvolatile memory for calibration constants, alarm levels, telephone numbers, and setup information.
 - b. 100 alarm events in revolving nonvolatile memory.
 - c. 32K bytes of discharge data in nonvolatile memory.
 - d. 1.6K bytes resistance test records.
 - e. 1.65K bytes historical data.

- f. Flash memory for firmware upgrades.
3. Measurement Capability
- (a). Individual cell voltage
 - (b). Individual cell DC resistance accomplished by applying a momentary load at user defined intervals.
 - (c). Individual intertier resistance measurements performed at user defined intervals.
 - (d). Total overall battery voltage per string.
 - (e). Ambient or pilot cell temperature per string for temperature trending.
 - (f). System discharge logging of the overall voltage, individual cells, discharge current, and temperatures.
 - (g). Float current per string.
4. System Hardware Requirements
- (a). LEDs indicating alarms, communications, and processor status.
 - (b). Wiring harnesses with supplied connectors to be terminated in the field during installation.
 - (c). Individual fused leads to each battery cell/jar for resistance test load cables, and resistor terminated leads for voltage sense.
 - (d). Ring connector terminals at each connection.
 - (e). Ambient temperature probes, electrolyte temperature probes, shunt and shunt adapters, current/float cable assemblies, float current measurement transducer for each string, float charging current probes, external network interface equipment including necessary cables, and current and voltage transducers.
 - (f). “U” wall mount bracket for mounting each monitor to a concrete wall.
 - (g). One USB port for connection of a laptop for local data viewing or service.
5. System Software Requirements
- (a). The software shall operate on the Windows 7 Professional, Windows 2000, and XP compatible software for data analysis, display, archiving, and trending.
 - (b). The software shall be responsible for maintaining a database of all information gathered from the monitors for future analysis and reporting.
 - (c). The software shall be configurable for wither a central, local or service computer application. The central configuration shall be responsible for permanently removing

any data that may reside in the monitor E2 memory. The local configuration will not permanently remove data from E2 memory and will allow it to remain for the central computer. The service configuration will allow service technicians to call for real time analysis from any accessible phone line.

- (d). The software shall be able to auto-poll multiple monitoring systems on a programmed schedule.
6. Password Protection: The battery monitoring system shall require a password to allow any programming or calibration changes either via remote connection or local connection.
7. System Performance
- (a). The battery monitoring system shall monitor, display, and record the battery bank voltage, battery discharge current, individual cell voltages, configured temperature, individual cell resistance, and inter-tier resistances. All these parameters shall be continuously monitored in real time during normal operation and during all battery discharges, except for resistance test, which is a user programmable event.
 - (b). The battery monitoring system shall transfer all battery parameters specified above at the remote central computer at user defined intervals.
 - (c). The system shall automatically display, record, and provide a print-out of all alarm conditions, as and when they occur, at the remote central computer. The reporting shall include the following parameters:
 - (a). Individual cell voltage high and low alarm
 - (b). Individual internal resistance high alarm.
 - (c). Individual internal resistance warning as a percentage of alarm threshold.
 - (d). Inter-tier resistance high alarm.
 - (e). Overall voltage high and low alarm.
 - (f). Temperature high and low
 - (g). Individual cell voltage low alarm during discharge.
 - (h). Discharge string current.
 - (i). Discharge time alarm set in hours/minutes.
 - (j). Float current high alarm.
 - (d). Each alarm record shall include defined limits, alarming parameter, show the time and date of the event, and the peak value reached during the violation.
 - (e). Each parameter alarm shall be configurable for a latching or non-latching alarm contact function.

- (f). As user defined, the system shall automatically page or fax a report to responsible personnel when any alarm thresholds are violated.
- (g). The system shall provide and maintain a complete, real-time discharge event log and a dynamic on-line display of battery voltage, individual cell voltages, battery string current, and ambient temperature whenever the battery is in a discharge mode. In addition to the numerical display, the system shall provide a graphical display of the battery voltage and cell voltages versus time that allows playback of the discharge event.
 - (a). Store historical record of the internal cell resistance of each cell.
 - (b). Display the actual real time numbers (or stored snapshots) of all battery parameters at the remote central computer. Additionally, the display shall provide individual graphical representation of all battery parameters in relation to alarm thresholds.
 - (c). Provide automatic voltage logging of overall voltage, individual cell voltages, and temperature at user defined intervals for trending analysis.

8. System Report Generation Capabilities

- (a). Alarm condition reporting – tabular, fax, or pager.
- (b). Cell/jar out-of-limits summary report – tabular.
- (c). Individual cell voltages over time – graph or tabular.
- (d). Individual cell resistance values over time – graph or tabular.
- (e). Total battery voltage over time – graph or tabular.
- (f). Battery temperature / room temperature over time – graph or tabular.
- (g). Discharge report: total battery voltage decay vs. time – graph or tabular.
- (h). Discharge report: cell voltage decay vs. time – graph or tabular.
- (i). Discharge hit summary report – tabular.
- (j). Discharge hit interval summary report – tabular.
- (k). General summary report of battery and monitor status of all systems to the battery or string level base on user set thresholds.
- (l). Detail summary reports of battery and monitor status of all systems with a line graph trend of any parameter that violated a threshold.

9. User's Guide

- (a). Each substation with a battery monitor installation shall have one set of MBTA's manuals, which include the following information as a minimum:

- (a). Installation and commissioning instructions
- (b). Operating instructions

10. Laptop Computers

- (a). The vendor shall supply one laptop computer per substation for interfacing with the battery monitor's USB port in order to service the monitor and to locally download cell test data. Each laptop's specifications shall equal or exceed those for the Lenovo Model T410 provided with discrete graphics capability. Each laptop shall equal or exceed the following important equipment specifications and accessories:
 - (a). Processor: Intel Core i7-620M
 - (b). Operating System Language: Windows 7 Professional 32 US English, or later
 - (c). Total Memory: 4GB
 - (d). Hard Drive: 320 GB Hard Disk Drive, 7200 rpm.
 - (e). System Graphics: NVIDIA NVS 3100m Graphics 256MB DDR3 with AMT.
 - (f). External Connection Ports: VGA, Ethernet, DisplayPort, four USB slots, smartcard reader, card reader, single headset jack, ExpressCard/34, 1394, eSATA, Kensington lock port, and a modem jack.
 - (g). Integrated Wi-Fi: ThinkPad b/g/n
 - (h). Power Accessories: ThinkPad and Lenovo 65W AC Adapter (spare power adapter) and ThinkPad Battery 25+ (spare battery).
 - (i). Portable Carrying Case: Lenovo Messenger Max Case
 - (j). Security Accessory: Kensington MicroSaver Security Cable Lock from Lenovo.
- (b). The vendor shall supply with each laptop an extended warranty service package valid for a period of three (3) years transferable to the MBTA.

F. Spill Containment System

1. Station battery installation shall be provided with a spill containment and absorption system. The materials used, method of application, and completed installation must fully comply with all Federal, state and local requirements.
2. A spill containment and absorption system shall be supplied consisting of perimeter rails, synthetic membrane floor liner, and absorbent pillows as follows:
 - (a) Perimeter rails shall be 4" high and constructed of non-corrosive material, including all corner pieces and splices to form a free flow barrier. Flammability rating shall be V-0.
 - (b) The synthetic membrane floor liner shall be a minimum of 6 mil thick plastic material with a flame rating of VTM-0. No floor preparation or treatment shall be required prior to installation.

- (c) Absorbent pillows shall be constructed of rugged industrial fabric with a VTM-0 flammability rating. Absorbent pillows shall be manufactured in modular dimensions to facilitate placement within the perimeter rails of the containment structure. Each pillow shall be filled with an absorbent material capable of absorbing acids and/or base solutions that will discolor upon contamination to provide a visual indicator. Absorption capability per pillow shall be approximately 1 gallon of acid and/or base depending on the exact dimensions of each pillow.

G. DC Distribution Panelboard

1. A circuit breaker panelboard shall be provided with the substation battery system for distributing the 125 Vdc control power. Panelboard and all circuit breakers shall be Underwriters' Laboratory (UL) approved, and rated for operation on ungrounded 125 Vdc.
2. Panelboard interior shall consist of a steel backplate structure holding the bus and terminal assemblies. The backplate shall be removable and shall be adjustable in depth unless the assembly for the panelboard is specifically designed to ensure proper depth positioning of the panel interior without adjustment. Breakers shall be bolt-on type, factory installed. All spaces shall be fully bussed and equipped requiring no modification for the addition of future breakers. Unused space shall be covered to preclude accidental access to the bus.
3. Buses shall be of copper, silver plated, braced to withstand a short circuit equal to the highest short circuit capacity of any breaker installed in the panel.
4. Circuit breakers shall be molded case, two pole with trip free mechanism. Trip elements shall be thermal and magnetic type.
5. Circuit breakers shall have a minimum interrupting rating of 10,000 Amperes at 125 Vdc. The buses and main circuit breaker in the panelboard shall have a continuous current rating of approximately 200 percent of the maximum load of the duty cycle, or a minimum of 200A. Provide branch circuit breakers in the panelboard in the quantities and ratings required by the actual equipment proposed by DB Entity.
6. Panelboard shall be factory assembled, furnished with NEMA type 1 general purpose surface mounting cabinet. Cabinet shall be of a gauge not less than that specified by the applicable UL standard. Wiring gutters shall conform to the requirements of the National Electrical Code and the applicable UL standards, but in no case shall be less than four inches. Box shall be furnished with single size knockouts or may be field drilled. Spare knockouts or combination knockouts shall not be furnished.
7. Panelboard front shall be of a gauge not less than that specified by the applicable UL standard and shall be of cold rolled or other suitable steel with concealed hinges, concealed trim clamps and flush catch and lock. Lock shall be keyed as accepted by the MBTA. A typewritten directory with plastic covering shall be installed on the interior of the door.
8. Cabinet shall be hot-dipped galvanized after fabrication. Front shall be thoroughly cleaned and finished with a rust inhibiting primer. Panelboard shall be finished in accordance with Article 1.15 of Section 16203.

9. In addition to nameplates specified in Article 1.08 of Section 16203, the DB Entity shall provide a nameplate on the door of the panelboard engraved "125 VOLTS DC DISTRIBUTION PANEL". Nameplate shall have white letters, 1/2" high on red background.
10. The DB Entity shall provide the main circuit breaker at the top of the distribution panel which shall accommodate the two battery leads, sized as required by the DB Entity.

H. Equipment Experience and Serviceability:

1. The vendor shall demonstrate that the proposed equipment has a proven reliability record in a DC traction power substation environment by furnishing a minimum of three references with names of contact persons and phone numbers at the referenced transit authorities in the United States. The subject equipment must have been in service at the referenced facility for a minimum of ten (10) years.
2. The equipment vendor shall preferably have a service center within 250 miles of Boston MA in order to be able to provide technicians, spare parts and accessories at short notice to enable the MBTA to minimize any disruption to the operating system in the event of any battery system problems. The vendor shall provide the location and name of facilities within this radius.

I. Eyewash Station

1. Provide a self-contained, wall mounted eyewash station adjacent to the station batteries. The DB Entity shall propose the eyewash station for review and acceptance by the Agency.

J. Warranty

1. A written copy of the manufacturer's warranty for batteries and charger/eliminator shall be included with the bid proposal.
2. For station batteries, the MBTA requires a one-year full guarantee from in-service date or 18 months from date of shipment, whichever occurs first. There after the warranty should be pro-rated for the remaining 19 years of the designed battery service life.
3. For the battery charger/eliminator, the MBTA requires a one-year full guarantee from in-service date or 18 months from date of shipment, whichever occurs first. There after the warranty should be pro-rated for the remaining 19 years of the designed battery charger service life.

2.9 SUPERVISORY EQUIPMENT

A. General

1. The requirements for additions and modifications to MBTA's existing SCADA system and for furnishing substation supervisory equipment are specified in Section 16492.
2. Details of the requirements of the substation equipment to interface with the SCADA system are provided in Articles 1.05 and 1.06, this Section and also identified in Section 16311 Appendix A – Substation Automation System.

3. As necessary, a supervisory terminal cabinet shall be provided to provide an easily accessible point of interface between the substation and SCADA systems. Strong preference is for all SCADA interfaces to be provided via fiber optic cable or ethernet Cat 6 cable to the substation PLC / SCADA LAN.

B. Supervisory Terminal Board (STB) – If required

1. The Supervisory Terminal Board (STB) shall be housed in a NEMA 12 enclosure, fabricated from not less than 12 gauge sheet steel. It shall be provided with a factory-installed floor stand, to make the terminal box a free-standing, floor-mounting cabinet.
2. Hinged, full access double doors shall be provided in front. Doors shall be of overlapping design, furnished with neoprene gaskets and a three-point latching mechanism with key-locking handle. Doors shall be provided with stops to hold them securely in the open position.
3. A full size panel shall be installed in the enclosure for mounting of terminal blocks.
4. Terminal blocks furnished shall conform to the requirements specified in Article.109 of Section 16203. A minimum of 25 percent spare terminals shall be provided for future application.
5. The STB shall be finished inside and out in accordance with Article 1.15 of Section 16203.
6. The DB Entity shall provide a nameplate on the door in accordance with Article 1.08, Section 16203, engraved in ¾” black letters: ‘SUPERVISORY TERMINAL BOARD’.
7. The STB shall be suitable for top or bottom entry of cables as indicated on the Design Documents.

2.10 SUBSTATION AUTOMATION EQUIPMENT

Refer to Section 16311 Appendix A.

2.11 TECHNICAL SUPPORT EQUIPMENT

A. General

1. The DB Entity shall ensure that adequate supply of equipment, parts, materials, tools and required equipment for protection of operating personnel are available at the site for orderly installation and testing of equipment without undue delay. In addition to equipment and parts needed to commission the substation, the DB Entity shall furnish the following parts, listed in Article 2.11.B below, to the MBTA upon commissioning the substation.

B. Requirements

1. The DB Entity shall furnish the following items, delivered with the shipment of related equipment for which they are required, unless otherwise directed by the MBTA. A complete list of the support equipment being provided shall be provided by the DB Entity prior to commissioning, for review and acceptance by the MBTA. The list shall include relay model numbers and fuse ratings.

- a. One complete 15 kV class circuit breaker, identical to the other 15 kV breakers provided per substation.
- b. One complete 750 Vdc class feeder circuit breaker, identical to the other 750 Vdc breakers provided per substation.
- c. Three additional 13.8kV and 1000 Vdc current limiting fuses to match the fuses installed in the equipment per substation.
- d. Ten percent of all control and auxiliary circuit fuses and two percent of all fuse blocks installed in the equipment (but not less than two fuses and one fuse block of each rating).
- e. For each type and rating of power DC circuit breaker, one of each type for every four circuit breakers of electromotive device integral to the breaker, used for closing and tripping, including but not be limited to, closing coils, spring charging motors, trip coils or holding coils, per substation. This includes circuit breaker control modules where applicable.
- f. One of each type for every four circuit breakers of spring used in each type of circuit breaker, per substation.
- g. For each type of AC and DC power circuit breaker, one set of primary power current carrying disconnect assemblies, two complete sets of secondary control disconnect assemblies and one set of auxiliary switches, per substation.
- h. Six replacement diodes for each traction rectifier provided for each substation.
- i. Six diode fuses for each traction rectifier provided for each substation.
- j. One surge arrester assembly of each type provided per substation.
- k. One bimetallic thermal device for rectifier heat sink over-temperature detection per traction rectifier provided.
- l. Two protective relays of each type, including multifunction relays/intelligent protection relays, complete with case per substation.
- m. One of each type of rectifier-transformer over-temperature detection devices (Devices 26 and 49) per rectifier transformer provided. This includes temperature gauges as well as thermocouples.
- n. Spare Parts: Provide spare parts kits as recommended by the manufacturer for each installation.
- o. SAS requirements per Section 16311 Appendix A
- p. Two of each type of control, auxiliary, and timing relays of each type furnished in the 750 Vdc switchgear, rectifier, rectifier transformer, and negative equalizer bus. Foreign relays not available in this country from local suppliers (such as C&S relays) will require triple the amount.

- q. One plug-in electronic control card of each type, for the battery charger per substation.
- r. One complete set of accessories per substation, in a lockable tool cabinet, required for installation, adjustment, testing, maintenance and dismantling of all the equipment to be furnished in this Section. As a minimum the accessories listed as applicable to each piece of equipment in the appropriate Articles in this Section shall be provided and shall be those required for major equipment such as AC and DC switchgear, high and low voltage circuit breakers, rectifier transformers, rectifiers and auxiliaries, station battery and bus ducts. Below lists the expected tools, other than special tools, that are considered necessary for installation, adjustment, testing and maintenance.
 - (i) Box end combination Wrench Set – Metric – Suggested Item Craftsman Model # D818270 or equal.
 - (ii) Box end combination Wrench Set – Standard - Suggested Item Craftsman Model # D818260 or equal.
 - (iii) Socket Set: Metric & standard sockets - Suggested Item Craftsman Model # 34271 or equal.
 - (iv) Screw Driver set - Suggested Item Craftsman Model # 31798 or equal.
 - (v) Adjustable wrench set (large size) - Suggested Item Craftsman Model # 44916 or equal.
 - (vi) Pliers Set - Suggested Item Craftsman Model # 45450 or equal.
 - (vii) Adjustable Pliers - Suggested Item Craftsman Model # 45439 or equal.
 - (viii) Nut driver set & Allen (Hex) Keys - Suggested Item Craftsman Model # SRS358320 or equal.
 - (ix) Leveling Kit – Suggested Item Bosch Model #GLL 2-15 or equal.
 - (x) Vise grips/Locking pliers Set - Suggested Item Sheffield Model # 64002 or equal.
 - (xi) Crimper/stripper - Suggested Item Knipex Model # 97 21 215 or equal.
 - (xii) Wet & Dry industrial Vacuum (large capacity, on casters) - Suggested Item Craftsman Model # 12007 or equal.
 - (xiii) Portable Air Compressor - Suggested Item Craftsman Model # 15215 or equal.
 - (a) Short & long blower air compressor attachments
 - (xiv) Klein Items
 - (xv) Torque wrench – for bolts $\leq 1/2''$ - Suggested Item Klein Model # 57000 or equal.
 - (xvi) Torque wrench – for bolts $> 1/2''$ - Suggested Item Klein Model # 57010 or equal.
 - (xvii) Cat 5 Voice & Data Cable Termination Kit – Suggested Item Greenlee Model #45469 or equal.
 - (xviii) Advanced tool kit for fiber cables – Suggested Item Corning Model # TKT-Fibertech-Pro or equal.
- s. A three-step platform stool with wheels that lock when weight is applied and handrails, as accepted by the MBTA, per substation.

- t. One set per substation of the following substation operator's safety equipment meeting MBTA's safety requirements:
 - (i) Switchman's full length coat with hood (large), 40 calorie/cm² Salisbury Model No. SK40L, or similar as accepted by the MBTA. Complete with storage bag.
 - (ii) Class 2 Rubber gloves kit (large), Rubber, complete with leather hand protectors and storage bag, Salisbury Cat. No. GK214RB11, or similar as accepted by the MBTA.
- u. Touch-up paint as identified for each equipment in each associated Article of this Section shall be provided, per substation.
- v. One heater ammeter of each type per substation.
- w. One lot of load measuring meters, relays, contactors, timers and voltage multipliers or limiters, if used, per substation.
- x. Five (5) LED lamps of each color and five (5) lamp holders, per substation.
- y. Five (5) control switches of each type such as Device CS, 01, 101, 43, and 143, per substation.
- z. DC Circuit Breaker Tester – Supply Receptacle (per substation)
 - (i) A 3 phase, 480 Vac receptacle shall be provided supplied from the 480V distribution panel fitted with a 100A branch breaker.
 - (ii) The 3 phase wall receptacle, rated 100A, with spring loaded cover shall be installed by the DB Entity. Receptacle box to be Appleton #AJS, AJAC, ACP1034DC, or equal and shall be compatible with the 4 pin connector use by the existing DC circuit breakers testers owned by the MBTA.
- aa. AC Cable tester -Supply Receptacle (per substation)
 - (i) A 2 pole wall receptacle, rated 50A, with spring loaded cover shall be installed by the DB Entity. The receptacle shall be NEMA type 10-50R for connecting the MBTA's cable testing device. The receptacle shall be connected to the AC distribution panel in the substation and configured for 208V supply.
- bb. One single phase relay testing unit to test the AC and DC relays associated with the project. The unit shall provide for secondary injection of relays and be able to provide a variable DC supply voltage. Unit to be provided with all required operating instructions and computer software for interfacing with windows based office computers. EUROSMC type PTE-100-C-Plus or approved equivalent shall be provided. The unit shall be available for use, by the MBTA, during testing and commissioning of the first substation if requested.
- cc. One of each of the following piece of test equipment per every four traction power substations:

- (i) Fluke 117/323-KIT Electrician's Combo Kit with Digital Multimeter & RMS Clamp Meter
- (ii) Fluke 1555/KIT Insulation Resistance Tester Kit (10kV)
- (iii) Hipotronics Transformer Turn Ratio test equipment –TTR 2796
- (iv) Fluke VT02 Visual IR Thermometer
- (v) Omicron – CMC 256Plus

dd. DC Circuit Breaker Tester

- (i) Provide a 600 Vdc high current circuit breaker tester for field testing and calibration of the direct acting magnetic devices. This trip device is the primary protection for the traction power feeder breakers and therefore a safety critical aspect of the equipment. One tester per for every four traction power substations is required.
- (ii) ANSI standard C37.17, applicable for this testing is vague in regards to field testing. The acceptable tolerance for field testing is that the trip current must fall within 10% of the marked scaled setting.
- (iii) The breaker tester must be compatible with DC circuit breakers presently available. The breaker tester must also provide an output that will not produce inaccurate results when used to test circuit breakers manufactured by ABB, Myers, Whipp & Bourne, Siemens or GEC which are currently in use on the MBTA system. The intent is to have a DC circuit breaker tester which can be used to test the majority, if not all, of the MBTA DC circuit breakers.
- (iv) As a minimum, the DC circuit breaker tester shall provide an output current suitable to test the breakers provided under this Contract. The test unit shall have a minimum output of 20 kA for 1 second and shall satisfy the circuit breaker suppliers' recommendation for appropriate testing of their equipment.
- (v) The DC breaker tester shall comprise a variable high current output power and regulator unit(s), and a control unit housing control circuitry, instrumentation, overcurrent, thermal and ground fault protection, and a high accuracy digital output ammeter and timer. Phenix HC20C or approved equal will be acceptable.
- (vi) The tester shall be operated from a 3 phase, 480 Vac input. Maximum expected continuous input current shall be provided by the DB Entity.
- (vii) The tester shall be provided with two 25' supply cables fitted with Appleton 4 pin connectors. A 100A, 3 phase wall receptacle with spring loaded cover shall be installed by the DB Entity. Receptacle box to be Appleton #AJS, AJAC, ACP1034DC, or equal and shall be compatible with the 4 pin connector provided with the test unit.
- (viii) The tester must be portable, include lifting hooks and proper moving instructions.
- (ix) The DB Entity shall submit the proposed DC high current circuit breaker for acceptance by the MBTA. Details provided shall include current output capability, weights, accuracy of metering, dimensions, input supply requirements, accessories provided and harmonic distortion data.

- (x) Two full sets of operating and maintenance instructions must be provided. One set shall be provided with the breaker tester, the other set shall be submitted to the MBTA for review and acceptance.
- (xi) The DC high current breaker tester shall be delivered to the substation prior to substation commissioning.
- (xii) After arrival on-site and prior to the substation entering service, the DB Entity shall provide training on the use of the tester. The training shall occur on-site using the DC high current breaker tester provided and shall be set up for two classes with up to four Engineers attending each class. The DB Entity shall submit the proposed training procedure and schedule to the MBTA for review and acceptance.
- (xiii) Warranty: The DC high current breaker tester shall be provided with a manufacturer's warranty for a minimum period of one year from the date of the first training class.

PART 3 - EXECUTION

3.1 GENERAL

- A. The DB Entity shall install all equipment specified in this Section in accordance with requirements of this Section, DB Volume 1, Contract Terms and Conditions, and the DB Entity's accepted Shop Drawings, with MBTA-accepted changes only, if any. DC traction feeder positive and negative return cables and DC traction power disconnect switches shall be installed in accordance with Section 16126. Low voltage power and control wiring installation including installation of required conduit and fittings, cable trays, junction, pull and terminal boxes and related materials shall be in accordance with Section 16050. The completed installation shall provide fully coordinated and fully operational electrical system.
- B. The DB Entity shall take every precaution in handling, setting, aligning and assembling the equipment to avoid distortion of frames. The DB Entity shall become thoroughly familiar with the manufacturers' instructions before attempting to handle, install and operate the equipment. The DB Entity shall ensure that all personnel working with the equipment fully understand the operation of the various components to avoid mis-operation, damage to equipment and possible personnel injury.
- C. All equipment assembly connections to mechanically assemble the units shall be made by the DB Entity, including all bolted connections between shipping units, between equipment and bus duct enclosures and anchoring the equipment to the floor.
- D. All electrical connections between shipping units, including all bolted bus connections and connections of control and auxiliary circuits, shall be made by the DB Entity.
- E. Conduits, cable trays and cables for control and auxiliary circuits for interconnecting equipment and devices of this Section are not all shown on the Design Documents. The DB Entity shall determine the routing of these cables and raceways as required to satisfy all specified control, indication, supervisory and auxiliary functions. The DB Entity shall ensure that the specified cable entry locations identified in the equipment specifications, this Section, are complied with. Installation of cables shall be in accordance with DB Entity-prepared and MBTA-accepted cable schedules, routing diagrams and installation drawings. Cable trays directly above the area

of the epoxy insulated floor, above the traction rectifiers and above the DC switchgear shall be fiberglass.

- F. The DB Entity shall make all ground connections to the equipment from the ground buses in the substation as described in this Section and shown on the Design Documents.
- G. All structural steel members used for support of electrical equipment and materials to be furnished shall be hot-dip galvanized in accordance with ASTM A153.
- H. Complete installation shall be tested and checked out in accordance with Article 3.03 of this Section and as specified in other applicable Articles of this Section.
- I. The DB Entity shall be responsible for all equipment during transportation, delivery and installation. All equipment shall be suitably packaged at all times meeting the requirements of the equipment manufacturers. Equipment packaged for transport and storage shall be protected from damage due to environmental conditions and properly secured. 'Shockwatch' labels shall be applied to all main equipment during transport. Where necessary equipment shall be heated or stored in a controlled environment during storage. Any signs of equipment deterioration or damage during shipping or storage shall be rectified to the satisfaction of and at no expense to the MBTA.

3.2 INSTALLATION

A. 15 kV AC Switchgear

- 1. The 15 kV switchgear shall be fully assembled and completely installed in accordance with manufacturer's instructions at the location shown on Design Documents.
- 2. Switchgear base channels, furnished with the switchgear, shall be installed in the floor slab by the DB Entity. The switchgear units shall be anchored to the base channels with a sufficient number of bolts to withstand impact resulting from breaker operation and to satisfy the seismic requirements specified in Article 1.03 of this Section. All bolts required for anchoring the switchgear shall be furnished by the DB Entity.
- 3. Switchgear units shall be assembled in such a manner as to ensure proper leveling, proper alignment between the various shipping groups, and proper placement of all primary circuit conduits installed for purposes of equipment interconnection.
- 4. Breaker test cabinet shall be installed at the location shown on the Design Documents. A clear space of 1/4", minimum, shall be provided between the back of the cabinet and the wall. Steel channels or straps, or equal of suitable thickness shall be fastened to the masonry and be drilled and tapped for mounting the test cabinet using galvanized bolts. The DB entity shall furnish, install and connect the 125 volt DC control supply wiring from a dedicated circuit breaker in the DC distribution panel.
- 5. The DB Entity shall furnish and install 120V AC and 125V DC auxiliary circuits as required from dedicated circuit breakers in the AC and DC distribution panels.
- 6. After completion of switchgear installation, the DB Entity shall ensure that all doors and the drawout fuse and PT carriages operate freely and the breaker removable elements and the ground and test device can be moved into and removed from the housings easily in a

controlled and consistent manner. The DB Entity shall correct all misalignments to the satisfaction of the MBTA.

B. Rectifier Transformers

1. Rectifier transformers shall be fully assembled and completely installed in accordance with manufacturer's instructions at locations shown on the Design Documents.
2. Low voltage terminals of the transformers shall be connected to the non-segregated phase bus duct as specified in Article 2.05 of this Section.

C. Rectifiers and Accessories

1. Rectifier units shall be fully assembled and completely installed in accordance with MBTA's accepted manufacturer's drawings at locations shown on the Design Documents.
2. Insulated anchors, furnished with the rectifiers, shall be installed in the floor slab and tested by the DB Entity in accordance with manufacturer's instructions and Section 09671. The floor and wall area at the rectifier units and surrounding area as shown on the Design Documents shall be covered with a layer of epoxy insulating material by the DB entity, to insulate the rectifier enclosures from the building structure (see Section 09671). The adjacent building structure, as applicable, may be insulated using fiberglass sheets. Sheets shall be flame retardant, low smoke and provide electrical insulation to a minimum of 1000V. The insulation shall be installed from the floor up to the height of the substation lighting or minimum of 3' above the highest point of the equipment whichever is higher. Care shall be taken that the insulated floor area is not scraped or otherwise damaged during installation. All fastening hardware required for anchoring the rectifier units shall be furnished by the DB Entity. After completion of the installation the rectifier enclosures shall be completely insulated from the building structure. The installation of rectifiers shall satisfy seismic requirements specified in Article 1.03 of this Section.
3. Rectifier units shall be connected to the rectifier transformers via the AC anode buses and to the rectifier DC main circuit breakers in the DC switchgear via the positive cathode buses as specified in Article 2.05 of this Section. Rectifier negative terminals shall be connected to the negative equalizer bus and drainage board, specified in Article 2.06 of this Section, via the negative cathode buses.
4. The DB Entity shall furnish and install 120V AC and 125V DC auxiliary circuits as required from dedicated circuit breakers in the AC and DC distribution panels.

D. DC Switchgear

1. DC switchgear shall be fully assembled and completely installed in accordance with MBTA's accepted manufacturer's drawings at location shown on Design Documents.
2. Insulated anchors, furnished with the DC switchgear, shall be installed in the floor slab and tested in accordance with manufacturer's instructions by the DB Entity and Section 09671. The floor and wall area at the DC switchgear and surrounding area, as shown on the Design Documents, shall be covered with a layer of epoxy insulated material by the DB Entity to insulate the switchgear enclosure from building structure (see Section 09671). The adjacent building structure, as applicable, may be insulated using fiberglass sheets. Sheets shall be

flame retardant, low smoke and provide electrical insulation to a minimum of 1000V. The insulation shall be installed from the floor up to the height of the substation lighting or minimum of 3' above the highest point of the equipment whichever is higher. Care shall be taken that the insulated floor area is not scraped or otherwise damaged during installation. All fastening hardware required for anchoring the switchgear shall be furnished by the DB Entity. After completion of the installation, the DC switchgear structure shall be completely insulated from the building structure. The installation of switchgear shall satisfy seismic requirements specified in Article 1.03 of this Section.

3. The switchgear units shall be assembled in such a manner as to ensure proper leveling, proper alignment between the various shipping groups, and proper placement of all the conduits and cable trays that are required for equipment interconnection. The DB Entity shall make all necessary electrical connections between the units of the assembly, including the joints in the 750 Volt positive bus.
4. The rectifier main DC circuit breakers shall be connected to the rectifiers via the positive cathode buses as specified in Article 2.05 of this Section.
5. The DB Entity shall furnish and install 120V AC and 125V DC auxiliary circuits as required from dedicated circuit breakers in the AC and DC distribution panels.
6. The DC circuit breaker test cabinet shall be installed at the location shown on the Design Documents. A clear space of ¼", minimum, shall be provided between the back of the cabinet and the wall. Steel channels or straps, or equal, of suitable thickness shall be fastened to the masonry and tapped and drilled for mounting of the test cabinet using galvanized machine bolts. The DB Entity shall furnish, install the 125V DC control supply wiring from a dedicated circuit breaker at the DC distribution panel.
7. After completion of the installation, the DB Entity shall ensure that all doors operate freely and the breaker removable elements can be moved into and removed from the housings without encountering a change of elevation from within the housing to the floor. The DB Entity shall correct all misalignments to the satisfaction of the MBTA.

E. AC Bus Duct and DC Bus

1. The bus ducts interconnecting the rectifier transformer and rectifier equipment shall be fully assembled and completely installed in accordance with MBTA's accepted manufacturer's plan and detail drawings as shown on the Design Documents.
2. Bus ducts shall be provided with suitable mounting hangers supported from the ceiling slab or structural members, or as directed by the MBTA. DB Entity shall furnish and install all strut assemblies, brackets, rods, clamps, suspension fittings and miscellaneous steel to provide a complete, firm and rigid support system for the bus ducts under all operating conditions and during short circuits. Supports shall be designed and installed in a manner to minimize induced circulating currents and induced magnetic heating.
3. All ferrous elements of the support system shall be hot dipped galvanized in accordance with ASTM A153. Hangers supporting rectifier positive cathode buses and ungrounded portions of anode and cathode negative buses shall be provided with approved insulators to insulate the bus enclosures from the building structure.

4. Bus duct shall be assembled in such manner as to ensure proper alignment between the shipping sections and the associated equipment. After alignment and leveling, the bus enclosure shall be bolted to the equipment and then the enclosure splice plates shall be attached and securely fastened.
5. Insulated bus enclosure sections shall be installed as identified in Article 2.05 of this Section.
6. Before electrical connections are made, all contact surfaces shall be wiped clean (sandpaper or abrasive tools shall not be used) and covered with a coat of approved electrical antioxidant compound. Joints in bus conductors shall be made using splice plates on each side of the conductor. Connections to equipment terminals shall be made with flexible connectors as specified in Article 2.05 of this Section. All joints shall be made with a minimum of 4-½” silicon bronze bolts and nuts. All nuts shall be provided with approved locking devices. All bolts shall be tightened to the torque of 40 foot-pounds, or as required by the MBTA, using an accurate torque wrench.
7. After completion, all joints shall be covered by die-molded, flame retardant polyvinyl chloride boots, or approved equal providing full voltage insulation for the joint. These boots shall be easily removable for inspection of the joint without destruction of the boot.

F. Negative Equalizer Bus and Drainage Board

1. The negative equalizer bus and drainage board shall be fully assembled and completely installed in accordance with MBTA’s accepted manufacturer's drawings at the location shown on the Design Documents.
2. The enclosure shall be fastened to the floor slab using a sufficient number of machine bolts and expansion anchors provided by the DB Entity to satisfy the seismic requirements as specified in Article 1.03 of this Section.
3. The negative bus shall be connected to the rectifiers via the negative cathode busduct as specified in Article 2.05 of this Section. The negative busduct enclosures shall be accurately aligned and leveled for proper attachment to the negative equalizer bus enclosure.
4. The DB Entity shall furnish and install 120 Vac and 125 Vdc auxiliary circuits as required from dedicated circuit breakers in the AC and DC distribution panels.

G. 15 kV Circuit Breaker Control and Instrument Panel

1. The 15 kV circuit breaker control and instrument panel shall be completely assembled and installed in accordance with MBTA-accepted manufacturer's drawings at the location shown on Design Documents.

H. Station Battery, Charger and Accessories

1. Battery racks shall be assembled in accordance with manufacturer's instructions at location shown on the Design Documents. The individual rack members shall be firmly bolted together to form rigid structures. Battery cell jars shall be mounted on plastic rails and provided with restraining rails for earthquake protection.

2. Each battery cell on the racks shall be numbered with approved, clearly visible numerals as required in Article 2.08.B of this Section. Numbering shall start from battery positive terminal.
3. The DB Entity shall remove the battery cells from shipping containers and inspect each cell for damage. If electrolyte has been lost in transit and the level is higher than 1/2" below top of plates, the DB Entity shall top off the cells with manufacturer's approved electrolyte. Cells with electrolyte level lower than 1/2" below top of plates shall be replaced by the DB Entity.
4. Cell jars shall be set on rack with plates at right angles to the rails. Jars shall be spaced on the rack so that the intercell connectors can be installed without stressing the cell posts. All current carrying surfaces shall be scraped bright and clean and covered with a thin film of approved electrical grease. Bolts shall be tightened to proper tension and the surplus grease wiped off. After completion of all connection, the polarity of each cell shall be checked with a voltmeter.
5. The DB Entity shall install the power supply-battery charger unit at location shown at Design Documents, or as required by the MBTA. Unit shall be fastened to the floor using approved expansion anchors.
6. The DC distribution panel shall be installed at the locations shown on the Design Documents. A clear space of 1/4", minimum, shall be provided between the back of the panel and the wall. Steel channels or strips, or equal, of suitable thickness shall be fastened to the masonry and drilled and tapped for mounting the panel using galvanized machine bolts.
7. After the completed installation is tested and checked out in accordance with all applicable portions of Article 3.03 of this Section, the battery shall be given a freshening charge to assure that all cells are fully charged.
8. Install battery monitoring system in accordance with manufacturers' instructions.

I. Supervisory Equipment

1. The SCADA supervisory system shall be integrated in the substation in accordance with MBTA accepted manufacturer's drawings at the location shown on Design Documents. The DB Entity shall be responsible for programming both the supervisory master unit and the substation SCADA/SAS units.
2. The RTUs shall be fastened to the floor slab with a sufficient number of machine bolts and expansion anchors to satisfy the seismic requirements as specified in Article 1.03 of this Section.
3. Telephone circuits for communication and data transfer between the substation SCADA and backup RTUs and master terminal equipment will be provided and installed by others. These lines will be terminated with surge protection devices provided and installed by others. Extensions of these lines from the surge protectors to the RTU equipment shall be furnished, installed and connected by the DB Entity.
4. A qualified technical representative from the equipment manufacturer shall be provided by the DB Entity to assist in proper installation and interfacing of the supervisory equipment.

J. Substation Automation System (SAS)

1. The SAS and all associated components shall be completely assembled and installed in accordance with MBTA-accepted manufacturer's drawings at the location shown on the Design Documents.

3.3 TESTS

A. General

1. All equipment to be furnished and installed shall be subject to the following test program. Testing shall include factory tests and field tests.
2. The DB Entity shall formulate an overall test program for all equipment furnished under this Section, which shall include but not be limited to the tests specified in this Section, to ensure equipment compliance with the relevant standards, all requirements of this Section, and satisfactory and reliable performance in intended operation. The overall test plan and expected schedule for testing should be submitted to the Project for review and acceptance at least four weeks prior to the first expected factory test. All factory tests shall be identified in the overall test plan, and all tests shall be offered for witnessing in accordance with article 3.03.B below.
3. The DB Entity shall furnish detailed, step-by-step test procedures for each factory and field test. The test procedures shall be submitted for acceptance by the MBTA in accordance with article 3.03.B.1 below. Blank sample test record and result sheets shall be included for acceptance. Where applicable, test pass/fail criteria shall be included in the test procedure and check off boxes shall be provided to indicate when each step has been successfully performed.
4. The DB Entity shall maintain a consolidated factory and field testing punch list listing all items requiring repair, further testing and steps omitted for execution at a later date. All factory test punch list items must be addressed and the MBTA notified of such prior to the Equipment being released from the manufacturer's premises. All punchlist items shall be resolved to the satisfactory of the MBTA prior to equipment handover to the MBTA.
5. Tests at the factory shall include but not be limited to:
 - a. Manufacturer's standard tests.
 - b. Tests as listed in Article 3.03.C of this Section.
 - c. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Article 3.03.C of this Section.
 - d. Any other tests to ensure satisfactory performance of equipment (including 'mock-up' tests of the substation automation system)
6. Tests in the field shall include but not be limited to:
 - a. Tests as listed in Article 3.03.D of this Section.

- b. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Article 3.03.D of this Section.
 - c. Acceptance tests as per current NETA acceptance testing specifications.
 - d. Any other tests to ensure satisfactory performance of equipment, including full detailed functional tests specific to the operational requirements of the equipment detailed in this specification and in Section 16311A.
7. The DB Entity shall meet the requirements in Article 3.03.B of this Section, for testing and shall furnish certified test reports as specified in Article 3.03.E of of this Section for obtaining clearance for packing and shipment of equipment tested.

B. Conditions for Tests

1. General Conditions

- a. Prior to testing of any equipment specified in this Section, all of the following conditions shall be fulfilled by the DB Entity:
 - (i) The DB Entity has made the "For Record" submittal of shop drawings of the equipment scheduled for testing to the MBTA. Please note that the "For Record" submittal shall be made only after the previous submittal has been accepted by the MBTA.
 - (ii) The DB Entity-prepared test plan and detailed step by step test procedure has been submitted to and accepted by the MBTA.
 - (iii) Upon completion of (1) and (2) above, a minimum of four weeks advance notification shall be given to MBTA on the scheduled date of tests to enable them to witness the tests.

2. Witnessing Tests

- a. MBTA will witness complete testing of all equipment unless a waiver is granted, in which case test reports of equipment, and associated cleared punch list, for which waiver was granted shall be submitted for review to obtain clearance for packing and shipping. Waiver of witnessing tests on any one piece equipment shall not be construed as a waiver for all remaining equipment either of the same type or different type.
- b. Prior to witness testing, the supplier shall have previously tested the equipment to prove compliance with the test procedure and equipment requirements. A copy of these completed test documents should be made available to the MBTA for review prior to the witness testing.

3. Responsibility

- a. The DB Entity shall assume full responsibility during the factory and field testing of all equipment and installation provided by the DB Entity. Should there be any loss or damage to such equipment, materials or the building as result of these tests, the DB Entity shall be fully responsible for replacing the damaged equipment and repairing the

building. Replacement of damaged equipment shall include all costs, including but not limited to, transportation of, and installation and testing of replacement equipment.

4. Rejection and Re-testing

- a. Failure of equipment to withstand tests or to meet specified ratings or requirements shall be sufficient grounds for rejection of equipment.
- b. Any equipment rejected shall be re-tested in presence of the MBTA, and/or his representative, after rectification. If the modifications or changes are such as to affect any of the drawings, diagrams or any other documents submitted and accepted by the MBTA, revised drawings of diagrams shall be submitted, showing proposed changes and MBTA's acceptance obtained before changes or modifications are made on the equipment. Modification or changes which do not warrant revision of any drawing, shall be furnished to the MBTA along with notice of re-testing.
- c. If it is not possible to rectify rejected equipment, new equipment shall be manufactured and the requirements of the drawings and design calculations of the original unit shall be applicable for the new unit.

5. Cost of Rectification or New Unit

- a. The entire cost of rectification or new unit shall be borne by the DB Entity including retesting and cost of witnessing retesting.

6. Costs of Tests

- a. The price for conducting all factory and field tests and witness testing in presence of the MBTA, and/or his representative, including entire cost of rectification, re-testing and supplying new unit(s), shall be deemed to be included in the Contract Price. The expense related to travel, lodging and boarding for the MBTA and/or his representative for witnessing of test will, however, be borne by the MBTA at no expense to the DB Entity, except when re-testing is required. In the latter case, all expenses for travel and lodging will be borne by the DB Entity as directed by the MBTA. In the event a second retest is required for the same equipment, the DB Entity shall bear, in addition to the above costs, the cost of all meals and the hourly payroll costs, including overhead and fringe benefits of the MBTA and/or his representative(s) attending the retest.

C. Factory Tests

1. General

- a. If facilities for conducting any of the tests listed below are not available at manufacturer's plant, these tests shall be conducted elsewhere by manufacturer or by an independent agency as accepted by the MBTA. The DB Entity shall, however, clearly indicate in the DB Entity's proposal the tests for which manufacturer does not have facilities and intends to submit test reports from an independent agency. This should also be clearly identified in the overall test plan as required in article 3.03.A.2 above.

2. 15 kV Switchgear

- a. The following tests listed in ANSI C37.09 as "Design Tests" shall be conducted on one 15 kV class representative circuit breaker with the circuit breaker inserted in its housing:
 - (i) Maximum voltage tests
 - (ii) Power frequency tests
 - (iii) Continuous current carrying tests
 - (iv) Dielectric withstand tests
 - (a) Power frequency withstand voltage tests
 - (b) Lightning Impulse withstand voltage tests
 - (v) Standard operating duty tests
 - (vi) Interrupting time tests
 - (vii) Transient recovery voltage tests
 - (viii) Short-circuit current interrupting tests
 - (ix) Load current tests
 - (x) Capacitor switching current tests
 - (xi) Mechanical endurance tests
 - (xii) Control voltage tests
 - (xiii) Design tests on pressurized components
 - (xiv) Sealed pressure systems leakage tests
 - (xv) Radio influence voltage tests as per NEMA SG4
- b. Following tests listed in ANSI C37-09 as "Design Tests" for high voltage circuit breakers shall be conducted on the ground and test device of the 15 kV switchgear, with the ground and test device inserted in the switchgear:
 - (i) Maximum voltage tests
 - (ii) Power frequency test
 - (iii) Short-circuit current interrupting tests to establish the closing and latching capability, applying the short-circuit test supply between the line terminals of the ground and test device and the switchgear ground bus
 - (iv) Momentary current test, applying the test supply between the line terminals of the ground and test device and the switchgear ground bus
 - (v) Dielectric withstand tests:
 - (a) Power frequency withstand voltage test
 - (b) Lightning Impulse withstand voltage test
- c. Following tests listed in ANSI C37.09 as "Production Tests" shall be conducted at the manufacturer's facility on each and every 15 kV class circuit breaker and ground and test device:
 - (i) Current and linear coupler transformer tests
 - (ii) Nameplate check

- (iii) Resistors, heaters, and coil check tests
 - (iv) Control and secondary wiring check tests
 - (v) Clearance and mechanical adjustment check tests
 - (vi) Mechanical operation tests
 - (vii) Timing tests (not required for ground and test device)
 - (viii) Stored energy operating mechanism tests
 - (ix) Power frequency withstand voltage tests
- d. Following tests listed in ANSI C37.20 and NEMA SG5 as "Design Tests" shall be conducted on the 15 kV metal-clad AC switchgear assembly:
- (i) Dielectric tests
 - (a) Power frequency withstand tests
 - (b) Lightning Impulse withstand tests
 - (c) Test of busbar insulation
 - (ii) Rated continuous current tests
 - (iii) Momentary current tests
 - (iv) Mechanical operation tests
 - (v) Flame-retardant tests
- e. Following tests listed in ANSI C37.20 and NEMA SG5 as "Production Tests" shall be conducted at the manufacturer's facility on the 15 kV metal-clad AC switchgear assembly:
- (i) Mechanical operation tests
 - (ii) Grounding of instrument transformers cases test
 - (iii) Electrical operation and control wiring tests
 - (a) Control wiring continuity test
 - (b) Control wiring insulation test
 - (c) Polarity tests
 - (d) Functional and sequence tests
 - (iv) Checking of indicating instruments and transducers at zero, midpoint and full scale or full output
 - (v) Nameplate check
- f. In lieu of Design Tests specified above for AC circuit breakers and AC switchgear assembly, the DB Entity may submit detailed test certificates from the manufacturer or an independent agency conducted on similar circuit breakers and similar switchgear assemblies for MBTA's review. The MBTA may waive some or all of the tests at his discretion.

3. Rectifier Transformer

- a. The following tests shall be conducted at the manufacturer's facility on one rectifier transformer:
- (i) Temperature rise tests: Tests to determine that the winding temperature rise is within the permissible limits after delivering full load continuously plus fulfilling the additional specified duty cycle. For this purpose, manufacturer shall determine the temperature rise of the windings by resistance after applying the specified two hour load cycle to a transformer which has already attained steady state temperature rise at 100 percent continuous load. Dissolved Gas Analysis (DGA) tests shall be performed in accordance with ANSI C57.104 before the temperature rise test, and immediately after each test.
 - (ii) A demonstration of hottest spot temperature rise for the extra heavy traction service duty cycle shall be required of one transformer for essentially identical units with results that are consistent with the requirements of IEEE C57.18.10. The maximum allowable hottest spot temperature rise shall not cause insulation loss of life. Actual or calculated hot spot temperature rise during this extra heavy traction service test cycle shall be measured/calculated and recorded in the certified transformer test report for use by the MBTA. Furthermore, the manufacturer shall inform the MBTA of any other factor than may limit the rating of the transformer for the application noted herein.
 - (iii) Impedance and load loss tests at 100 percent and 150 percent of rated current on the rated voltage connection of the unit, and at 100 percent (ONAN rating) at all De-energized Tap Changer positions.
 - (iv) Commutating reactance and resistance test as per ANSI C57.18.10.
 - (v) Full design impulse test at ambient temperature on all transformer terminals. Test shall consist of reduced full wave, two chopped waves and a full wave of 110 kV on the HV and 45 kV on the LV windings. The resulting oscillograph records of the applied voltage and neutral current traces shall be submitted with the test reports.
 - (vi) Audible sound level test in accordance with C57.12.00 and C57.12.90. The audible sound level test of rectifier transformer shall be conducted at no load, nominal tap, with the transformer energized at rated voltage and frequency.
- b. The following tests listed in ANSI C57.12.90, ANSI C57.18.10 and ANSI C34.2 shall be performed at the manufacturer's facility on each rectifier transformer:
- (i) Resistance measurements on all windings on the rated voltage connection and at all taps.
 - (ii) Ratio tests on the rated voltage connection and on all tap connections.
 - (iii) Polarity and phase-relation tests on the rated voltage connection.
 - (iv) Excitation current loss test at rated voltage on the rated voltage connection.
 - (v) Excitation current test at rated voltage and frequency on the rated voltage connection.

- (vi) Dielectric tests:
 - (a) Applied voltage
 - (b) Induced voltage
 - (c) Insulation resistance
- (vii) Partial discharge test
- (viii) Nameplate check

4. Rectifier

- a. The following tests listed in ANSI C34.2 shall be performed on one rectifier:
 - (i) Rated current test
 - (ii) Harmonic analysis test which shall be performed on the AC input and DC output circuits.
 - (iii) Audible sound level test, in accordance with IEEE C57.12.91 but applied to a rectifier, rather than a transformer. The audible sound level test of the rectifier shall be conducted at no load with the rectifier energized at rated voltage and frequency.
 - (iv) Reduced voltage, 160 percent full load current balance test. With load on and temperature stabilized, measure temperature of ambient air in and air out of the rectifier unit, temperature of each of four selected diodes and their associated heat sinks using same positions on each unit and current in each diode.

Note: Increase current by 7 percent waveform and conduction angle adjustment factor to compensate for loadings by reduced voltage and short circuit.

- b. The following production tests specified in ANSI C34.2 shall be performed on each rectifier at the manufacturer's facility:
 - (i) Dielectric tests
 - (ii) Rated voltage test and efficiency
 - (iii) Rectifier loss tests
 - (iv) Rectifier balance test at 100% load
 - (v) Additional manufacturer's standard tests
 - (vi) Functional tests
 - (vii) Nameplate check

5. Rectifier Surge Voltage and Short Circuit Tests

- a. The following tests shall be conducted on one rectifier package consisting of the rectifier transformer, rectifier and interconnecting bus ducts, and 15 kV test circuit breaker provided by the DB Entity, all assembled in line. Test setups shall include primary supply system having minimum 150 MVA short circuit capacity, protective devices adjusted to provide pick-up values and operating times conforming to those proposed for final installation, shunts, properly calibrated meters and recording oscillographs, shorting devices, loading devices and other associated appurtenances as may be required. The 13.8 kV circuit connecting the AC circuit breaker to the rectifier transformers shall consist of 50' of 3-1/c 350kcmil cables, or a circuit having equivalent surge impedance. Tests specified other than the short circuit tests, may be carried out at less than 150 MVA test supply.
- b. Open circuit test to ensure ability to withstand transient surge voltages in steps as follows:
 - (i) Energize transformer and rectifier at rated voltage and no load by closing rectifier AC breaker.
 - (ii) De-energize transformer and rectifier by tripping rectifier AC circuit breaker.
 - (iii) Record voltage wave forms and amplitudes at AC circuit breaker line side terminals, rectifier transformer high and low voltage terminals, rectifier output terminals and at critical points in surge protection network during close and trip operation.
 - (iv) Repeat test a minimum of ten times to ensure maximum transient.
 - (v) Maximum crest of transient surge voltages at AC circuit breaker terminals and rectifier transformer high voltage terminals shall not exceed the value specified in Article 2.02 of this Section for the rectifier transformer bushings.
 - (vi) Maximum crest of transient surge impressed on rectifier shall not exceed 75 percent of the voltage withstand rating of the diodes.
- c. Short circuit test to determine short circuit current in steps as follows:
 - (i) Energize the transformer and rectifier at rated voltage with no load.
 - (ii) Short rectifier output terminals with shorting device.
 - (iii) Clear short (bolted fault) by tripping the rectifier AC circuit breaker by its protective devices.
 - (iv) Record current waveform and amplitude at rectifier output terminals during shorting operation.
 - (v) Calculate theoretical values of peak and sustained short circuit currents for rated voltage fault on a system having maximum and minimum available short circuit MVA and X/R ratios as provided in the Service Condition Article 1.06.B of this Section. Calculate theoretical transformer overvoltage and the test supply system X/R ratio required to obtain a minimum of these values on actual test set-up for the maximum and minimum MVA levels specified above.

(vi) Repeat short circuit test with transformer energized at theoretical overvoltage and the X/R ratio of the test supply system adjusted to the value calculated above. Continue to adjust voltage until calculated peak and sustained values of current are realized.

d. Determine the commutating reactance and resistance of the rectifier package so the voltage regulation may be calculated to ensure compliance with output voltage characteristics set forth in Article 2.03.D of this Section. Proof shall be provided by the DB Entity that methods proposed for measurement of commutating reactance and resistance are accurate and valid to the complete satisfaction of the MBTA. Failing acceptable proof, the DB Entity shall perform a voltage regulation test by actual loading of the rectifier package in a method to be specified by the MBTA.

6. Rectifier Current Unbalance and Load Current Tests

a. The following test shall be conducted on one rectifier package, including the rectifier transformer, rectifier and interconnecting bus ducts, assembled in line. Test set-up shall include necessary supply and loading systems, including switchgear and protective devices, air handling system with temperature controlled at 105°F, shunts, thermocouples, properly calibrated meters, and associated appurtenances as may be required. Reduced voltage and reduced capacity supply system will be acceptable for certain portion of these tests providing currents specified are increased by 7 percent wave form and conduction angle adjustment factor to compensate for loading by short circuit. Individual silicon diode junction temperatures shall not exceed design values established in DB Entity's load and short circuit calculations as determined from actual case temperature, using DB Entity's junction versus case temperature data.

b. Current balance/unbalance test to ensure compliance with requirement for current balance between paralleled legs in each phase in steps as follows:

(i) Apply 100 percent full load current and measure diode currents in each paralleled leg in each phase.

(ii) Remove one fuse in one leg of each phase so as to create maximum diode current unbalance; then apply 100 percent full load current and measure diode currents in remaining legs on each phase.

(iii) With one fuse removed in one leg of each phase, as in test above, apply 150 percent full load current for two hours, superimpose five one-minute overloads of 300 percent full load current and one 15-second overload of 450% full load current as specified in Article 2.03.D of this Section, and measure diode current in the leg which had maximum current in test with 100 percent load current.

c. Load current test to ensure compliance with rectifier current rating and ability of rectifier to withstand short circuit under load in steps as follows:

(i) With one fuse removed in one leg of each phase as in test above, apply 100 percent full load current until constant diode temperature is reached.

(ii) Apply 150 percent full load current for two hours immediately after completion of test above with 100 percent full load current.

- (iii) Superimpose five one-minute overloads of 300 percent full load current followed by one 15-second of 450% full load current per Article 2.03.D of this Section, during the step described above.
 - (iv) Apply the highest value of short circuit obtained in the short circuit tests identified above, duration of short circuit to be the operating time of the short time relays and ac breaker opening time, as soon as practical after the application of the 450% load, expected to be within one minute.
 - (v) Record load current, ambient air temperature, supply air temperature, discharge air temperature, transformer winding hot-spot temperature, and diode case temperature in leg having maximum current unbalance at sufficiently close time intervals to provide accurate current-time-temperature relationship.
 - (vi) Monitor rectifier commutation with oscilloscope during two hour test loadings set forth in test above to ensure normal operation. If possible, photograph trace or rectifier input voltage wave forms.
 - (vii) The above-specified current balance test and load current test may be conducted at a lower ambient temperature and the results interpolated for the specified ambient of 105 degrees F. Supporting data and calculations shall be submitted, together with the test results, to the MBTA for review and acceptance.
- a. The DB Entity may propose to combine some of the rectifier package tests identified above. The proposed combination of tests shall be submitted for acceptance by the MBTA but shall not omit any of the requirements identified.

7. 750 Vdc Switchgear

- a. The following tests listed in ANSI C37.14 as "Design Tests" shall be conducted on one representative DC circuit breaker of each rating:
- (i) Dielectric withstand test
 - (ii) Continuous current test
 - (iii) Load (low) current switching tests
 - (iv) Short-circuit current interrupting test: The short circuit current test value and X/R ratio shall be for the substation with the highest available short circuit current, and the equivalent of all substation rectifiers feeding the DC bus (refer to paragraph 1.06.B of this Section). The fault shall be between the load side terminals of the feeder breaker and the substation negative bus. The DC power source shall preferably be from silicon diode bridge rectifiers. MBTA's acceptance shall be obtained prior to testing if other sources of supply are to be used. Previous test certifications may be proposed, subject to acceptance by the MBTA, in lieu of repeating this test if they equal or exceed the MBTA system capacity as identified above.
 - (v) Endurance tests

- (a) Electrical endurance test
 - (b) Mechanical endurance test
- b. The following tests listed in ANSI C37.14 as "Production Tests" shall be conducted at the manufacturer's facility on each and every DC circuit breaker:
- (i) Calibration test on the individual direct acting trip device prior to final assembly
 - (ii) Control and secondary wiring check test
 - (iii) Dielectric withstand test
 - (iv) Mechanical operation test
 - (v) Calibration test on fully assembled circuit breakers
 - (a) Direct acting trip devices - The percent error for trip currents versus the calibration marks on the device and the repeatability errors must be within the tolerances specified in ANSI C37-17 for direct acting trip devices.
 - (b) Undervoltage trip device
 - (vi) Manufacturer's standard tests not included in the above tests.
 - (vii) Checking of indicating instruments and transducers at zero, midpoint and full scale or full output.
- c. The following tests listed in ANSI C37.20 as "Design Tests" shall be conducted on the DC switchgear assembly.
- (i) Dielectric tests
 - (ii) Rated continuous current tests
 - (iii) Momentary current tests
 - (iv) Short circuit withstand test
 - (v) Flame-retardant tests
- d. The following tests listed in ANSI C37.20 as "Production Tests" shall be conducted at the manufacturer's facility on the DC switchgear assembly:
- (i) Mechanical operation tests
 - (ii) Electrical operation and control wiring tests
 - (a) Control wiring insulation test
 - (b) Polarity tests

- (c) Sequence tests, including operation of load measuring scheme with actual voltages and currents applied. Sequence tests shall be made with breakers in "test" position also with breaker in "connected" position.
- (d) Tests to prove the operation of all devices and indicating instruments, including protective relays, at all settings.
- (e) Check indicating instruments, transducers and isolation amplifiers at zero, midpoint and full scale or full output.

(iii) Nameplate check

8. Bus Duct

- a. Following tests shall be conducted at the manufacturer's facility on one unit of each rating as specified under "Design Tests" in ANSI C37.23 for metal enclosed bus:
 - (i) Dielectric tests
 - (a) Power frequency withstand
 - (b) Impulse withstand
 - (ii) Temperature rise tests
 - (iii) Momentary current tests
 - (iv) Electrical operation and control wiring tests
- b. In addition, the temperature rise test as described below shall be conducted on one representative anode bus duct.
 - (i) Measure temperature rise of bus conductors in 40°C ambient at continuous 160 percent rated load, to be applied until all readings have stabilized. This test may be performed concurrent with the in-line tests specified for rectifier package tests, provided the readings have stabilized, during the two hour application of 160 percent load. For the purposes of this test, readings will be considered to have stabilized when the rate of temperature rise is less than one °C per hour.
- c. Power frequency withstand tests shall be conducted at the manufacturer's facility on each and every shipping length as specified under "Production Tests" in ANSI C37.23 for metal enclosed buses.
- d. If manufacturer submits detailed test report of these tests conducted on similar unit(s) for MBTA's review, MBTA may waive some or all of the design tests at his discretion.

9. Negative Drainage Board and Negative Equalizer Bus

- a. The following tests shall be conducted at the manufacturer's facility on the negative equalizer bus and drainage board:

- (i) Dielectric tests
 - (ii) Rated continuous current test
 - (iii) Momentary current test
 - (iv) Mechanical operation test
 - (v) Electrical operation and control wiring tests:
 - (a) Control wiring continuity test
 - (b) Control wiring insulation test
 - (c) Diode and shunt polarity tests
 - (d) Functional and sequence tests
 - (vi) Nameplate check
- b. If manufacturer submits detailed test reports of the rated continuous current and momentary current tests conducted on similar unit(s) for MBTA's review, MBTA may waive one or both of these tests at his discretion.

10. 15 kV Breaker Control and Instrument Panel

- a. The following tests shall be conducted at the manufacturer's facility on the 15 kV breaker control and instrument panel:
- (i) Electrical operation and control wiring tests:
 - (a) Control wiring continuity test
 - (b) Control wiring insulation test
 - (c) Functional and sequence tests
 - (ii) Checking of indicating instruments at zero, midpoint and full deflection
 - (iii) Nameplate check

11. Battery Monitor System

- a. Battery Monitoring System
- (i) Factory Acceptance Tests: Each battery monitors and its software shall be factory tested before shipment to the MBTA to demonstrate the functionality and performance required by this specification. The vendor shall provide written certification for each of the factory acceptance tests, complete with the signature(s) and date(s) for the responsible staff performing the acceptance tests. In addition, a written copy of the full factory test procedure shall be submitted to the MBTA

indicating the results of each test and the associated acceptance criteria for assigning a “pass” or “fail” outcome.

12. Supervisory Equipment

- a. All tests listed in DB Entity-prepared and MBTA's accepted factory test procedure shall be conducted on the supervisory equipment at the manufacturer's facility.

13. Substation Automation System

- a. All tests listed in DB Entity-prepared and MBTA's accepted factory test procedure shall be conducted on the supervisory equipment at the manufacturer's facility.

D. Field Tests

1. General

- a. The DB Entity shall perform the following field tests on all equipment specified in this Section after installation of the equipment. Field tests are to be performed to supplement the factory tests and to ensure proper operation of equipment and proper calibration and coordination of protective devices. The DB Entity shall furnish and set up all special equipment required for these tests, including relay test set, switches, properly calibrated indicating instruments, recording oscillographs, timing devices, shorting devices, loading devices and other associated appurtenances as may be required.
- b. The work includes furnishing of labor, material, test instruments and services necessary to perform required testing and checking of electrical equipment and installation.
- c. All tests shall be successfully completed to show that the installation meets the specification requirements and that the equipment and devices operate as intended, before final acceptance by the MBTA.
- d. Tests and checkouts shall be conducted in accordance with the DB entity-supplied, MBTA-accepted test procedures as specified herein and in National Electrical Code, Massachusetts State Electrical Code and applicable Standards and Specifications of ANSI, NEMA, IEEE, ICEA, AEIC, and NETA.
- e. The DB Entity shall provide properly qualified personnel who shall be responsible for supervising, coordinating, and performing all electrical field testing and checking work and who maintains a written record of all tests conducted and all punch list items for later correction or re-testing. The results of all field tests shall be verified by an independent test laboratory employed by the DB Entity.
- f. Testing and checkouts shall be performed in the presence of the MBTA.
- g. The DB Entity shall furnish five copies of all test results to the MBTA. Results sheets shall include date of test, personnel involved, items tested, type of tests and test data and shall be signed off by the test Engineer in charge. The DB Entity shall also submit the punch list signed off to showing completion.

- h. Any equipment or material damaged due to improper test procedure or test apparatus handling shall be replaced or restored to original condition by DB Entity at the DB Entity's expense.
 - i. Safety devices including but not limited to rubber gloves and blankets, screens and barriers, danger signs and padlocks, shall be used to protect and warn all personnel in the vicinity of the tests.
 - j. All test instruments used shall have a certified calibration sticker showing last date of calibration and expiration date.
2. Field Test Requirements

- a. The DB Entity shall formulate a complete, detailed step by step Field Test Procedure for all equipment to be furnished and installed under this Section and associated equipment interfaces associated with the work. Test procedure shall be comprehensive and shall include the required tests as specified in relevant standards of ANSI, NEMA, IEEE, and NETA, supplementing the Factory Test Procedure. The Field test procedure shall also include an index of all the proposed tests, estimated duration, overall schedule, test sequence and shall identify MBTA personnel requirements to fulfill the test program. The detailed procedure for performing the specified short circuit tests shall include step-by-step test procedure supplemented by circuit diagrams, details of instrumentation, safety interlocks and back-up trips provided.
- b. The DB Entity shall submit the detailed, step-by-step test procedures to the MBTA for review and acceptance well in advance of the commencement of field tests. The DB Entity may submit the procedures individually per equipment. MBTA reserves the right to add, delete or make necessary changes in the test procedure. The DB Entity is responsible for the performance and installation of the equipment furnished under this Section, he shall, therefore, prior to testing, verify that the installation is proper and in accordance with all applicable installation instructions specified herein.
- c. Perform continuity and dielectric tests to prove the correctness of circuitry per the MBTA Design Documents.
- d. Each and every AC and DC circuit breaker shall be thoroughly inspected and certified by the DB Entity's Engineer.
- e. Check relay and trip device settings and coordination.
- f. Perform functional and operational tests of all equipment and of all devices and circuits including operations between equipment.
- g. Perform phantom load tests on rectifier transformer AC switchgear protective devices to ensure calibration as outlined in Article 1.06.D of this Section. Phantom load tests may be carried out by secondary injection to the protection relays.
- h. Perform short circuit tests on rectifier and AC and DC switchgear to ensure calibration of rectifier, AC switchgear and DC switchgear protective devices, and overall coordination of protective devices as outlined in Article 1.06.D of this Section, and to confirm adequate short-time current capability or DC circuit breakers. Short circuit tests shall be

conducted at the substation. Circuit breaker of suitable rating furnished by the DB Entity may be used as a shorting device. Graphical results of all parameters for each test shall be recorded and furnished with field test reports. The MBTA may waive any or all of the short circuit tests described below at his/her discretion at any time. The DB Entity shall conduct the following tests:

- (i) Energize the both rectifiers in the substation and close the main (rectifier) DC circuit breakers. Short-circuit output terminals of one rectifier. Check for proper protective device coordination and fault isolation as follows:
 - (a) Main rectifier DC circuit breaker of short circuited rectifier should be tripped by the instantaneous reverse overcurrent device, Device 32 to clear the fault from the rectifier operating in parallel.
 - (b) Device 32 shall also trip the AC circuit breaker of short-circuited rectifier to clear the fault from the AC system.
 - (c) Protective devices of rectifier operating in parallel shall not operate during this test.
 - (d) Record results of test such as total inrush current, steady-state fault current, impulse time of faulted unit, clearing time of faulted unit. Primary system voltage and short circuit capacity shall be tabulated.
- (ii) Repeat the above test, short circuiting the output terminals of the other rectifier unit instead. Check for proper co-ordination of protective devices and fault isolation and tabulate the results.
- (iii) Energize one rectifier in the substation with its associated main DC breaker closed and close the DC feeder breaker specified by the MBTA. Short circuit the load side of the closed DC feeder breaker. For proper protective device coordination and fault isolation, the DC traction feeder breaker instantaneous series overcurrent trip channel in the Device 150M multifunction feeder protection relay shall trip the faulted feeder breaker and successfully clear the fault. No other breakers should trip. Load measuring should activate but be unsuccessful while the short circuit remains applied. Tabulate results such as total let-through current and total clearing time, and record primary system voltage and short circuit capacity.
- (iv) Repeat the above test (3) using the other rectifier unit and short circuit the load side of the MBTA specified DC feeder breaker. For proper protective device coordination and fault isolation, the DC traction feeder breaker instantaneous series overcurrent trip channel in the Device 150M multifunction feeder protection relay shall trip the faulted feeder breaker and successfully clear the fault. No other breakers should trip. Load measuring should activate but be unsuccessful while the short circuit remains applied. Tabulate results as outlined above.
- (v) Energize both rectifiers in the substation with both main DC breakers closed and close the DC feeder breaker specified by the MBTA. Short circuit the load side of the closed DC feeder breaker. For proper protective device coordination and fault isolation and DC breaker interrupting capability demonstration, the DC traction feeder breaker instantaneous series overcurrent trip channel in the Device 150M multifunction feeder protection relay shall trip the faulted feeder breaker and

successfully clear the fault. No other breakers should trip. Load measuring should activate but be unsuccessful while the short circuit remains applied. Tabulate results such as total let-through current and total clearing time, and record primary system voltage and short circuit capacity as above.

- (vi) Energize one rectifier in the substation and close the main (rectifier) dc circuit breaker. Short-circuit the load terminals of the main (rectifier) DC circuit breaker. For proper protective coordination, rectifier AC circuit breaker of the faulted unit shall be tripped by AC feeder time overcurrent unit of relay Device 50/51. The short circuit current will flow until interrupted by the AC circuit breaker. Tabulate the results.
- (vii) Equipment and substation building shall be inspected after each of the above mentioned tests for damage. Failure of the equipment either to withstand these tests or to coordinate or to meet other Section requirements shall be sufficient grounds for rejection of equipment.
- i. At the MBTA's discretion, MBTA's personnel in conjunction with the DB Entity shall test the rate-of-rise trip channel in each Device 150M multifunction DC feeder protection relay in the substation by placing a short circuit on the far end of the electrical section on which the associated feeder breaker is used. The MBTA may waive any or all of the short circuit tests described below at his/her discretion at any time.
 - (i) Relay settings shall be supplied by the DB Entity. Testing shall be done with the rate-of-rise device set no lower than 20 percent above its bottom setting corresponding to a fault farthest away from the breaker. The setting shall allow the start and acceleration of trains at any point in the section supplied by the circuit breaker, without tripping the rate-of-rise relay.
 - (ii) If the breaker fails this test, the DB Entity shall adjust or modify the breaker components or relay settings. The breaker or relay settings must fully meet the requirements to the satisfaction of the MBTA. Any deviation from these requirements will be considered cause for rejection of the DB Entity's rate-of-rise circuitry.
 - (iii) The DB will be furnished the feeder, overhead contact system or third rail, and return circuit impedance data, and related information of train equipment.
 - (iv) All the work external to the substation for conducting this test, including furnishing equipment for shorts along the various points shall be provided by the DB Entity.
- j. Equipment and Instruments
 - (i) Check alignment and proper operation of all equipment including relays, operating mechanisms, clearances, adjustment of contacts, and accessory equipment.
 - (ii) Test indicating instruments, such as ammeters, voltmeters, and other instruments, by checking and adjusting pointers on zero scale with no load or voltage applied, also at midpoint and full scale.

- (iii) Check the isolation amplifiers/transducers for linearity and gain from 1-Volt-to-1-Volt through 1-Volt-to-100-Volt.

k. Battery Monitoring System

- (i) Site Acceptance Tests: The battery monitor system supplier shall prepare site acceptance test procedures, which shall be used to validate the functionality and performance required by this specification.

- (ii) System Installation, Start-up, Commissioning and Training

- (a) The battery monitoring supplier shall provide a field start-up engineer to supervise the system installation at each battery monitor locations. Supervision of the installation does not necessarily imply full time presence during all installation work. However, the start-up engineer must be present during critical times of the installation process, which includes as a minimum, the initial site planning visit, initiation of work to familiarize installation workers with the methods and procedures to perform the work, and a daily presence at the site thereafter to confirm that the work is proceeding as planned.

- (b) After installation, the battery monitoring supplier shall provide a field engineer to start up each battery monitor location and perform all required site acceptance tests to demonstrate that the system meets the functionality and performance of this specification. Before initiating each acceptance test, the field engineer shall co-ordinate with the MBTA to schedule this event at a mutually agreed time and date. A copy of the acceptance test procedure shall be provided to the MBTA a minimum of five (5) days before the start of each test. A signed copy of the completed acceptance test shall be provided for the MBTA's records for each monitor location. Acceptance testing shall also take place at the two remote central computers to ensure that the vendor's monitoring software is performing as required in this specification. A copy of the acceptance test procedure for the central computers shall be provided to the MBTA a minimum of five (5) days before the start of each test. A signed copy of the completed acceptance report for each of the central computers shall be provided for the MBTA's record.

l. Supervisory Equipment

- (i) The DB Entity shall test and verify all wiring installed in the Contract, including wiring to the SAS and SCADA.
- (ii) The supervisory equipment at the substation interfacing with the supervisory system at the High Street Operations Center and Cabot Yard shall be end-to-end tested in accordance with a DB Entity-prepared, MBTA-accepted test procedure.
- (iii) All status, control and analog functions shall be individually tested and checked out and the results recorded, individually, in the test report. Analog devices shall be checked for linearity at zero, 50 percent and 100 percent output and calibrated for proper output to SCADA.

(iv) The DB Entity shall be responsible for conducting end-to-end function testing from the SCADA control room to the field equipment. Testing shall be performed in conjunction with the MBTA, who shall operate all SCADA control room equipment.

m. 600 Volt Wire and Cable

(i) Test in accordance with Article 3.08, Section 16201.

n. Grounding

(i) Test in accordance with Article 3.08, Section 16450.

o. Medium Voltage Cabling

(i) Test in accordance with section 16120.

E. Test Reports

1. The DB entity shall submit five certified copies of test reports for all the tests conducted at the factory and in field for the MBTA's acceptance. Test reports shall be submitted to the MBTA within seven (7) days after completion of tests. In case of "Design Tests" and tests on rectifier packages, test reports shall include original data, detailed calculation of test data used to arrive at the results and interpretation of results. Test reports shall contain the characteristics and curves where required for interpretation of results.
2. Result of AC and DC circuit breaker function test shall be tabulated individually for each breaker, indicating each function tested.

SECTION 16311 - APPENDIX A

SUBSTATION AUTOMATION SYSTEM AND SCADA INTERFACE

PART 1 – GENERAL

1.1 SUMMARY

- A. This section describes the work requirements for the Substation Automation System (SAS) to be provided traction power substations (TPSS) in this Contract and their integration to the existing SCADA system. The SAS shall be a fully redundant system which utilizes a combination of programmable automation controllers, intelligent electronic devices and other networking devices for the protection, monitoring and control of TPSS equipment via local control switches, human machine interface (HMI) workstations, and SCADA. The DB Entity shall provide hardware, software, and interconnections required for a complete and functional SAS. The SAS shall replace hard-wired interconnections between TPSS equipment and the SCADA terminal cabinet used for communicating control signals and monitoring device inputs and outputs (I/O). Interconnections between TPSS equipment and their respective Intelligent Electronic Device or Multipurpose relay shall be hard-wired. In addition, relay devices that trigger the 86-lockout relays shall preferably be hard-wired but

the DB Entity may propose an alternative software based method of hand-reset for these device subject to acceptance by the MBTA.

B. Section Includes:

1. Substation Automation System (SAS)
2. Interface and Integration to existing SCADA System
3. Programmable Automation Controllers (PAC)
4. Intelligent Electronic Devices (IED) and input/output devices
5. Multipurpose Relay (MPR)
6. Intelligent Protection Relay (IPR)

C. Related Sections:

1. Volume 2 Technical Provisions
2. Section 16201 – Basic Materials and Methods for Electrical Work
3. Section 16492 – SCADA Master Station and System Interface
4. Section 16495 – Electrical Acceptance Tests

1.2 REFERENCES

A. Definitions:

1. Intelligent Electronic Device (IED): Refers to any digital or numerical-based protection, metering, or automation device that has processing, recording and reporting capabilities and a local human machine interface (HMI).
2. DIO or IOM: Refers to a digital input and/or output device or module to integrate hardwired signals into the communications system. The DIO does not have integrated intelligence or processing or a HMI.
3. Human-Machine Interface (HMI): The user-interface for a device consisting of a display and buttons.
4. Failure: When the SAS or one of its components does not operate or communicate as designed and installed.
5. Repeated failure: Two or more failures of the same component; whether controller, IED, communications interface hardware, related hardware, or software.

6. Fail-safe: An attribute of a device where related substation equipment will be not left in an unsafe state or left unprotected in the event of a failure.
 7. Provide: Furnish and Install.
- B. Reference Standards:
1. Section incorporates by reference the latest revisions of the following documents, or the version required by the MBTA:
 2. Institute of Electrical and Electronics Engineers (IEEE)
 - a. IEEE C37.90.2, Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
 - b. IEEE 730, Standard for Software Quality Assurance Plans
 3. International Electrotechnical Commission (IEC)
 - a. IEC 60529, Degrees of protection provided by enclosures (IP Code)
 - b. IEC 60255-21, Electrical Relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment
 - c. IEC 61000-4, Electromagnetic compatibility (EMC)
 - d. IEC 1131-2, Programmable Controllers – Part 2: Equipment Requirements and Tests
 - e. IEC 61131-3, Programmable Controllers – Part 3: Programming Languages
 - f. IEC 61850, Communication networks and systems for power utility automation
 4. National Fire Protection Association
 - a. NFPA 70, National Electrical Code (with amendments by the MBTA)

1.3 SUBMITTALS

- A. Procedures: Contract Technical Provision Subsections 2.7 and 2.8
- B. System description of the SAS and subsystems
- C. Documentation demonstrating service proven design as described in this Section
- D. System support plan during commissioning and warranty period.
- E. Submit Product Data:

1. SAS components
2. Include technical details and operating manuals for hardware and software
3. MBTA information (reliability information of proposed product)
4. Upgrades, bug-fixes, patches and modification log

F. Submit Shop Drawings:

1. System block diagram
2. Panel layout plans
3. Rackmount layout plans
4. Substation layout plans (showing equipment location and access)
5. Equipment installation detail drawings
6. Input/output Lists
7. Input/output maps
8. SAS component list with IP addresses, user names, passwords, and function description
9. Wiring schematics with terminal block references
10. Wiring diagrams with detailed labels for components, contacts for each point and interface with equipment to be installed under this contract.
11. HMI application screen shots
12. Nameplate list
13. Bill of Materials

G. Software:

1. Provide development software for the SAS HMI applications.
2. Provide software used to program and maintain SAS components
3. Provide application code developed for the SAS in electronic format as directed by the MBTA. Application code shall not be proprietary.
4. Provide licenses for SAS software

- H. Technical Support Equipment list as described in this Section
- I. Recommended Spare Parts List
- J. Test procedures and reports:
 - 1. Prepare reports in accordance with Section 16950 Electrical Acceptance Tests.
 - 2. Submit factory design test procedure, test schedule and report
 - 3. Submit field test procedure, test schedule and report
- K. Operations and Maintenance (O&M) Manual:
 - 1. Submit data in accordance with Section 01700 Contract Closeout.
 - 2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
 - 3. Include accepted revisions of SAS submittals described in this Section.

1.4 SOFTWARE INTELLECTUAL PROPERTY RIGHTS

- A. Application software developed under this Contract, including source code, shall become the property of the MBTA.
- B. Development software for SAS components and HMI shall be property of the MBTA.

1.5 QUALITY ASSURANCE

- A. SAS components shall be UL labeled.
- B. SAS components that are not UL certified may be furnished with a Field Evaluation label provided by a third party testing laboratory. The testing laboratory shall be accepted by the MBTA.
- C. SAS component manufacturers and integrator shall preferably be ISO 9001 certified. ISO status shall be provided.
- D. A software quality assurance plan shall be used in accordance with IEEE Standard 730 or equivalent. The plan shall describe a mechanism for orderly software development.

1.6 REQUIREMENTS FOR SERVICE PROVEN DESIGN

- A. SAS components and software shall be of a proven design.
- B. Provide evidence of at least 5 similar systems that have been in successful operation preferably in rail transit projects for a minimum of 3 years.

1.7 RELIABILITY AND MAINTAINABILITY

- A. SAS shall be fail-safe, such that a hardware or software failure condition shall not result in an unsafe equipment state.
- B. The following fail-safe logic should be applied to the SAS, at minimum:

	Event	Action
1	Failure of rectifier, transformer, 72R, or 52T IED/DIO	<ul style="list-style-type: none"> • Remove affected rectifier/transformer from service. • Remaining AC and DC switchgear remain in service.
2	Failure of any IPR in AC switchgear	<ul style="list-style-type: none"> • Trips affected breaker.
3	Failure of any MPR in DC switchgear	<ul style="list-style-type: none"> • Trips affected breaker.
4	AC switchgear Bus Lockout (86B)	<ul style="list-style-type: none"> • Trips affected AC circuit breakers via hard wiring • Via SAS associated 72-R breaker tripped
5	Loss of ACCP IED/DIO	<ul style="list-style-type: none"> • Loss of remote metering and status only if status is provided to SCADA via SAS
6	Loss of MPAC	<ul style="list-style-type: none"> • Auto failover to hot standby PAC (SPAC)
7	Loss of SPAC after loss of MPAC	<ul style="list-style-type: none"> • See 1 above
8	Loss of communications to any IED/DIO or MPAC (and PAC)	<ul style="list-style-type: none"> • See 1 above. • Report communications failure.
8	Loss of communications to any IED/DIO not included above e.g. DIO for battery system, fire alarm and building status.	<ul style="list-style-type: none"> • Report communications failure.

- C. Power supply failure shall not result in loss of data or require any manual re-work such as programming or reconfiguration.
- D. Failure of an SAS component shall not damage or inhibit status, control, or monitoring of any other equipment.
- E. Repeated Failure:
1. Investigate and provide a failure analysis report outlining the root cause of failure. Report shall include a download of the history and compared to similar status reports downloaded at commissioning and startup.
 2. Provide recommendations for correcting the failure. Corrective actions shall be submitted for review by the MBTA.

3. Apply the corrective action after obtaining acceptance by the MBTA at no cost to the MBTA.
- F. The following components shall have a minimum mean time between failures (MTBF):
1. Main Programmable Automation Controller: 87,600 Hours
 2. LCMS LCD Display: 50,000 Hours
 3. LCMS Industrial Computer: 87,600 Hours
 4. Industrial Ethernet Switches: 87,600 Hours
 5. MPRs/IEDs: 87,600 Hours
- G. SAS shall be capable of accommodating upgrades, bug-fixes, patches and modifications. Fully document changes and submit documentation to the MBTA.

1.8 ENVIRONMENTAL REQUIREMENTS

- A. SAS components shall be designed to operate in the environment in which they will be installed and shall comply with and fully function in the environmental conditions specified in Section 16311 Traction Power Electrical Equipment and in this Section.
- B. The presence of transients on communication interfaces shall not cause the malfunction or blocking of critical communications.
- C. SAS components shall comply with the following requirements:
 1. Mechanical shock withstand: IEC 60255-21-2, Class 1.
 2. Vibration resistance: IEC 60255-21-1, Endurance Class1, Response Class 2.
 3. Seismic withstand: IEC 60255-21-3, Class 2.
 4. Electromagnetic field impulse withstand: IEC 61000-4-3, 10V/m.
 5. Radio frequency withstand: ANSI C37.90.2, 35V/m.
 6. Electrostatic discharge: IEC 61000-4-2, 8kV contact discharge, 15kV air discharge
 7. Magnetic Field Immunity: IEC 61000-4-8, 1000A/m for 3 seconds
 8. Dielectric: IEEE C37.90, 2500Vac on I/O, 3100Vdc on power supply
 9. Impulse: C37.90-2005, 0.5 J, 5kV

- D. SAS component circuit-boards shall have conformal coating for protection circuitry hazards.

1.9 WARRANTY

A. Warranty:

- 1. Provide on-site and remote support for the SAS throughout the entire warranty period.
- 2. Support shall include assistance with operation and maintenance of the system.
- 3. Provide a 10-year unconditional warranty on parts and labor.

B. Develop a comprehensive System Support Plan and submit to MBTA.

- 1. Describe technical support services to be provided during warranty period
- 2. Provide contact information for a minimum of three SAS support engineers
- 3. Develop protocols to address SAS system errors

PART 2- PRODUCTS

2.1 SAS GENERAL REQUIREMENTS

A. Design, furnish and install SAS for monitoring and control of traction power substation equipment for the following MBTA Green Line Traction Power Substation (TPSS):

- 1. Red bridge
- 2. Pearl Street
- 3. Ball Square
- 4. 3rd Avenue

B. The SAS shall be used as a communications network within the substation to transmit device statuses, breaker control, metering data, and facility I/O between substation equipment and SCADA. Refer to SAS Local Area Network Requirements in this Section.

C. The SAS shall have a Local Control and Monitoring Station (LCMS) for control and monitoring substation equipment at a central location within each substation. The LCMS is the human machine interface, or HMI, for the substation.

D. SAS shall consist of the following components:

- 1. Local Control and Monitoring Station (LCMS)

- a. Industrial Computer (LCMS Component)
 - b. LCD Rackmount Display (LCMS Component)
 2. Main Programmable Automation Controller (MPAC)
 3. Secondary Programmable Automation Controller (SPAC)
 4. Industrial Ethernet Switches (Managed and Unmanaged)
 5. Intelligent Electronic Devices (IED)
 6. Digital input/output Devices (DIO)
 7. Multipurpose Relays (MPR) (SAS requirement may be the interface with MPR's provided under separate equipment).
 8. Intelligent Protection Relays (IPR) (SAS requirement may be the interface with IPR's provided under separate equipment).
 9. Equipment Rack Enclosures
 10. Associated Peripherals
- E. SAS components shall also provide protective functions as described in the Section and Section 16311.
- F. The SAS local area network (LAN) shall replace hard-wired interconnections and logic to the SCADA terminal board used for communicating control signals and monitoring device I/O. A dual fully redundant network shall be provided.
- G. The SAS LAN shall be a secure network. Access to the SAS devices and embedded software shall be password protected. Submit a list of user names and passwords for SAS components.
- H. Transformer-rectifier lockouts (86, 86X) circuit logic shall be incorporated into the software of automation system. If a lockout handle is provided, then the 86 lockout device shall be hardwired into the SAS. Failure of an SAS component shall result in the failure mode actions listed in the table in Section 1.07. The DB Entity may propose a software base lockout device.
- I. The AC switchgear 86B-lockout relays shall trip AC breakers via a hard-wire connection.
- J. SAS components shall provide a watchdog alarm output to the MPAC/SPAC and SCADA upon failure.
- K. The SAS shall have redundant primary and secondary MPAC/SPAC. The secondary PAC (SPAC) shall be a fully functional controller and shall automatically assume full control of the system when the MPAC fails. This shall be a hot standby configuration.

- L. SAS components shall be of the same brand and model with similar modules and programming.
- M. SAS component storage memory shall be solid-state and non-volatile.
- N. All SAS equipment and IED's shall be located within the equipment such there is easy access to all operating controls, screens and terminals.
- O. Nameplates: SAS components shall have descriptive phenolic nameplates. Submit a nameplates list for review. Refer to Section 16203 for additional nameplate requirements.
- P. Submit a complete list of SAS component input/outputs (I/O) based on Points List in this Section.
- Q. The quantity of IEDs/DIOs shall be proposed by the DB Entity but shall maintain the following philosophy
 - 1. Each rectifier-transformer circuit shall be utilizing independent IED/DIOs such that failure of a component of one rectifier or transformer shall not affect the other unit(s).
 - 2. Each AC bus section shall utilize independent IED/DIOs for the 52T circuit breakers such that failure of a component of one rectifier-transformer circuit shall not affect the other bus section(s) or rectifier transformer(s).
 - 3. Each rectifier DC breaker shall utilize shall utilize independent IED/DIOs for the 72R circuit breakers such that failure of a component of one rectifier-transformer circuit shall not affect the other rectifier-transformer circuit.
 - 4. Each DC circuit breaker shall utilize and independent MPR.
 - 5. Each AC circuit breaker shall utilize and independent IPR.
 - 6. The ACCP shall utilize an independent IED/DIO.
- R. Submit a substation layout plan and panel layout plans showing proposed SAS equipment locations.
- S. The DB Entity shall propose the quantity additional I/O points, for review and acceptance by the MBTA, for the SAS and at each TPSS for indication or monitoring upon request at no additional cost to the MBTA. Points shall be made available to the LCMS and SCADA.

2.2 SAS LOCAL AREA NETWORK (LAN)

- A. SAS components shall be connected via Ethernet 100Base-TX, 100Base-FX, 1000Base-T, or 1000Base-X. The DB Entity shall propose network cables to be used for review and acceptance by the MBTA.
- B. Provide fast Ethernet over twisted pair 100base-TX for the following connections:

1. Managed Ethernet Switch (MES) and LCMS
 2. MES and MPAC
 3. MES and Service Laptop
 4. MPAC and SCADA
- C. Provide fast Ethernet over fiber 100Base-FX for the following interconnections. The DB Entity may propose use of twisted pair 100base-TX connections:
1. MES and SAS components installed in the AC control panel, AC switchgear, DC switchgear, transformers, rectifier control enclosures, negative drainage bus enclosure and negative enclosures (as applicable).
 2. Fiber Optic Cable: Full-duplex multi-mode optical fiber.
- D. Provide Gigabit Ethernet over fiber for interface to SCADA network switch for the following connections:
1. Fiber Optic Cable: Full-duplex multi-mode optical fiber.
- E. Provide hard-wired copper for device I/O for the following interfaces:
1. MPAC / SPAC and Supervisory Terminal Board as required Refer to Section 16492 for additional requirements.
 2. IED/DIO and AC circuit breakers.
 3. IED/DIO and transformers.
 4. IED/DIO and AC Control Panel control switches, transducers, and meters as required
 5. IED/DIO and rectifiers/negative switchboards
 6. IED/DIO and DC cathode breakers
 7. MPR and DC feeder breakers
 8. IED/DIO and 480V Unit Substation
- F. Synchronize time for SAS components with MPAC and SPAC.
- G. Submit a list of SAS components with assigned IP addresses.
- H. Refer to Figure 1 for Typical SAS Block Diagram. CAT6 cable shall be used for communications connections within equipment.

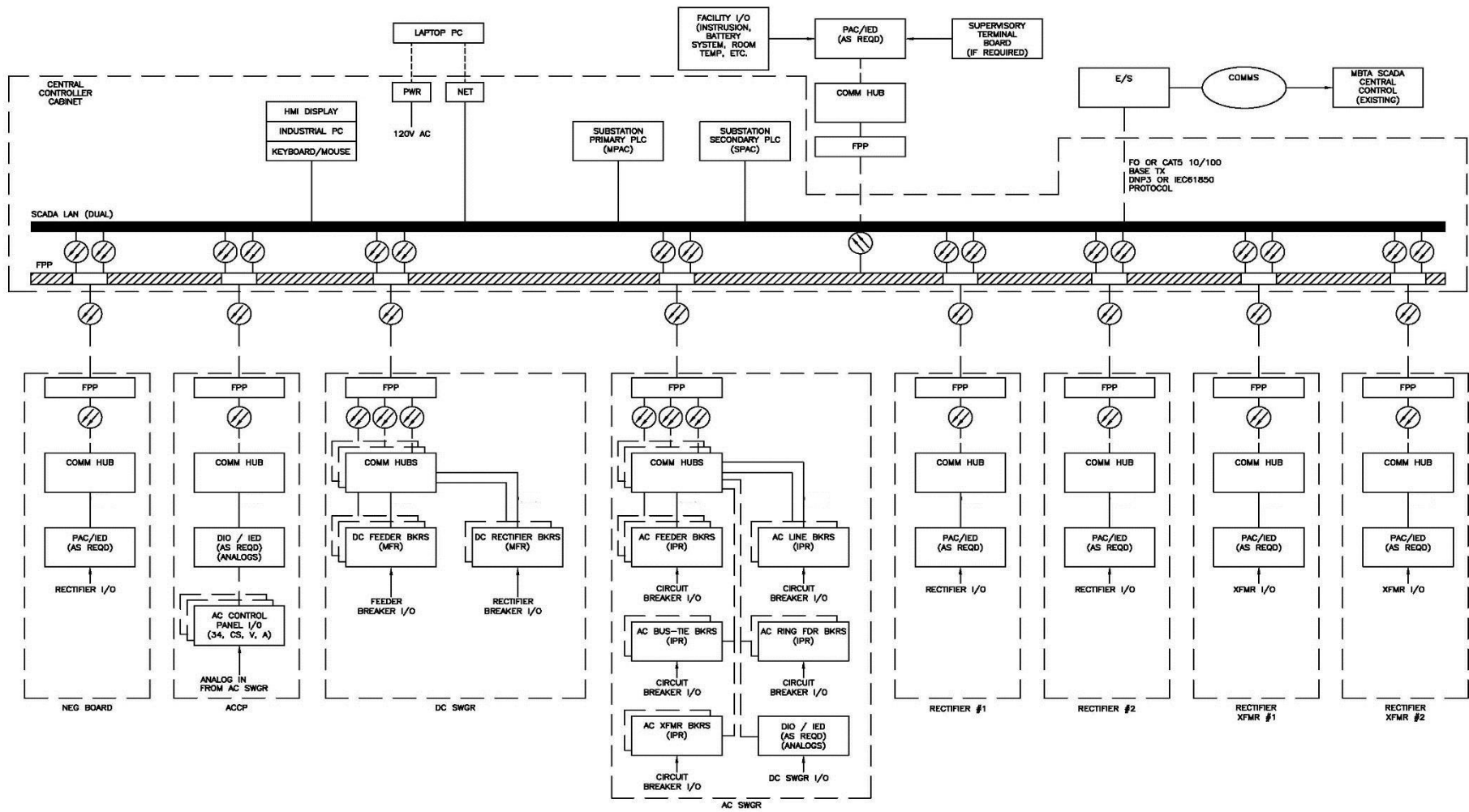


Figure 1 – Typical SAS Block Diagram

2.3 INTEGRATION TO EXISTING SCADA AND CENTRAL CONTROL

- A. Integrate the SAS to the existing SCADA system through the following interfaces and physical networks:
 - 1. Through SCADA Industrial Ethernet switch
 - a. Connect the SAS network to the SCADA network using fiber optic cable or CAT6 ethernet cable.
 - b. Configure SAS devices and network switch to communicate with the SCADA network.
 - c. Map SAS I/O for configuration of the SCADA system
 - d. Communication protocol: DNP3
- B. Refer to Section 16311/16492 Supervisory Terminal Board for additional information.

2.4 POWER REQUIREMENTS

- A. Available TPSS control power at substations: 125 Vdc
- B. For components that utilize 48Vdc or 24Vdc, provide redundant power supplies for each.
- C. Each component shall be separately fused from the 125 Vdc panel.

2.5 MAIN PROGRAMMABLE AUTOMATION CONTROLLER (MPAC) AND SECONDARY PROGRAMMABLE AUTOMATION CONTROLLER (SPAC)

- A. Provide a redundant, primary and secondary, MPACs for each TPSS.
- B. Primary and secondary MPACs shall be identical. The secondary PAC (SPAC) shall be configured to assume full control of the system upon failure of the primary MPAC.
- C. System shall be 'hot standby'. Standby configuration shall be provided for review and acceptance by the MBTA.
- D. MPAC/SPAC functional requirements:
 - 1. Data concentrator for the SAS
 - 2. Collect and log data, events, and alarms from the SAS, LCMS, TPSS facility I/O, and SCADA.
 - 3. Communicate indications, statuses, and control signals between SAS components.
 - 4. Send logged data to the LCMS.
 - 5. Time synchronization for SAS components

6. Role based user management security system with LDAP capability
 7. SAS event log server for local HMI and MBTA's Central Control SCADA Network
 8. Capable of converting data between communication protocols
 9. Utilizes IEC 61131 based logic engine for programming, including ladder diagrams, sequential function charts, function block diagrams, structured test and instruction lists.
- E. MPAC/SPAC specifications:
1. Storage: 4GB non volatile
 2. Communication Ports: USB, Ethernet, Serial
 3. Communication Protocols: DNP3, IEC 61850
 4. Power supplies: Redundant
 5. I/O modules: 8 output contacts, 24 input contacts.
 6. Time Sync: IRIG-B
- F. MPAC, SPAC and associated modules shall have free-standing terminals and shall be replaceable on site without requiring factory rewiring.

2.6 LOCAL CONTROL AND MONITORING STATION (LCMS)

- A. Provide an LCMS for each TPSS that consists of an Industrial Computer and an LCD Display to be used as the substation human machine interface (HMI).
- B. Industrial Computer or "Computer"
1. Functional requirements:
 - a. Access and display HMI applications for local control and monitoring of SAS components. Refer to HMI Application Design section for requirements.
 - b. Access, export, save and print event logs
 - c. Monitor SAS component health status and TPSS equipment status
 - d. Edit user management settings
 - e. Edit SAS component settings
 - f. Control AC and DC breakers

- g. Input to the computer shall be by a keyboard and mouse
 - h. Document viewer for doc, pdf, and dwg files
 - i. Accept and acknowledge alarms
2. Specifications, minimum:
- a. CPU: Intel i7 Processor 3.2 GHz, 12MB cache
 - b. Ethernet: 100Base-T, 1000Base-T
 - c. Memory: 8GB DDR3 RAM, ECC
 - d. Storage: SATA 128GB SSD HD
 - e. Ports: 4 USB ports, 2 serial ports
 - 1) Video: VGA port, DVI
 - f. Operating System: Windows 7 Ultimate or later
 - g. Humidity: 5 – 95 percent non-condensing
 - h. Input devices: Rackmount drawout Keyboard and mouse

C. LCD Rackmount Display

- 1. LCD Rackmount Display, or “Display”, shall be compatible with the Computer and be used as an HMI display for the SAS.
- 2. Display specifications:
 - a. Active matrix color TFT LCD
 - 1) Size: 20.1” diagonal, minimum
 - b. Response Time: 8ms
 - c. Input: Analog VGA, DVI; minimum
 - d. Resolution: 1600 x 1200 @ 60 Hz, minimum
 - e. Mount: 8U Flush mount on 19” rack
 - f. Lexan screen protection
 - g. NEMA 4X powder coated enclosure

2.7 INDUSTRIAL ETHERNET SWITCHES

A. Industrial Managed Ethernet Switches (MES)

1. Provide a redundant MES for each TPSS which automatically switches between primary and secondary devices to minimize downtime.
2. Provide patch panels and cables as necessary for a complete installation.
3. Used for interconnection of SAS components and the MBTA's Central Control SCADA network over fiber.
4. Functional Requirements:
 - a. Standards: IEEE 802.3x Flow control, IEEE 802.1Q VLAN, IEEE 802.1p Class of Service, IEEE 802.1X Authentication, SNMPv3, IEEE 1588v2 timing protocol
 - b. Configurable by a web browser
 - c. Industrial hardened to operate in the substation environment
5. Interface:
 - a. Fast Ethernet: 100Base-TX, 100Base-FX
 - b. Gigabit Ethernet: 1000Base-X
 - c. Accommodate connections required for SAS components plus spare RJ45 and fiber ports. DB Entity to propose the spare capacity to be installed for review and acceptance by the MBTA.
6. Device Requirements:
 - a. Ambient temperature: minus 40 to 85 degrees C.
 - b. Humidity: 5 – 95 percent non-condensing
 - c. Rack mountable in 19" rack

B. Industrial Unmanaged Ethernet Switches

1. Provide where interconnection between SAS component and MES via fiber is required and SAS component is without necessary fiber ports.
2. Interface:
 - a. Fast Ethernet 10/100Base-TX, 100Base-FX
3. Device Requirements:

- a. Ambient temperature: minus 40 to 85 degrees C
 - b. Humidity: 5 – 95 percent non-condensing
4. Approved Manufacturer:
- a. GarrettCom, SEL, MOXA
 - b. Substitutions: Section 00700 General Conditions.

2.8 INTELLIGENT ELECTRONIC DEVICES AND DIGITAL INPUT/OUTPUT DEVICES

A. AC Control Panel (ACCP) IED/DIO

- 1. Provide an IED/DIO for each ACCP.
- 2. Include necessary I/O, communication, and power modules for a complete installation.
- 3. Functional Requirements:
 - a. Monitor device I/O from meters, transducer, local/remote switches, control switches and other hardware within the ACCP as applicable.
 - b. Transmit control signals between the ACCP and the AC switchgear through the SAS network.
 - c. Transmit analog metering data and communicate device statuses from the ACCP to the SAS network.
 - d. Collect I/O from remote devices and AC switchgear statuses at the ACCP.
 - e. Refer to the Points List in this Section for control and monitoring points required by this Contract.
- 4. Device Requirements:
 - a. Ambient temperature: minus 40 to 85 degrees C
 - b. Humidity: 5 – 95 percent non-condensing
 - c. Inputs: AC current, AC voltage, DC transducer inputs, opto-isolated inputs
 - d. Outputs: DC and AC electromechanical outputs, and analog
 - e. Communication Ports: Ethernet 10/100BASE-T or 100BASE-FX
 - f. Protocols: DNP3, IEC 61850

B. Rectifier Transformer/Rectifier/Negative Switchboard, DC Main Circuit Breakers (72R), AC Rectifier-Transformer Circuit Breakers (52T) IED/DIOs

1. Provide an IED/DIO for each main DC circuit breaker, rectifier-transformer AC circuit breaker, rectifier transformer, rectifier and negative switchboard set. Refer also to Section 2.01.Q. The DB Entity may propose combining inputs/outputs at common locations/equipment to best utilize the equipment.
2. Include necessary I/O, communication, and power modules for a complete installation.
3. Functional Requirements:
 - a. Monitor device I/O from the rectifier transformers, rectifiers and negative switchboards.
 - b. Communicate statuses, indication, and control between IED/DIO and other SAS devices through the SAS network.
 - c. Refer to the Points List in this Section for control and monitoring points required by this Contract.
4. Device Requirements:
 - a. Ambient temperature: minus 40 to 85 degrees C
 - b. Humidity: 5 – 95 percent non-condensing
 - c. Inputs: AC current, AC voltage, DC transducer inputs, opto-isolated inputs
 - d. Time Code Input: Demodulated IRIG-B
 - e. Outputs: DC and AC electromechanical outputs, and analog
 - f. Communication Ports: Ethernet 10/100BASE-T or 100BASE-FX
 - g. Protocols: DNP3, IEC 61850

C. DC Multifunction Protective Relay (MPR)

1. Provide MPRs for each DC feeder breaker (172).
2. Functional Requirements:
 - a. Provide protective relaying functions for the DC circuit breakers. Refer to Section 16311 Rev for relay protection requirements.
 - b. Monitor device I/O from DC circuit breakers, transducers, control switches, and relays within each DC breaker cubicle.

- c. Transmit control signals from the control switch to the DC circuit breaker.
 - d. Transmit analog metering data and communicate device statuses to the MPAC/SPAC.
 - e. Collect I/O from remote devices for remote control by the HMI or SCADA.
 - f. Drive control switches used for trip and close functions of the DC circuit breakers.
 - g. Refer to the Points List in this Section for control and monitoring points required by this Contract.
3. MPR shall have its own local LCD display for viewing settings, values and statuses.
 4. All available functions of the MPR shall be preprogrammed and enabled as directed by the MBTA.
 5. Provide a four-position selector switch for each DC circuit breaker (rectifier and feeder) for selecting between the HMI, LOCAL, OFF, and SUPERVISORY for breaker control. Refer to Section 16311 Rev for requirements.
 6. Provide transducers, hardware and wiring for a complete installation.
 7. Device shall have chart recording features with PC software used for downloading and analyzing faults. Fault recording function shall capture analog and digital pre-fault and post-fault waveforms and data.
 8. Device shall be accessible for downloading events and chart recording information from the Workstation and a laptop computer via Ethernet connection to the MES.
 9. Protective Requirements:
 - a. Refer to Section 16311 Rev. In addition to the protection functions required any additional features available via the selected MPR shall be available through the SAS, installed and programmed but not enabled.
 10. Device Requirements:
 - a. Communication Ports: Ethernet
 - b. Communication Protocols: DNP 3.0, IEC 61850
 11. Approved Manufacturer/Product:
 - a. Siemens Sitras Pro, Microelectronica Scientifica UMLE or accepted equal.
 - b. Substitutions: Section 00700 General Conditions.

D. AC Intelligent Protective Relay (IPR)

1. Provide IPRs for each AC circuit breaker (52).
2. Functional Requirements:
 - a. Provide protective relaying functions for the AC circuit breakers. Refer to Section 16311 Rev for relay protection requirements.
 - b. Monitor device I/O from DC circuit breakers, transducers, control switches, and relays within each AC breaker cubicle.
 - c. Transmit control signals from the control switch to the AC circuit breaker.
 - d. Transmit analog metering data and communicate device statuses to the MPAC/SPAC.
 - e. Collect I/O from remote devices for remote control by the HMI or SCADA.
 - f. Drive control switches used for trip and close functions of the AC circuit breakers.
 - g. Incorporate logic for circuit breaker control interlocking.
 - h. Refer to the Points List in this Section for control and monitoring points required by this Contract.
3. IPR shall have its own local LCD display for viewing settings, values and statuses.
4. All available functions of the IPR shall be preprogrammed and enabled as directed by the MBTA.
5. Provide a four-position selector switch for each AC circuit breaker (rectifier and feeder) for selecting between the HMI, LOCAL, OFF, and SUPERVISORY for breaker control. Refer to Section 16311 Rev for requirements.
6. Provide transducers, hardware and wiring for a complete installation.
7. Device shall have chart recording features with PC software used for downloading and analyzing faults. Fault recording function shall capture analog and digital pre-fault and post-fault waveforms and data.
8. Device shall be accessible for downloading events and chart recording information from the Workstation and a laptop computer via Ethernet connection to the MES.
9. Protective Requirements:
 - a. Refer to Section 16311 Rev. In addition to the protection functions required any additional features available via the selected IPR shall be available through the SAS, installed and programmed but not enabled.
10. Device Requirements:

- a. Communication Ports: Ethernet
 - b. Communication Protocols: DNP 3.0, IEC 61850
11. Approved Manufacturer/Product:
- a. Siemens Sitras Pro, Microelectronica Scientifica UMLE or accepted equal.
 - b. Substitutions: Section 00700 General Conditions.
- E. Other Substation IED/DIO
- 1. Provide DIO for substation general equipment alarms, including but not limited to:
 - a. Battery system
 - b. Fire Alarm
 - c. Door intrusion system
 - d. Substation building temperature alarms
 - e. Unit substations
 - f. Substation battery monitoring system

2.9 EQUIPMENT RACK ENCLOSURE

- A. Enclosures shall house the LCMS, MPAC/SPAC, and MES at minimum
- B. Mount display at a height accepted by the MBTA.
- C. Provide cable guides, mounting rails, shelves, externally removable side panels, power strips, and other hardware required for a complete control cabinet installation.
- D. Enclosure shall be fully gasketed to protect from the intrusion of dust.
- E. Construction: 19" rack, 42U, 11 gage steel
- F. Finish: Powder-coat paint, black or grey to match the switchgear
- G. Hardware and accessories: Stainless steel
- H. Rating: 2,000 lbs
- I. Wiring: SIS 600V, 150-degrees
- J. Dimensions: 30" deep, minimum

K. Door:

1. Front: Gasketed, key lockable, clear Lexan door for clearly viewing SAS components from the exterior of the enclosure.
2. Rear: Gasketed, removable, vented steel door with reusable aluminum mesh air filter and air flow panels.

L. Ventilation:

1. Fan ventilated with a reusable aluminum mesh air filter.
2. Rack mounted digital temperature monitor and thermostatic fan controller.
3. Enclosure temperature shall be monitored by the SAS.

M. Submit rack mount layouts for approval.

2.10 GPS CLOCK (FUTURE)

A. Not used.

2.11 Technical Support Equipment (TSE)

A. Provide SAS TSE as indicated below. A set of the listed equipment shall be provided for every four substations:

1. Main Programmable Automation Controller: Quantity 2
2. LCMS Display: Quantity 2
3. LCMS Computer Workstation: Quantity 2
4. Industrial Ethernet Switch: Quantity 2 of each type
5. Intelligent Electronic Devices (IED)/Digital input/output devices (DIO): Quantity 2 of each type

B. TSE equipment shall include I/O, communication, and power supply modules necessary to make a complete unit.

C. Submit TSE list prior to delivery for review by the MBTA.

D. Delivery, Storage, and Handling

1. Schedule: Delivery of TSE shall be complete a minimum of 60 days before initial commissioning of the first TPSS.

2. Notice and Shipping List: Provide MBTA notice of delivery and a complete shipping list a minimum of 10 days before delivery. Shipping list shall include the following:
 - a. Quantity of each part
 - b. Manufacturer's part number
 - c. Serial number, if applicable
 - d. Description
 - e. Spaces for inserting date of delivery, signature of DB Entity, and signature of MBTA.
3. Authorization: TSE shall not be shipped until authorized by MBTA.
4. Location: Deliver TSE to a location in greater Boston, Massachusetts metropolitan area designated by the MBTA.
5. Packaging: Package and label TSE in moisture-proof containers suitable for shipment and storage. Attach copies of shipping list in the package and to the exterior of the package. Apply impactographs to shipments. Packages with triggered impactographs shall be replaced at no additional cost to the MBTA.
6. Unloading: Unload TSE in a manner that will prevent damage to the packages and the contents.
7. Inspection:
 - a. The DB Entity will open the packages and inspect TSE for damage. Damaged parts shall be replaced with undamaged parts and materials at no additional expense to the MBTA.
 - b. Sign shipping list with quantities verified, obtain MBTA's signature, and date. MBTA will retain the signed shipping list.

2.12 LCMS HUMAN MACHINE INTERFACE APPLICATION DESIGN

A. HMI functional requirements:

1. Used to control and monitor TPSS equipment from the local workstation.
2. Secured and Web-based accessibility to any workstation connected to the TPSS network.
3. Capable of capturing screen shots as a JPG or another image file accepted by the MBTA.

B. User Management System (UMS):

1. UMS shall provide a secure login for use of the HMI application.

2. Access to the HMI via the LCMS shall have three user levels, minimum:

User Level	Description
Level 1 (Low)	Local Read Only, No password required.
Level 2 (Maintenance)	Level 1 plus, remote access read only, download event log, acknowledge alarms, edit local/remote, control of breakers.
Level 3 (Supervisor)	Level 2 plus, control of breakers, edit settings.

3. Remote access to the HMI shall be password protected and only allow a Level 1 User Level.
 4. Selection of an object for control and modifying settings shall be password protected.
 5. Automatically display a numeric/alphanumeric QWERTY keyboard when a password must be entered to continue.
- C. Graphical User Interface:
1. Substation Control icons for transformers, rectifiers, breakers, and switches shall use electrical circuit symbols.
 2. Button icons shall be intuitively distinguishable from other status icons with graphical feedback for button presses.
 3. Mouse roll-overs shall provide button icon descriptions.
- D. Provide the following HMI Applications: Desktop, Single Line Diagram (SLD), Alarms, Event Log, Document viewer and Help Screen.
- E. Submit screen shots of the HMI design for review by the MBTA.
- F. Desktop:
1. Desktop shall be visible at all times and display the time, date, and navigation bar.
 2. Other applications shall be viewable in “windows” on the desktop.
 3. Time and Date:
 - a. Time shall be synchronized with the MPAC/SPAC.
 - b. Time format: 00:00:00
 - c. Date format: December 10, 2011
 4. Navigation Bar:

- a. Buttons for Substation Control, Annunciator, Event Log, Document Viewer, and Help applications
 - b. User shall be able to navigate to any application from any screen.
 5. Alarm Annunciation
 - a. Desktop shall have a general alarm indication visible from any application.
- G. Substation Control:
1. Display TPSS equipment and a single line diagram.
 2. Display interconnections to adjacent substations.
 3. Show equipment real time status for TPSS equipment.
 4. Real time status information to be provided in the application, minimum:
 - a. AC Line breaker: Current/Volts A, B, C, KWH, KVA, Closed/Open, Local/Remote (as applicable).
 - b. AC feeder breakers: Current/Volts A, B, C, KWH, KVA, Closed/Open, Local/Remote (as applicable)
 - c. DC feeder breakers: Current, Voltage, Closed/Open, Local/Remote
 - d. DC rectifier breakers: Current, Voltage, Closed/Open, Local/Remote
 - e. DC switches: Closed/Open (future)
 - f. Unit Substation circuit breakers: Closed/Open, Local/Remote
 5. Color Code:
 - a. Color shall indicate closed, open, or uncertain states of breakers and switches.
 - 1) Closed: Red
 - 2) Open: Green
 - 3) Fault: Yellow
 - 4) Uncertain: Grey or Blue
 6. Breaker Control:
 - a. Control functions shall be designed such that an accidental single-step selection of an object does not execute a control operation.

- b. Control operation for an object shall have its own control window.
 - c. Labels for the selection, confirmation, and execution shall be described without abbreviations. Final descriptions shall be accepted by the MBTA.
 - d. Control operations shall be automatically cancelled after 60 seconds if not executed.
 - e. Provide a cancel button for each step in the control sequence.
 - f. Control operation sequence:
 - 1) Select object on SLD, which opens up a control window
 - 2) Select operation (close/open) in control window
 - 3) Confirm operation in control window
 - 4) Execute operation in control window
7. Other Software / Monitoring Systems:
- a. SAS system shall support operation of proprietary software for other systems within the TPSS that are provided under the contract e.g. battery monitoring system software and metering software.
 - b. Each software shall be loaded on the substation computer and accessible via the HMI.

H. Alarms:

- 1. Annunciate alarms shown in Points List, at the end of this Section.
- 2. HMI shall display the Alarms screen when a critical alarm occurs.
- 3. Layout shall mimic an actual Annunciator with alarm windows.
- 4. Color Code:
 - a. Alarm: Flashing red.
 - b. Acknowledged alarm: Solid red
 - c. Alarms resolved before acknowledgment: Flashing yellow.
 - d. Default: Grey.
- 5. Alarms shall be acknowledged by selecting the flashing alarm.

I. Event Log:

1. Header: Alarm number, Date/Time, Description, Device and TPSS location
 2. Protective relay trip events shall contain electrical data information, i.e. current value that triggered an overcurrent trip.
 3. Event log shall display a minimum of 200 events with a scroll bar in event log window.
 4. Events shall be retained in memory for minimum 30 days.
 5. Events shall be downloadable to a laptop and a USB flash drive without deletion from the SAS.
 6. Log shall be in CVS or excel compatible format.
- J. Help Screen:
1. Help screen shall contain instructions for operating each application.
 2. Help content shall be indexed alphabetically by application.
 3. Provide contact information for technical support.
 4. Provide software version and date.
- K. Document Viewer:
1. Provide a document viewer application capable of viewing word documents, text files, and PDF.
 2. Viewer shall have zoom and scroll capabilities.
- L. HMI Software Approved Manufacturer:
1. SEL HMI, Wonderware with Substation Automation
 2. Substitutions: Section 00700 General Conditions.
- M. Example Screen Shots
1. The following screen shots are representative of the MBTA's existing SAS system. The DB Entity shall follow the layout, symbols, and organization per the attached screen shots. Screen configuration and requirements are subject to change based on proposed equipment and MBTA requirements.

Substation Overview AC Switchgear Transformers & Rectifiers DC Switchgear Communication & Network Event History Alarm Summary Alarm History

- Annunciator
- One Line
- Legend

RECT #1 LOCKOUT 86-T1	RECT #1 CONDITIONAL LOCKOUT 86X-T1	RECT #1 LOCKOUT CKT DC SUPPLY FAILURE 27R	TRANSFORMER #1 DC AUX CIRCUIT SUPPLY FAILURE 27RA		RECT #2 LOCKOUT 86-T2	RECT #2 CONDITIONAL LOCKOUT 86X-T2	RECT #2 LOCKOUT CKT DC SUPPLY FAILURE 27R	TRANSFORMER #2 DC AUX CIRCUIT SUPPLY FAILURE 27RA	
RECT #1 SURGE PROTECTION CKT FAILURE 99Y		RECT #1 STRUCTURE GROUNDED 64RX	RECT #1 STRUCTURE HOT 64R	RECT #1 INCOMPLETE START 48	RECT #2 SURGE PROTECTION CKT FAILURE 99Y		RECT #2 STRUCTURE GROUNDED 64RX	RECT #2 STRUCTURE HOT 64R	RECT #2 INCOMPLETE START 48
RECT #1 DOOR OPEN 33R	RECT #1 XFMR OVERTEMP 26TH/49WTH	RECT #1 NEG LEAD DISC SWITCH OPEN 89N	MAIN DC BREAKER 72-R1 REVERSE CURRENT TRIP 32X	DC SWITCHGEAR STRUCTURE GROUNDED 164SX	RECT #2 DOOR OPEN 33R	RECT #2 XFMR OVERTEMP 26TH/49WTH	RECT #2 NEG LEAD DISC SWITCH OPEN 89N	MAIN DC BREAKER 72-R2 REVERSE CURRENT TRIP 32X	
DC SWITCHGEAR STRUCTURE HOT 164S	13.8KV SWGR BUS A/B DIFF LOCKOUT 86B1/86B2 *	13.8KV SWGR BUS A/B UNDERVOLTAGE 47-1/47-2	13.8KV SWGR FEEDER CABLE OVERLOAD 51CX *	13.8KV SWGR LOCKOUT CKT DC FAIL 27B1/27B2 *				STATION BATTERY TROUBLE 59, 27BA, 27BB *	FIRE ALARM TROUBLE SW *
UNIT SUBSTATION TROUBLE 49 TSS	RECTIFIER TRANSFORMER LOW OIL 71-T1	RECTIFIER TRANSFORMER SUDDEN PRESSURE/ PRESSURE RELIEF 63P/63MR-1	13.8KV SWGR PROTECTIVE RELAY *		FIRE *	RECTIFIER TRANSFORMER LOW OIL 71-T2	RECTIFIER TRANSFORMER SUDDEN PRESSURE PRESSURE RELIEFE 63P/63MR-2		
RECT #1 DIODE FUSE BLOWN 59A/98		OIL CONTAINMENT SUMP PUMP TROUBLE **			RECT #2 DIODE FUSE BLOWN 59A/98	DC SWITCHGEAR 115V AC RELIABLE SUPPLY FAIL 27SB	DC SWITCHGEAR 125V DC CONTROL SUPPLY FAIL 27SA		

Annunciator Screen

**Reset Station
Trouble**

Manual-reset Lockout 86T(1) Present

Manual-reset Lockout 86T(2) Present

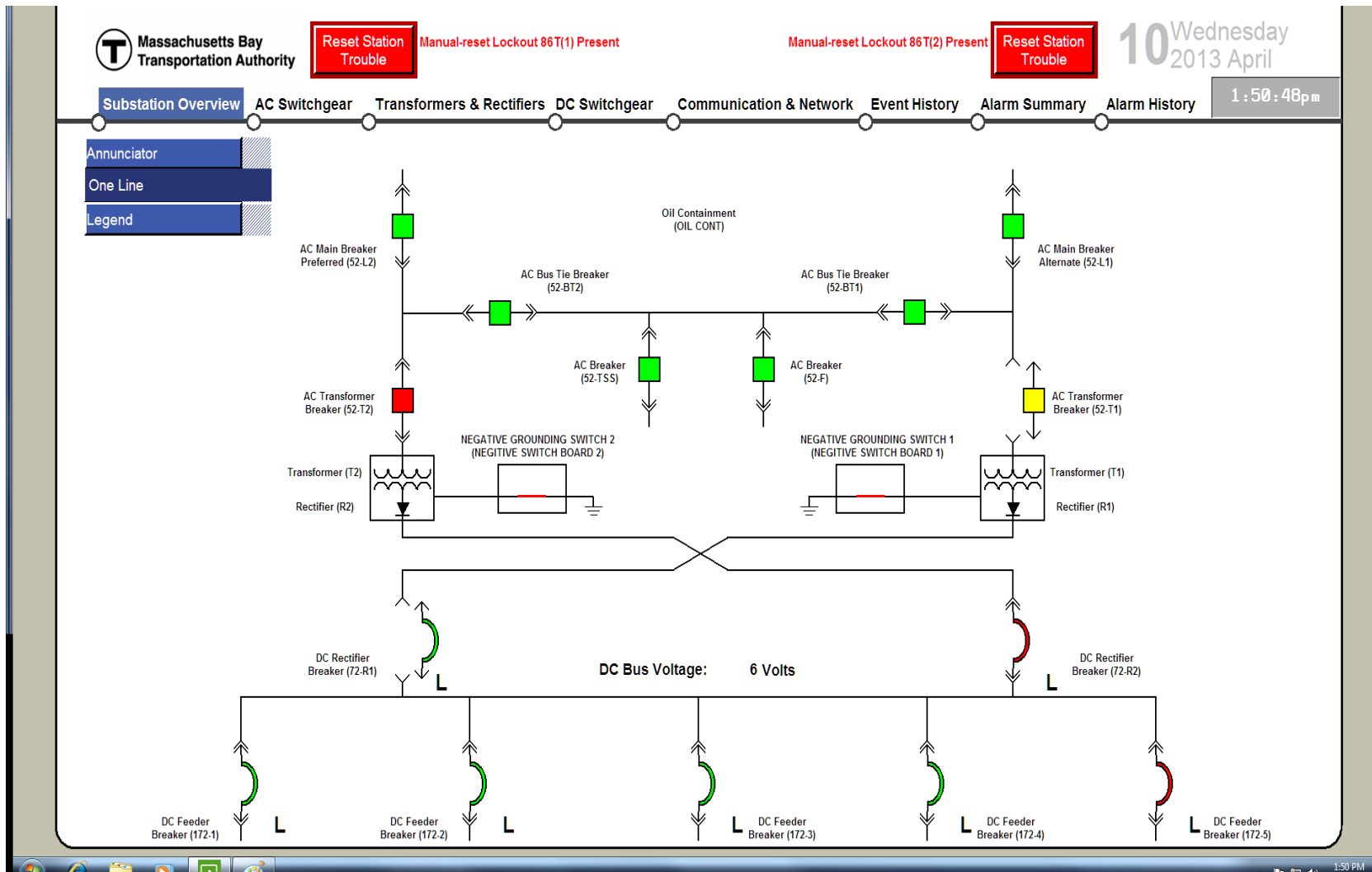
**Reset Station
Trouble**

- Substation Overview
- AC Switchgear
- Transformers & Rectifiers
- DC Switchgear
- Communication & Network
- Event History
- Alarm Summary
- Alarm History

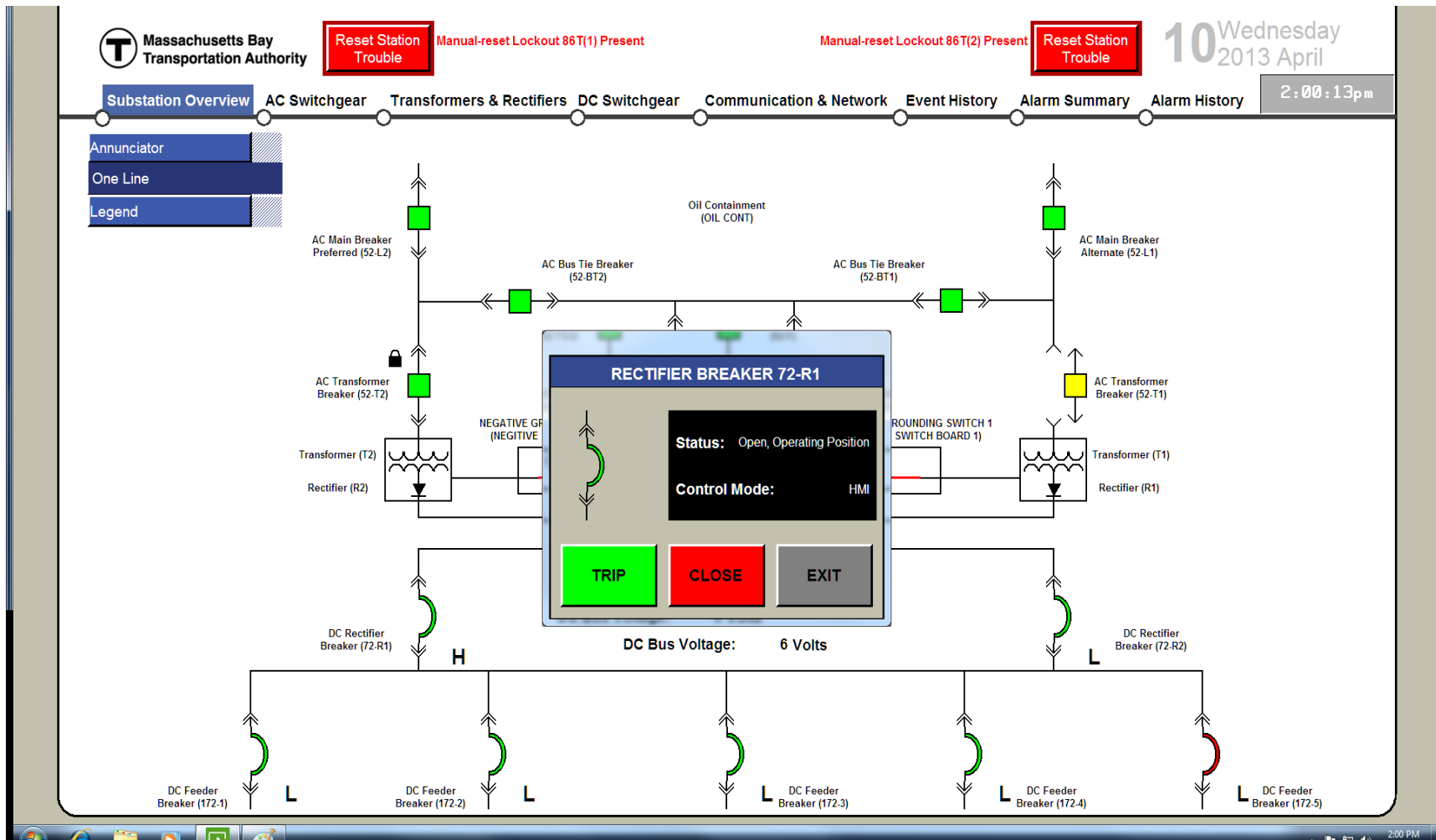
- Annunciator
- One Line
- Legend

RECT #1 LOCKOUT 86-T1	86T(1)	86TX(1)	RECT #2 LOCKOUT 86-T2	RECT #2 CONDITIONAL LOCKOUT 86X-T2	RECT #2 LOCKOUT CKT DC SUPPLY FAILURE 27R	TRANSFORMER #2 DC AUX CIRCUIT SUPPLY FAILURE 27RA	
RECT #1 SURGE PROTECTION CKT FAILURE 99Y	R1 Hot Structure 64R ● R1 Door Open 33 ● A1 Start Sequence Failure 48 ● U72R1 Reverse Current Trip 32 ● U72R1 CBCM Trip 32 ● 52T1 Locked Out 86RT ● 52T1 Sudden Pressure Relief 62P ● A1 T1 Low Oil 71T ● R1 2nd Stage Diode Fail 58T ● 89N1 Open ● 89N1 Not Closed ● R1 SEL2240 Comm Fail ● A1 SEL2440 Comm Fail ● U72R1 Comm Fail ●	R1 2nd Stage Diode Temp 26RH ● T1 27RA ● T1 2nd Stage Winding Temp 49WTH ● T1 2nd Stage Oil Temp 26TH ● R1 27R ●	RECT #2 SURGE PROTECTION CKT FAILURE 99Y		RECT #2 STRUCTURE GROUNDED 64RX	RECT #2 STRUCTURE HOT 64R	RECT #2 INCOMPLETE START 48
RECT #1 DOOR OPEN 33R	A1 T1 Low Oil 71T ● R1 2nd Stage Diode Fail 58T ● 89N1 Open ● 89N1 Not Closed ● R1 SEL2240 Comm Fail ● A1 SEL2440 Comm Fail ● U72R1 Comm Fail ●	EXIT	RECT #2 DOOR OPEN 33R	RECT #2 XFMR OVERTEMP 26TH/49WTH	RECT #2 NEG LEAD DISC SWITCH OPEN 89N	MAIN DC BREAKER 72-R2 REVERSE CURRENT TRIP 32X	
DC SWITCHGEAR STRUCTURE HOT 164S	89N1 Open ● 89N1 Not Closed ● R1 SEL2240 Comm Fail ● A1 SEL2440 Comm Fail ● U72R1 Comm Fail ●	EXIT				STATION BATTERY TROUBLE 59, 27BA, 27BB *	FIRE ALARM TROUBLE SW *
UNIT SUBSTATION TROUBLE 49 TSS							
RECT #1 DIODE FUSE BLOWN 59A/98			RECT #2 DIODE FUSE BLOWN 59A/98	DC SWITCHGEAR 115V AC RELIABLE SUPPLY FAIL 27SB	RECTIFIER TRANSFORMER LOW OIL 71-T2	RECTIFIER TRANSFORMER SUDDEN PRESSURE PRESSURE RELIEFE 63P/63MR-2	
					DC SWITCHGEAR 125V DC CONTROL SUPPLY FAIL 27SA		

Annunciator Screen – Expansion into lockout & Conditional lockout

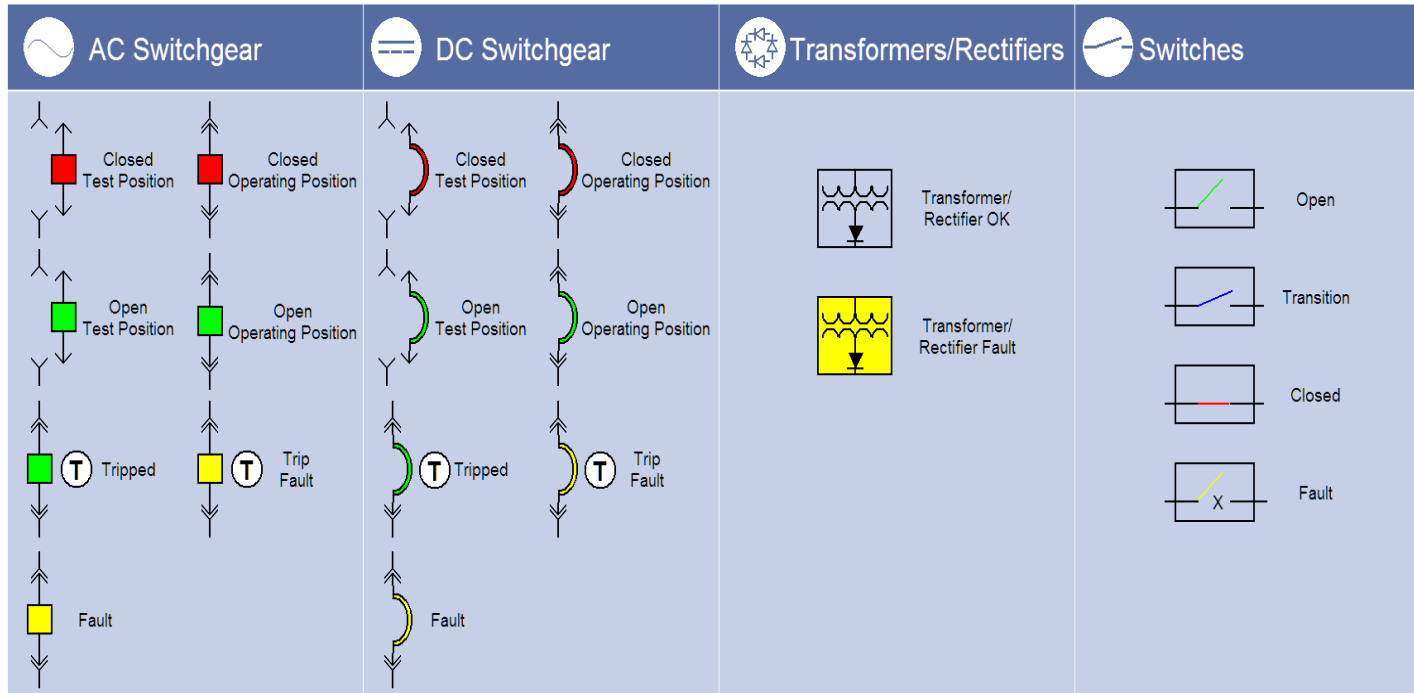


Substation Single Line Diagram




Substation Single Line Diagram – Typical Breaker Control

- Annunciator
- One Line
- Legend



Substation SAS Legend


Massachusetts Bay Transportation Authority

10 Wednesday 2013 April
 1:51:16pm

Reset Station Trouble
Manual-reset Lockout 86T(1) Present
Manual-reset Lockout 86T(2) Present
Reset Station Trouble

Substation Overview | **AC Switchgear** | Transformers & Rectifiers | DC Switchgear | Communication & Network | Event History | Alarm Summary | Alarm History

52-L2	52-BT2	52-TSS	52-F	52-BT1	52-L1
Status: Not Closed Voltage AB: 0.0 kVolts Voltage BC: 0.0 kVolts Voltage CA: 0.0 kVolts Current A: 0 Amps Current B: 0 Amps Current C: 0 Amps Power Usage: 2 6 2 9 2 6 1 MWh Breaker Closed (52-L2a) ● Bus Differential Lockout (86B) ● Phase Sequence/Undervoltage Alarm (47) ● Loss of Control Voltage (27A) ●	Status: Not Closed Current A: 0 Amps Current B: 0 Amps Current C: 0 Amps Breaker Closed (52-BT2a) ●	Status: Not Closed Voltage AB: 0.0 kVolts Voltage BC: 0.0 kVolts Voltage CA: 0.0 kVolts Current A: 0 Amps Current B: 0 Amps Current C: 0 Amps Power Usage: 0 kWh Breaker Closed (52-TSSa) ● Locked Out (86TSS) ●	Status: Not Closed Current A: 0 Amps Current B: 0 Amps Current C: 0 Amps Breaker Closed (52-Fa) ● Locked Out (86F) ●	Status: Not Closed Current A: 0 Amps Current B: 0 Amps Current C: 0 Amps Breaker Closed (52-BT2a) ●	Status: Not Closed Voltage AB: 0.0 kVolts Voltage BC: 0.0 kVolts Voltage CA: 0.0 kVolts Current A: 0 Amps Current B: 0 Amps Current C: 0 Amps Power Usage: 0 kWh Breaker Closed (52-L1a) ● Bus Differential Lockout (86B) ● Phase Sequence/Undervoltage Alarm (47) ● Loss of Control Voltage (27A) ●
Oil Containment		System Status		Fire Panel	
Loss Of Control Voltage ● Oil Present ● High Water ●		PLC Cabinet Door Open ●		Fire Alarm System Trouble ● Fire Alarm System Alarm ●	
		Battery Charger			
		Battery Voltage High ● AC Undervoltage ● DC Undervoltage ●			

AC Switchgear Status Screen

Massachusetts Bay Transportation Authority

Reset Station Trouble Manual-reset Lockout 86T(1) Present Manual-reset Lockout 86T(2) Present Reset Station Trouble


10 Wednesday 2013 April 1:51:30pm

Substation Overview AC Switchgear **Transformers & Rectifiers** DC Switchgear Communication & Network Event History Alarm Summary Alarm History

Breakers Rectifiers & NDS

52-T1	T1	72-R1	72-R2	T2	52-T2
Status: Fault Control Mode: Local Phase A: 0.00 Amps Phase B: 0.00 Amps Phase C: 0.00 Amps	Transformer Oil Temperature Alarm Transformer Oil Temperature Trip Transformer Winding Temperature Alarm Transformer Winding Temperature Trip Transformer Sudden Pressure Trip Transformer Pressure Relief Alarm Transformer Oil Level Alarm Transformer Oil Level Trip Loss of Control Voltage	Status: Open, Test Position Control Mode: Local Voltage: -65 Volts Current: 27.66 Amps Wattage: -1 Watts	Status: Closed, Operating Position Control Mode: Local Voltage: -65 Volts Current: 24.41 Amps Wattage: -1 Watts	Status: Closed, Operating Position Control Mode: Local Phase A: 0.00 Amps Phase B: 0.00 Amps Phase C: 0.00 Amps	72-R2 Selector Switch in REMOTE Position 72-R2 Selector Switch in LOCAL Position Master Relay 4 CLOSE command 72-R2 Control Switch in TRIP Position Remote TRIP command 86RT Lockout 86T/TX Lockout Redundant (A2) 86T/TX Lockout OPEN command when 72-R2 opens
72-R1 Selector Switch in REMOTE Position 72-R1 Selector Switch in LOCAL Position Master Relay 4 CLOSE command 72-R1 Control Switch in TRIP Position Remote TRIP command 86RT Lockout 86T/TX Lockout Redundant (A2) 86T/TX Lockout OPEN command when 72-R1 opens		CBCM 32 Direct Acting Trip Selector Switch in SUPV Position Selector Switch in HMI Position Selector Switch in LOCAL Position 72 Hand Switch in CLOSE Position 72 Hand Switch in TRIP Position Structure Grounded Structure Hot Internal Relay Fault Loss of Control Voltage	CBCM 32 Direct Acting Trip Selector Switch in SUPV Position Selector Switch in HMI Position Selector Switch in LOCAL Position 72 Hand Switch in CLOSE Position 72 Hand Switch in TRIP Position Structure Grounded Structure Hot Internal Relay Fault Loss of Control Voltage	Transformer Oil Temperature Alarm Transformer Oil Temperature Trip Transformer Winding Temperature Alarm Transformer Winding Temperature Trip Transformer Sudden Pressure Trip Transformer Pressure Relief Alarm Transformer Oil Level Alarm Transformer Oil Level Trip Loss of Control Voltage	72-R2 Selector Switch in REMOTE Position 72-R2 Selector Switch in LOCAL Position Master Relay 4 CLOSE command 72-R2 Control Switch in TRIP Position Remote TRIP command 86RT Lockout 86T/TX Lockout Redundant (A1) 86T/TX Lockout OPEN command when 72-R2 opens

Rectifier / Rectifier Transformer Set Status Screen


Massachusetts Bay Transportation Authority

Reset Station Trouble
Manual-reset Lockout 86T(1) Present

Manual-reset Lockout 86T(2) Present
Reset Station Trouble
10
Wednesday
2013 April

Substation Overview
AC Switchgear
Transformers & Rectifiers
DC Switchgear
Communication & Network
Event History
Alarm Summary
Alarm History
1:51:47pm

Breakers

Rectifiers & NDS

⚡
R1
Loss of Control Voltage

- Diode Temperature Alarm
- Diode Temperature Trip
- Blown Surge Arrestor 1 Fuse
- Blown Surge Arrestor 2 Fuse
- Structure Ground Alarm
- Structure Hot Trip
- Cabinet Door Open Trip

		Bank											
		1	2	3	4	5	6	7	8	9	10	11	12
Diode	A	●	●	●	●	●	●	●	●	●	●	●	●
	B	●	●	●	●	●	●	●	●	●	●	●	●
	C	●	●	●	●	●	●	●	●	●	●	●	●

⚡
R2
Loss of Control Voltage

- Diode Temperature Alarm
- Diode Temperature Trip
- Blown Surge Arrestor 1 Fuse
- Blown Surge Arrestor 2 Fuse
- Structure Ground Alarm
- Structure Hot Trip
- Cabinet Door Open Trip

		Bank											
		1	2	3	4	5	6	7	8	9	10	11	12
Diode	A	●	●	●	●	●	●	●	●	●	●	●	●
	B	●	●	●	●	●	●	●	●	●	●	●	●
	C	●	●	●	●	●	●	●	●	●	●	●	●

⚡
89N-1

Status: Closed

NDS-1 Closed ●

NDS-1 Open ●

89 - A: 5 Amps

89 - B: 4 Amps

89 - C: 5 Amps

⚡
89N-2

Status: Closed

NDS-2 Closed ●

NDS-2 Open ●

89 - A: 5 Amps

89 - B: 6 Amps

89 - C: 5 Amps

Rectifier and Negative Drainage Status Screen

172-1	172-2	172-3	172-4	172-5
Status: Open, Operating Position	Status: Open, Operating Position	Status: Open, Operating Position	Status: Open, Operating Position	Status: Closed, Operating Position
Control Mode: Local	Control Mode: Local	Control Mode: Local	Control Mode: Local	Control Mode: Local
Voltage: -65 Volts	Voltage: -65 Volts	Voltage: -65 Volts	Voltage: -97 Volts	Voltage: -65 Volts
Current: 17.90 Amps	Current: 14.64 Amps	Current: 17.08 Amps	Current: 8.95 Amps	Current: 11.39 Amps
Wattage: -4 Watts	Wattage: -6 Watts	Wattage: -4 Watts	Wattage: -6 Watts	Wattage: -6 Watts
CBCM 76 Direct Acting Trip <input type="radio"/>	CBCM 76 Direct Acting Trip <input type="radio"/>	CBCM 76 Direct Acting Trip <input type="radio"/>	CBCM 76 Direct Acting Trip <input type="radio"/>	CBCM 76 Direct Acting Trip <input type="radio"/>
Selector Switch in SUPV Position <input type="radio"/>	Selector Switch in SUPV Position <input type="radio"/>	Selector Switch in SUPV Position <input type="radio"/>	Selector Switch in SUPV Position <input type="radio"/>	Selector Switch in SUPV Position <input type="radio"/>
Selector Switch in HMI Position <input type="radio"/>	Selector Switch in HMI Position <input type="radio"/>	Selector Switch in HMI Position <input type="radio"/>	Selector Switch in HMI Position <input type="radio"/>	Selector Switch in HMI Position <input type="radio"/>
Selector Switch in LOCAL Position <input checked="" type="radio"/>	Selector Switch in LOCAL Position <input checked="" type="radio"/>	Selector Switch in LOCAL Position <input checked="" type="radio"/>	Selector Switch in LOCAL Position <input checked="" type="radio"/>	Selector Switch in LOCAL Position <input checked="" type="radio"/>
72 Hand Switch in CLOSE Position <input type="radio"/>	72 Hand Switch in CLOSE Position <input type="radio"/>	72 Hand Switch in CLOSE Position <input type="radio"/>	72 Hand Switch in CLOSE Position <input type="radio"/>	72 Hand Switch in CLOSE Position <input type="radio"/>
72 Hand Switch in TRIP Position <input type="radio"/>	72 Hand Switch in TRIP Position <input type="radio"/>	72 Hand Switch in TRIP Position <input type="radio"/>	72 Hand Switch in TRIP Position <input type="radio"/>	72 Hand Switch in TRIP Position <input type="radio"/>
Load Measuring Bypass Switch in BYPASS Position <input type="radio"/>	Load Measuring Bypass Switch in BYPASS Position <input type="radio"/>	Load Measuring Bypass Switch in BYPASS Position <input type="radio"/>	Load Measuring Bypass Switch in BYPASS Position <input type="radio"/>	Load Measuring Bypass Switch in BYPASS Position <input type="radio"/>
Direct Acting Over Current Trip <input type="radio"/>	Direct Acting Over Current Trip <input type="radio"/>	Direct Acting Over Current Trip <input type="radio"/>	Direct Acting Over Current Trip <input type="radio"/>	Direct Acting Over Current Trip <input type="radio"/>
Timed Over Current Trip <input type="radio"/>	Timed Over Current Trip <input type="radio"/>	Timed Over Current Trip <input type="radio"/>	Timed Over Current Trip <input type="radio"/>	Timed Over Current Trip <input type="radio"/>
Line Test In Progress <input type="radio"/>	Line Test In Progress <input type="radio"/>	Line Test In Progress <input type="radio"/>	Line Test In Progress <input type="radio"/>	Line Test In Progress <input type="radio"/>
Rate of Rise Trip <input type="radio"/>	Rate of Rise Trip <input type="radio"/>	Rate of Rise Trip <input type="radio"/>	Rate of Rise Trip <input type="radio"/>	Rate of Rise Trip <input type="radio"/>
Internal Relay Fault <input type="radio"/>	Internal Relay Fault <input type="radio"/>	Internal Relay Fault <input type="radio"/>	Internal Relay Fault <input type="radio"/>	Internal Relay Fault <input type="radio"/>

DC Switchgear Status Screen

Bottom Pg Up Up Down Pg Down Top



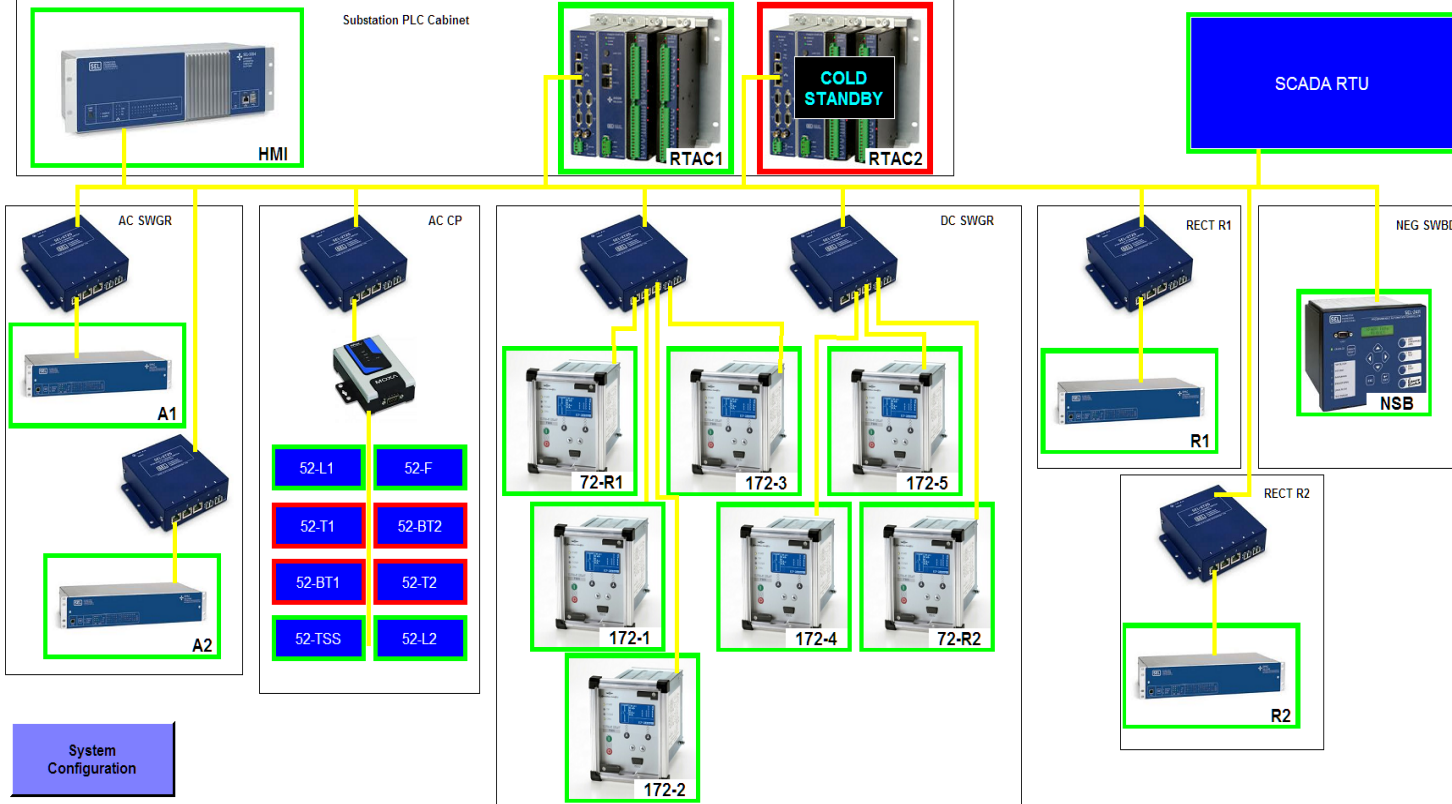
Message	Date	Time	ACK
52-T2: Breaker Open	04/10/13	1:54:56pm	
72-R2: Breaker Open	04/10/13	1:54:56pm	
72-R2: Breaker Closed	04/10/13	1:54:47pm	
52-T2: Breaker Closed	04/10/13	1:54:46pm	
172-3: Breaker Open	04/10/13	1:50:30pm	
172-3: Breaker Closed	04/10/13	1:49:24pm	
172-4: Line Test in Progress	04/10/13	1:48:57pm	
172-5: Breaker Closed	04/10/13	1:48:54pm	
172-5: Breaker Open	04/10/13	1:47:57pm	
172-1: Breaker Open	04/10/13	1:44:39pm	
172-2: Breaker Open	04/10/13	1:44:36pm	
172-4: Breaker Open	04/10/13	1:44:30pm	
172-5: Line Test in Progress	04/10/13	1:38:04pm	
172-5: Selector Switch in LOCAL Position	04/10/13	1:21:12pm	
172-5: TOC is Connected	04/10/13	1:21:12pm	
72-R1: Selector Switch in LOCAL Position	04/10/13	1:21:08pm	
72-R1: Breaker Open	04/10/13	1:21:08pm	
72-R2: Selector Switch in LOCAL Position	04/10/13	1:21:04pm	
72-R2: TOC is Connected	04/10/13	1:21:04pm	
172-1: Breaker Closed	04/10/13	1:21:00pm	
172-1: Selector Switch in LOCAL Position	04/10/13	1:21:00pm	
172-1: TOC is Connected	04/10/13	1:21:00pm	
172-2: Selector Switch in LOCAL Position	04/10/13	1:21:00pm	
172-2: TOC is Connected	04/10/13	1:21:00pm	
172-2: Breaker Closed	04/10/13	1:21:00pm	
172-4: Selector Switch in LOCAL Position	04/10/13	1:20:58pm	
172-4: TOC is Connected	04/10/13	1:20:58pm	
172-4: Breaker Closed	04/10/13	1:20:58pm	
172-3: Selector Switch in LOCAL Position	04/10/13	1:20:57pm	
172-3: TOC is Connected	04/10/13	1:20:57pm	

Substation Event History Status Screen



Message	Date	Time	ACK
T1 is Offline	04/10/13	1:58:11pm	
F is Offline	04/10/13	1:58:09pm	
BT1 is Offline	04/10/13	1:58:01pm	
BT2 is Offline	04/10/13	1:58:01pm	
L2 is Offline	04/10/13	1:58:00pm	
L1 is Offline	04/10/13	1:57:55pm	
SS is Offline	04/10/13	1:57:54pm	
T2 is Offline	04/10/13	1:57:40pm	
F is Offline	04/10/13	1:56:49pm	1:56:52pm
T2 is Offline	04/10/13	1:56:46pm	1:56:52pm
L1 is Offline	04/10/13	1:56:44pm	1:56:52pm
SS is Offline	04/10/13	1:56:43pm	1:56:52pm
T1 is Offline	04/10/13	1:56:40pm	1:56:52pm
BT1 is Offline	04/10/13	1:56:33pm	1:56:52pm
BT2 is Offline	04/10/13	1:56:33pm	1:56:52pm
L2 is Offline	04/10/13	1:55:31pm	1:56:52pm
52-T2: 86T or TX Lockout	04/10/13	1:54:55pm	1:56:52pm
72-R2: Internal Relay Fault	04/10/13	1:54:55pm	1:56:52pm
172-3: Load Measuring Bypass Switch in BYPASS Position	04/10/13	1:49:22pm	1:56:52pm
172-4: Load Measuring Bypass Switch in BYPASS Position	04/10/13	1:49:09pm	1:56:52pm
Rectifier 1: Bank 9 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 11 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 10 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 12 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 5 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 6 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 8 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 7 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 4 Diode Trip	04/10/13	1:19:30pm	1:56:52pm
Rectifier 1: Bank 3 Diode Trip	04/10/13	1:19:30pm	1:56:52pm

Substation Alarm History Status Screen



Substation SAS Network Status

2.13 DEVELOPMENT SOFTWARE

- A. Provide a user-friendly PC/Windows based development environment suitable for SAS/HMI application software updating and modification.
- B. The environment shall be dedicated solely to creating control/monitoring software. It shall use familiar, standardized editors bundled into a single application.
- C. The environment shall include a graphics editor and online help tools to simplify the development of SAS/HMI application software.
- D. The environment shall comply with IEC 61131-2 standards for programmable logic controllers.
- E. Provide de-bug, documentation and machine startup facilities in the environment.
- F. Provide complete user training for the application of development environment.
- G. Provide complete user documentation for the environment complying with Section 01700 Contract Closeout.

2.14 FACTORY ACCEPTANCE TEST

- A. The SAS shall be factory tested prior to installation in the substation.
- B. Design test shall be used to verify proper functionality of the system and verify contract requirements. Design test shall utilize as many field devices as possible for the source controls and indications and shall prove the system end-to-end.
- C. Factory acceptance test shall be a witness test. Simulation of field devices shall be acceptable.
- D. A mock-up TPSS I/O board shall be used to simulate substation equipment I/O.
- E. Test Procedure:
 - 1. Submit a step-by-step test procedure prior to test.
 - 2. Testing shall include steps to prove the reliability and maintainability conditions of the SAS listed in this Section.
 - 3. Include specific acceptance criteria and expected results for each step.
 - 4. Include a test schedule.
 - 5. Test procedure must be accepted by the MBTA prior to testing.

6. The DB Entity shall test data polling, communications, and time synchronization for the following:
 - a. Interconnectivity between SAS components
 - b. Between SAS components and substation electrical equipment
 - c. MPAC/SPAC and the SCADA Terminal Board
 - d. The DB Entity shall test data polling and communications at the point of interface with the SCADA system. Testing software may be used to simulate the communication interface between the SAS and SCADA.
 7. The DB Entity shall perform functional tests on the LCMS including, but not limited to, the following:
 - a. Desktop
 - b. Navigation Bar
 - c. Annunciator
 - d. Event Log
 - e. Substation Control
 - f. Graphical Interface
 - g. User Management System
 8. Include copies of relevant standards and diagram required for the test.
 9. The DB Entity shall be responsible for integration of the SAS system with all equipment including SCADA.
- F. Submit test reports in accordance with Section 16495 Electrical Acceptance Tests.

2.15 POINTS LIST

- A. Provide the following points for control, monitoring, status and indication to the SAS LCMS and SCADA for each TPSS.
- B. Points shall be applied to each piece of equipment in each Category.

Category	Point Description
ACCP	AC Breaker trip/close control
	AC Breaker remote trip/close control
	AC Breaker open/closed status
	AC Breaker Local/Remote/HMI/Off status
	Current Phases A, B, C (as applicable)
	Voltage Phases A, B, C (as applicable)
	AC Breaker KW, KWH, KVA (totalizing shall be performed within the SAS)
AC Switchgear	AC Breaker trip/close control
	AC Breaker remote trip/close control
	AC Breaker open/closed status
	AC Breaker 50/51/51N Protection Operated
	AC Breaker Local/Remote/HMI/Off status
	Current Phases A, B, C (as applicable)
	Voltage Phases A, B, C (as applicable)
	AC Breaker KW, KWH, KVA (totalizing shall be performed within the SAS)
	Bus Differential Protection Operated 87B
	Bus Lockout 86B

Category	Point Description
Rectifier/Transformer Set	Rectifier/Rectifier Transformer #1 in Soak Mode
	Rectifier/Rectifier Transformer #2 in Soak Mode
DC Switchgear	DC Breaker (feeder, rectifier) trip/close control
	DC Breaker (feeder, rectifier) remote trip/close control
	DC breaker (feeder, rectifier) open/closed status
	DC breaker (feeder, rectifier) Local/Remote/HMI/Off status
	102X DC breaker load measuring
	Overvoltage
	Undervoltage
	176/176X Instantaneous Overcurrent Trip
	176F Timed Overcurrent Trip
	150FX Rate of Rise di/dt
	Loss of Control power
	DC Voltage
	DC Current
	197X Cable Alive indication
	32 Reverse Current (rectifier breaker)
	Transfer Trip (Programmed feature, not enabled)
	Transfer Trip Lockout (Programmed feature, not enabled)
	33 Access Door
164S DC Switchgear Hot Structure	
164SX DC Switchgear Grounded Structure	

Category	Point Description
Traction Power Transformers	49WT Over Temperature 1 Alarm
	49WTH Over Temperature 2 Trip
	26T Oil Over Temperature Alarm
	26TH Oil Over Temperature Trip
	63P Sudden Pressure Relay
	63MR Pressure Relief
	71T Oil Level Relay
	Temperature Monitor Status
Rectifiers	Over Temperature 1 Alarm
	Over Temperature 2 Trip
	Temp Monitor Status
	Diode Failure 1 Alarm 58A
	Diode Failure 2 Trip 58T
	Access Doors 33
	48 Incomplete Sequence Relay
	99Y Rectifier Surge Suppression Monitor
	27RA DC Auxiliary Control Under Voltage
	64R Rectifier Hot Structure
	64RX Rectifier Grounded Structure
	86 Lockout Relay
	86X Conditional Lockout Relay
	164S Rectifier Hot Structure
	164SX Rectifier Grounded Structure
Elapsed Time Meter	
Rectifier Overtemperature Trip counter	
Negative Switchboard	89N Negative Disconnect Switch open/closed status
Battery Chargers	Battery Alarm/Control 1
	Battery Alarm/Control 2
	Battery Alarm/Control 3
	Battery Alarm/Control 4
	Battery Alarm/Control 5
	Battery Alarm/Control 6
Battery Charger Monitor	Alarms and status as required.
Category	Point Description

Unit Substation	Main Breaker & Bus-tie trip/close control
	Main Breaker & Bus-tie remote trip/close control
	Main Breaker & Bus-tie open/closed status
	Main Breaker & Bus-tie Local/Remote/HMI/Off status
TPSS Facility I/O	High Temperature Alarm
	Fire/Smoke alarm
	Intrusion Zone 1 (access doors)
	HVAC Status Alarm
	27Q Pump Power Fail (if applicable)
	71W Sump High Water (if applicable)
	99Q Oil Detected in Sump (if applicable)
	Substation trouble (30X)
SAS	MPAC Watchdog Alarm
	Equipment Rack Over temperature Alarm
	ACCP IED Watchdog Alarm
	AC Switchgear IED Watchdog Alarm/IPR Watchdog
	MES Watchdog Alarm
	MPR Watchdog Alarm
	Rectifier Transformer/Rectifier IED Watchdog Alarm
	DIO Watchdog
	LCMS Watchdog Alarm

C. In addition, provide the points listed in Section 16311.

2.16 TRAINING

- A. Provide instruction to a level of detail necessary for operation, configuration, and preventive, corrective, and overhaul maintenance of SAS.
- B. Location: The training program shall be conducted at location designated by the MBTA in the Greater Boston Area.
- C. Training Format: Training shall include classroom and hands-on instruction. A minimum of fifty percent of the time shall be spent on hands-on instruction.
- D. Training Duration:
 - 1. Size of classes, time and location for the training shall be accepted in advance by the MBTA. The DB Entity shall propose the training content and expected duration.
- E. Training Instructors:

1. Provide qualified training instructors who have direct knowledge and experience in the subject matter that they will present.
 2. Instructors shall be capable of providing detailed explanations of the operation and maintenance of both systems and individual devices and answering any questions that may arise during classes.
 3. Instructors shall be fluent in English.
 4. Instructors shall be able to provide instruction that can be understood by high school graduates with no basic experience in the SAS.
- F. Training Instructor Orientation: If required, a minimum of 30 days before starting training, training instructors shall attend a 1-day orientation at the MBTA to become familiar safety regulations and facilities, and to be advised of student qualifications and expectations.
- G. Trainees: MBTA Operation and Maintenance personnel.
- H. Training Materials:
1. Submit training materials for acceptance by the MBTA.
 2. The training materials shall be high quality, professionally prepared, and support the training courses.
 3. The same training materials shall be used for each class so that each class is exposed to the same information and comments can be collected on training manuals.
 4. If the instructor modifies lesson plans or other elements of the training during actual training, update and distribute the affected training materials to trainees. Submit the revised training materials after training is complete.
 5. All training materials shall become the property of the MBTA at the completion of the training program. Replace damaged training materials before delivering to the MBTA.
- I. Document Format
1. Documents shall be MS Windows compatible files using a software format agreed upon by the MBTA.
 2. Drawings shall be in AutoCAD format.
 3. Both documents and drawings shall also be provided in PDF format.
 4. Photographic images shall be JPG files.
- J. Media
1. Provide electronic files on USB flash drives.

2. Provide final versions of hard copy training materials printed on 8-1/2 x 11 paper.
3. Provide drawings on 11 x 17 paper.
4. Binders for hard copies shall be heavy duty D-ring style.

K. Training Scope and Content

1. Training content shall include the configuration, operation and maintenance of the following SAS components:
 - a. MPAC/SPAC
 - b. LCMS
 - c. IEDs/DIOs
 - d. MPRs / IPR's
 - e. Network Switches, managed and unmanaged.
 - f. Equipment Rack
2. Training instruction shall include at a minimum the following:
 - a. Introduction to the equipment, including terminology, identification of major components, and location in the substation
 - b. Problem symptoms, troubleshooting techniques and repair procedures
 - c. Hands-on experience in troubleshooting systems with faults by artificially introducing faults in the equipment
 - d. Removal and replacement of components
 - e. Disassembly and reassembly for the purpose of component familiarity and any special processes
 - f. Instruction in the use and maintenance of all special tools and processes
 - g. Safety instruction for all maintenance activities
 - h. Overhaul procedures
 - i. Customizing the LCMS HMI screens using the developer software
 - j. PLC (MPAC) network configuration for the interface with the existing MBTA SCADA System.

PART 3 EXECUTION

3.1 ASSEMBLY

- A. SAS hardware installation shall be identical and interchangeable between substations, including wire numbering, and marking.
- B. Provide wiring, terminal blocks, and hardware in accordance with Section 16201 Basic Materials and Methods for Electrical Work for a complete SAS installation.
- C. Provide SAS accessories and peripherals necessary for a complete installation.
- D. Wiring:
 - 1. Interconnecting wiring in accordance with Section 16201 Basic Materials and Methods for Electrical Work
 - 2. Wire and cables shall be identified whenever they enter or leave a housing or enclosure, and at terminals.
 - 3. Provide labels in accordance with Section 16201 Basic Materials and Methods for Electrical Work
- E. Spare Capacity:
 - 1. Design system with a suitable spare capacity to be proposed by the DB Entity. Typical minimum spare requirement is 30%. This shall include:
 - a. Wiring terminals
 - b. Inputs and outputs of same kind per modular controller unit
 - c. Spaces for additional modules for each modular unit
- F. Workmanship:
 - 1. Install equipment, enclosures, wire, cable, conduits and wireways in a neat and secure manner, level and plumb, and in true alignment with adjoining work.
 - 2. Equipment enclosures and installation shall comply with local and national codes including, but not limited to UL 508A and NFPA 70.

3.2 FIELD ACCEPTANCE TEST (FAT)

- A. The DB Entity shall perform an FAT on substations with SAS equipment fully integrated.

- B. The FAT's shall be performed under the supervision of a qualified manufacturer's technical representative. This representative shall assist proper coordination of the SAS with the MBTA's SCADA system.
- C. The DB Entity shall perform operational tests to confirm proper control operation of TPSS through the SAS and SCADA system.
- D. SAS operational testing shall, at a minimum, include the following tests:
 - 1. Communication testing between SAS components
 - 2. Point-to-point and I/O testing between SAS components and TPSS equipment
 - 3. Logic testing of SAS components
 - 4. Verification of data communications message formats and protocol, including all I/O bit assignments for SAS equipment
- E. LCMS operational tests shall include the following:
 - 1. Alarm annunciation and acknowledgement
 - 2. Breaker trip and close
 - 3. Substation local, remote, HMI, off settings
 - 4. Desktop
 - 5. Navigation Bar
 - 6. Annunciator
 - 7. Event Log
 - 8. Substation Control
 - 9. Graphical Interface
 - 10. User Management System
 - 11. QWERTY keyboard operation
 - 12. Time/Date synchronization
 - 13. Navigation to and from each HMI application
- F. IPR and MPR operational tests shall include the following:

1. Breaker trip and close
 2. Device local, remote, HMI, off
 3. Time/Date synchronization
 4. Analog/Digital I/O testing
 5. Control Interlocking
- G. SCADA operational tests shall include the following:
1. Communication testing between SCADA and MPAC/SPAC
 2. Alarm annunciation and acknowledgement
 3. Remote breaker trip and close
 4. Substation local, remote, HMI, off positions

END OF SECTION

SECTION 16450

GROUNDING FOR THE TRACTION POWER SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work included: This Section specifies furnishing, installing, and testing of the complete grounding systems for each of the traction power substations. Also this section specifies furnishing, installing, and testing of ground cable taps and ground rods, as needed, to connect ground systems to the structural frame work, transformer grounding pads and fencing.
- B. The requirements include:
 - 1. Substation Ground Grid at each Traction Power substation.
 - 2. Ground bus within each traction power substation.
 - 3. Ground connections between ground bus and ground grid at traction power substations.
 - 4. Ground connections to equipment within traction power substations.
 - 5. Grounding to Traction power transformers and equipment installed outdoors.
 - 6. Grounding of Substation fences (around outdoor equipment).
 - 7. Connection of surge arresters to the substation ground grid.

1.2 SUBMITTALS

- A. Product submittals in accordance with Section 2.8.
- B. As-built drawings. Submit prior to final acceptance of the work, drawings showing complete layout of systems installed including physical location of ground rods to which connections were made.
- C. Field Quality Control Test Report. Submit reports complying with requirements of Part 3 "Field Quality Control" Article 3.8.

PART 2 - PRODUCTS

2.1 BARE GROUND WIRE

- A. Soft drawn copper, Class A or Class B stranded, meeting the requirements of ASTM B8; size in accordance with the NEC except where sizes specified herein are larger than those required by NEC; UL listed, Label A for lightning protection conductors. Grounding cable shall be continuous without joints or splices through its length.

2.2 INSULATED GROUND WIRE

- A. Copper, Class B Stranded, 600-Volt, 90 degree C, NEC type THWN; meeting requirements of AAR Specifications No. 535.2; sized as indicated; and UL listed.

2.3 PRODUCTS USED FOR COPPER THERMITE WELDED CONNECTIONS

- A. Use products for copper thermite welded connections which are the products of one manufacturer and are produced for the specific application for which they are used.
- B. Use materials and equipment which meet or exceed the applicable requirements of the AAR Manual, Electrical Section.
- C. Coating Materials for Thermite Welded Connections: Use black, rubber based compound coating materials, which are soft, permanently pliable, moldable, and unbacked, not less than 1/8" thick, with properties as follows:

Solids	100 percent
Density	12.0 pounds per gallon minimum
Penetration	90-130 ASTM D5
Water Absorption	0.10 percent maximum ASTM D570
Dielectric Strength	500 volts/mil ASTM D149
Volume Resistivity	2,000 megohms-inches ASTM D257 5,000 megohms-cm ASTM D257
Service Temperature	Minus 40 degrees to 160 degrees F.
Chemical Resistance	Melting point, none; flammability, slow burning (ASTM C653); resists alcohol, water, aqueous hydrochloride and sodium hydroxide; dissolved by carbon tetrachloride, naphtha gasoline, mineral spirits, ketones, and benzene.
Highly cohesive and Adhesive	Adheres strongly to metals and concrete and to itself.

2.4 BOLTED GROUNDING CONNECTORS

- A. For solderless type made of high strength electrical bronze with silicon bronze clamping bolts and hardware; designed such that bolts, nuts, lock washers and similar hardware which might nick or otherwise damage the ground wire will not directly contact the ground wire.

2.5 GROUND BUS

- A. 1/4" x 2" copper bus bar mounted on the wall of the substation (not within 6' of the rectifiers or DC switchgear); drilled and tapped to receive ground cable connections from the ground rod assembly and ground connections for equipment as required.

2.6 GROUND RODS

- A. Medium carbon steel core, copper clad by the molten weld casting process; sizes as required by the design; UL approved.

2.7 JUMPERS

- A. Jumpers shall be tin-plated copper, braided and flexible.

2.8 SURGE ARRESTERS

- A. Connect surge arresters directly to ground in accordance with the design.
- B. Unless otherwise specified connect surge arresters to ground using #2/0AWG covered copper conductors.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Perform testing as specified in Article 3.8 Field Quality Control of this Section.

3.2 GENERAL GROUNDING REQUIREMENTS

- A. General. Provide station electrical grounding complying with procedures of NEC and ANSI/IEEE Standard 80.
- B. Provide substation ground grid and all necessary connections at each traction power substation.
- C. Provide all required structural and equipment grounding.
- D. Unless otherwise indicated, all underground grounding connections shall be by exothermic welding. Unless otherwise indicated, all connections located outdoors to steel structures, fence posts or similar equipment shall be “Servit” post mechanical fittings or equal. Do not use compression or mechanical connections underground. Grounding connections shall not be soldered.
- E. Grounding conductors shall be protected from physical and environmental damage.
- F. Oxide inhibiting compound shall be used for all mechanical connections where copper to aluminum or copper to steel connections are made. The compound shall be applied to all copper, steel and aluminum parts. Aluminum contact surfaces shall be abraded after application of the inhibiting compound.
- G. Equipment Ground Conductors
 - 1. The following equipment shall be grounded:
 - a. 13.8kV AC switchgear (two ground connections to the substation ground bus)
 - b. Rectifier Transformers (two connections to grounding pads on each transformer from ground grid)
 - c. Surge arresters
 - d. All other traction power substation equipment except DC switchgear, rectifier and DC busducts.
 - e. All electrical equipment (not related to traction power) shall be grounded.
 - 2. 13.8kV cables entering the AC switchgear shall be shielded. Where applicable, the cable shields shall be grounding to the switchgear isolated ground bus.
 - 3. Each 13.8kV AC cable shall be grounded at one end only. The opposite end shall have the cable shields pulled back and isolated from ground.

4. Connect each steel conduit entering equipment with equipment ground conductor connected to the equipment ground bus, colored green.
 5. Do not ground DC traction power equipment - Rectifiers and DC switchgear and DC busducts.
- H. At Double-Ended Substations Serving Station Service Equipment – Refer to Electrical Design Specifications and Plans.
1. Connect the Double Ended Substation equipment to the traction power substations ground grid as shown in the Design Documents. The double ended substations shall have a neutral bus with isolating links and single ground between neutral bus and ground bus. The neutral bus shall be insulated from switchgear housing and conduits.
- I. As applicable, provide convenience outlets having ground fault circuit breakers, complying with Section 16201 Basic Materials and Methods for Electrical Work.

3.3 EQUIPMENT GROUNDING

- A. At each traction power substation, install one-quarter inch by 2” copper ground bus continuously around inside periphery or as shown in the Design Documents and connect to grounding electrodes at intervals as required. Ground bus shall not be installed within 6’ of the DC switchgear or rectifiers.
- B. 13.8kV AC Switchgear and Switchboards.
1. Connect continuous equipment ground bus at each end by copper ground wire to building or facility ground bus. Do not connect the isolated ground bus to the substation ground.
 2. Provide ground wire equal in size to largest conductor in line feeding equipment, but not less than No. 6 AWG, nor larger than No. 4/0 AWG.
 3. Install ground wire in rigid steel conduit bonded at both ends.
- C. Wiring, Channels, Cable Trays, Metallic Conduit, Rigid Electrical Metallic Tubing, Flexible Conduits, Metallic Boxes, Panelboards, Generator Frames and Transformer Enclosures.
1. Ground to ground bus with copper ground conductors sized as specified in the Mandatory Specifications.
- D. Motors, Lighting Fixtures and Equipment
1. Accomplish grounding with equipment ground.
 2. Provide equipment ground conductor electrically and mechanically continuous from system equipment and neutral ground connection at source of supply to equipment to be grounded.
- E. Building Type Conductors
1. Where conductors are installed in raceways, run equipment ground conductor for alternating current systems within raceways with circuit conductors.

2. Provide copper equipment ground conductor minimum one size smaller than phase conductors, except having minimum size of No. 12 and maximum size No. 4/0 AWG.
 3. Identify equipment ground conductors with colored green type THW insulation, except where green insulation is not available on larger sizes, black colored insulation shall be used and suitably identified with green tape at each junction box or device enclosure.
- F. Junction Boxes and other enclosures sized above five square inches. Securely bond equipment ground conductors to enclosures utilizing equipment ground bus or lug.
- G. At each transformer ensure two connections are made to the ground grid at the site.

3.4 FENCE GROUNDING

- A. Substation fences around the transformers shall be connected to the ground grid and shall be made electrically continuous.
- B. Substation gates shall be provided with a ground connection to the substation ground grid and the required hardware installed to allow for grounding of the gates at all times.

3.5 SUBSTATION GROUND GRID

- A. Ground Bus. Provide copper ground conductors sized as indicated, buried to minimum depths and in accordance with details as required. Note: Other specifications may reference the ground grid as the ground bus loop.
- B. Ground Electrodes
1. Space electrodes as required, and connect each electrode to ground copper conductor as indicated.
 2. Provide copper-coated, high-strength steel rods conforming to ASTM B228, Grade 40HS, sizes as indicated, having threaded bronze couplings, and driven to depths indicated. Additionally, locate top of electrodes minimum depth below grade and in accordance with details as required.
 3. Where soil conditions make it impossible to drive ground electrodes to depth required, provide three ground rods spaced maximum of 10' apart in shape of equilateral triangle and interconnected with copper ground conductor as required.
 4. Make below-grade connections by brazing or thermite welding.
 5. Bury ground rods vertically with rod top a minimum of 6" below grade. If extensive rock formation is encountered relocate ground rod or provide supplemental ground rods as directed by the MBTA.
 6. To meet maximum allowable ground resistance requirements, install additional ground rods as necessary.
- C. Steel Columns and Other Materials.
1. Connect exposed steel columns to ground grid or ground bus at intervals required. Make connections at steel columns 18" above finished floor in web of columns.
 2. Connect steel columns inside buildings to ground bus, with continuous bare copper conductor, as indicated.

- D. Where miscellaneous metal objects, including piping, vessels, and structural shapes, are within 6' of the DC switchgear or rectifier equipment do not ground the equipment but refer to the MBTA for direction.

3.6 CONVENIENCE OUTLETS

- A. Ground all convenience outlets in accordance with the NEC.

3.7 THERMITE WELDING CONNECTIONS

- A. Connect electrical wires together, to reinforcing steel or soldier piles, as indicated, by thermite welding using the manufacturer's recommended molds and size of charges for application.
- B. Prepare the material to be welded and perform thermite welding in accordance with manufacturer's instructions.
- C. Test completed thermite welds before coating by striking with two pound hammer. If cracks develop, replace welds at no additional expense to the MBTA. When required by the MBTA, test the electrical continuity of bonds.
- D. Apply coating so that it extends one inch beyond point of attachment to steel member, overlaps wire coating one inch, and provides insulation thickness equivalent to wire insulation, but not less than 1/8" in thickness. Do not apply coating material at ambient temperatures below 20 degrees F or above 125 degrees F. Maintain, by an approved method, curing temperature within above temperature range for at least four hours after application of coating. Protect coating by approved means until embedment.
- E. Where exothermic welds are made to a galvanized surface, remove the galvanizing using a grinding wheel to expose a clean surface. After welding, touch up the steel surface with zinc rich primer.

3.8 FIELD QUALITY CONTROL

- A. Testing Building Structural Grounding / Substation Ground Grid
 - 1. General. After installation of ground grid and ground electrodes, and prior to interconnection of other grounding systems perform ground resistance testing.
 - 2. Test Procedure: Submit grounding test procedures in advance of any testing.
 - 3. Test Report. Provide report giving results of testing procedures, which shall also include temperature, humidity, and condition of soil at time of tests.
 - 4. Ground Resistance Testing
 - a. Testing. Verify that resistance between ground and absolute earth for the grounding system does not exceed two ohms without benefit of chemical treatment or other artificial means, unless indicated otherwise in the Construction Specifications.
 - b. Test Equipment and Method. Perform testing using ground resistance direct-reading single test meter utilizing alternating current fall-of-potential method and two reference electrodes.
 - c. Test Procedure

1. Orient ground electrode to be tested and two reference electrodes in straight line space minimum 50" apart.
2. Drive two reference electrodes five feet deep.
- d. Test Requirement or Limits. If ground resistance exceeds two ohms, install additional ground electrodes until resistance is two ohms or less.
5. Notify MBTA prior to back filling the ground grids. Place no backfill until inspection by MBTA is completed and the grounding installation approved.

B. Testing Equipment Grounding

1. General. After installation of ground connections and ground bus, test the grounding system for continuity. Continuity testing shall be completed for each separate ground bus, ground connection, ground conductor.
2. Test Procedure: Submit grounding continuity test procedures in advance of any testing.
3. Test Report. Provide report giving results of testing procedures, which shall also include resistance of each connection in milliohms.

END OF SECTION

SECTION 16451

CORROSION CONTROL AND STRAY CURRENT MITIGATION

PART 1 - GENERAL

1.1. DESCRIPTION

- A. This section specifies the requirements for providing, installing and testing corrosion control and stray current mitigation equipment for metallic utility pipelines and transit structures.
- B. Installation of all corrosion control and stray current mitigation components shall be in accordance with this specification.
- C. The corrosion control systems include electrical continuity (joint bonding), isolation flanges, isolation unions, coatings, galvanic cathodic protection, lightning and AC current surge protection (if required) for isolation fittings, and corrosion control test facilities. The stray current mitigation systems include bonding of concrete reinforcing steel, bonding of sheet pile and soldier pile wall sections, application of waterproofing membranes (under a separate specification), installation of cables, conduits and monitoring/testing facilities.
- D. The DB Entity shall employ or retain a NACE International certificated Corrosion Specialist or Cathodic Protection Specialist to supervise and certify the work included in this section. The individual must have a minimum of five years of experience in the installation and testing of corrosion control and stray current mitigation systems for DC rail transit systems. The duties of the Corrosion Specialist or Cathodic Protection Specialist shall include but may not be limited to:
 - a. Oversee and certify installation and related testing, including pipe joint bonding, electrical continuity testing, test station installation, galvanic cathodic protection systems, and corrosion control equipment. Individual must participate in field activities to the extent required by the work. Minimum requirement for personnel performing field testing is NACE International Corrosion Technician certification.
 - b. Issue a letter of compliance indicating all corrosion control and stray current mitigation measures are satisfactorily installed and comply with contract documents. The letter of compliance shall be signed by the NACE International Corrosion/Cathodic Protection Specialist.

1.2. RELATED WORK

- A. Section 03300 Cast In Place Concrete
- B. Section 16450 Grounding for the Traction Power System

1.3. STANDARDS

- A. American Association of State Highway and Transportation Officials, HB 17, Standard Specification for Highway Bridges
- B. ASTM International A48, Standard Specification for Gray Iron Castings

- C. ASTM International B843, Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
- D. ASTM International C150, Standard Specification for Portland Cement
- E. ASTM International C452, Standard Test Method for Potential Expansion of Portland-Cement Mortars Exposed To Sulfate
- F. ASTM International D257, Standard Test Methods for DC Resistance or Conductance of Insulating Materials
- G. ASTM International D512, Standard Test Methods for Chloride Ion in Water
- H. ASTM International D513, Standard Test Methods for Total and Dissolved Carbon Dioxide in Water
- I. ASTM International D1293, Standard Test Methods for pH of Water
- J. ASTM International D1452, Standard Practice for Soil Exploration and Sampling by Auger Borings
- K. ASTM International D1498, Standard Test Method for Oxidation-Reduction Potential of Water
- L. ASTM International D2000, Standard Classification System for Rubber Products in Automotive Applications
- M. ASTM International D4220, Standard Practices for Preserving and Transporting Soil Samples
- N. ASTM International D4327, Standard Test Method for Anions in Water by Suppressed Ion Chromatography
- O. ASTM International D4658, Standard Test Method for Sulfide Ion in Water
- P. ASTM International G51, Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing
- Q. ASTM International G57, Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method
- R. ASTM International G165, Standard Practice for Determining Rail-to-Earth Resistance
- S. ASTM International – NACE International G193, Joint Standard, Standard Terminology and Acronyms Related to Corrosion
- T. ASTM International G200, Standard Test Method for Measurement of Oxidation-Reduction Potential (ORP) of Soil
- U. American Petroleum Institute 5L, Specification for Line Pipe
- V. American Water Works Association C111, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
- W. American Water Works Association C210, Liquid Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines

- X. American Water Works Association C217, Petrolatum and Petroleum Wax Tape Coatings for the Exterior of Connections and Fittings for Steel Water Pipelines
- Y. American Water Works Association C219, Bolted, Sleeve-Type Couplings for Plain-End Pipe
- Z. American Water Works Association C900, Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 in. Through 12 in. (100 mm Through 300 mm) for Water Transmission and Distribution
- AA. Institute of Electrical and Electronics Engineers (IEEE), IEEE C2, National Electrical Safety Code (NESC)
- BB. NACE International – The Society for Protective Coatings, NACE No. 2/SSPC-SP10, Joint Surface Preparation Standard, Near-White Metal Blast Cleaning
- CC. NACE International – The Society for Protective Coatings, NACE No. 3/SSPC-SP6, Joint Surface Preparation Standard, Commercial Blast Cleaning
- DD. NACE International, SP0169, Standard Practice, Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- EE. NACE International, SP0177, Standard Practice, Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems
- FF. NACE International SP0188, Standard Practice, Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
- GG. NACE International SP0274, Standard Practice, High-Voltage Electrical Inspection of Pipeline Coatings
- HH. NACE International SP0286, Standard Practice, Electrical Isolation of Cathodically Protected Pipelines
- II. NACE International TM0497, Standard Test Method, Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems
- JJ. National Electrical Manufacturers Association, 250, Enclosures for Electrical Equipment (1000 Volts Maximum)
- KK. NSF International/American National Standard Institute NSF/ANSI 61, Drinking Water System Components – Health Effects
- LL. The Society for Protective Coatings, Paint 16, Coal Tar Epoxy-Polyamide Black (or Dark Red) Paint
- MM. The Society for Protective Coatings, Paint 33, Coal Tar Mastic, Cold Applied
- NN. Transit Cooperative Research Program, Report 155, Track Design Handbook for Light Rail Transit, Second Edition
- OO. Underwriters Laboratories 508A, Standard for Industrial Control Panels

1.4. DEFINITIONS

- A. Definitions for most terms utilized in this specification are available in ASTM International – NACE International G193, Standard Terminology and Acronyms Relating to Corrosion. Definitions for relevant terms not included in the G193 standard are provided below:
1. Track-to-Earth Resistance – The electrical resistance between a defined length of track and remote earth. Typically expressed in terms of ohms normalized to 1,000' of track (2 rails).
 2. Theoretical Resistance – The calculated resistance of a structure based on the length and linear resistance characteristics of the structure, including the resistance contribution of continuity bonding materials.
 3. Test Station – An enclosure containing cables or wires connected to a structure or structures for connection of test instruments to make potential or current measurements. May also contain cables connected to permanently installed electrodes or other embedded or buried instrumentation.
 4. Drainage Cable – A cable specifically designed to conduct collected stray current from the affected structure to the source of the stray current.
 5. Thermite Welding – Also known as exothermic welding, is a welding process that employs an exothermic reaction of a thermite composition to heat the metal and create a permanent low resistant bond.

1.5. SUBMITTALS

- A. Qualifications: NACE International Corrosion Specialist or Cathodic Protection Specialist certification.
- B. Qualifications: Field testing personnel, NACE International Corrosion Technician certification.
- C. Test procedures and Test Plan: The DB Entity shall submit a detailed written description of the proposed testing schedule and procedures to the MBTA or designee for review a minimum of 2 weeks prior to the scheduled testing start date. Testing shall not commence prior to receipt of approval for the test procedures and test plan from the MBTA.
- D. Instrumentation: The DB Entity shall submit a list of instruments to be used for the testing. The list shall include the manufacturer name, model number, serial number, and calibration certificate for each instrument. The calibration certificate shall show that each instrument was calibrated by an independent testing laboratory within 12 months of the date of testing.
- E. Documentation: The Design-Build Entity shall submit all record drawings, test data and calculations in the form of a report to the MBTA or designee for each installation or required test for review and acceptance. All reports shall be accompanied by a letter of compliance signed by the NACE International Corrosion/Cathodic Protection Specialist.
- F. Product Data: The DB Entity shall submit product data demonstrating compliance with the requirements of this section. At a minimum the data shall include the manufacturer's name, model number, serial number (if applicable), chemical composition, dimensions, material properties and finish. Product data shall be submitted for the following products:
1. Magnesium anodes;

2. Silver/silver chloride reference electrode;
3. Copper/copper sulfate reference electrode;
4. Cathodic protection test stations;
5. Mastic coating;
6. Coal tar epoxy coating;
7. Isolation joint and mechanical coupling external coating;
8. Isolation joint internal coatings;
9. Flange isolation materials;
10. Structure crossing isolation material;
11. Casing spacers;
12. Casing end seals;
13. Stray current junction boxes;
14. Stray current test stations.

G. Acceptance Testing Report: An acceptance testing report shall be submitted within 15 working days of the completion of the testing. The report shall include, at a minimum, all testing procedures utilized, record drawings, tabulated test data and conclusions as to the operational status of all tested components.

PART 2 - PRODUCTS

2.1. MAGNESIUM ANODES

- A. Standard Potential Magnesium Anode. Packaged standard (ASTM B843 Grade AZ63B) type comprised of magnesium ingot, wire, and prepared backfill.
- B. Lead wire: Single-conductor insulated cable, 12 AWG minimum, factory-connected to anode with connection sealed with cast epoxy-resin encapsulation.
- C. Backfill: Anode to be packaged in permeable cloth sack containing compacted backfill of mixture with the following requirements:

MATERIAL	PERCENT
Gypsum	75
Bentonite	20
Sodium Sulfate	5

- D. Open Circuit Potential: Minimum potential of 1.5 volts referenced to copper/copper sulfate reference cell.
- E. High Potential Magnesium Anode. Packaged high potential (ASTM B843, Grade M1C) type comprised of magnesium ingot, wire, and prepared backfill.
- F. Lead wire: Single-conductor insulated cable, 12 AWG minimum, factory-connected to anode with connection sealed with cast epoxy-resin encapsulation.
- G. Backfill: Anode to be packaged in permeable cloth sack containing compacted backfill of mixture with the following requirements:

MATERIAL	PERCENT
Gypsum	75
Bentonite	20
Sodium Sulfate	5

- H. Open Circuit Potential: Minimum potential of 1.75 volts referenced to copper/copper sulfate reference cell.

2.2. ISOLATION FITTING PROTECTION

- A. Electrical isolation fittings shall be protected from lightning surges and the development of excessive AC and DC voltage across the insulating element(s). Protection of the isolation fitting shall be in compliance with NACE International SP0177.

2.3. SILVER/SILVER CHLORIDE REFERENCE ELECTRODE

- A. The silver/silver chloride reference electrode shall consist of a thermodynamically stable gelled Ag/AgCl element packaged in a cotton bag housing containing a backfill that provides good electronic and mechanical bonding to the structure through wide temperature variations. The electrode shall be provided with one #14 AWG HMWPE cable for attachment to the structure and one #22 AWG two conductor shielded cable for routing to the test station. The length of the cables shall be sufficient such that no splicing is required. The electrode shall have a minimum design life of 50 years.

2.4. COPPER/COPPER SULFATE REFERENCE ELECTRODE

- A. The copper/copper sulfate reference electrode shall consist of a gelled copper/copper sulfate element packaged in a cotton bag filled with a bentonite/gypsum mixture that retains moisture and inhibits the migration of contaminants from the surrounding soil to the electrode. The electrode shall be provided with one #12 HMWPE cable for routing to the test station. The length of the cable shall be sufficient to extend to the test station without splicing. The electrode shall have a minimum design life of 50 years and a stability of +/- 5mV or less.

2.5. CATHODIC PROTECTION TEST STATION

- A. Post Mounted Test Station. A 4.5” diameter cast aluminum body with a threaded outlet to fit a minimum 1.25” diameter rigid steel conduit. A screw on cast aluminum cover with an o-ring watertight

seal and the words TEST STATION cast into the exterior face of the cover. The test station shall contain an insulated mounting panel with a minimum of 5 terminals consisting of 0.25" diameter nickel plated brass or stainless steel hardware. All cables terminated in the junction box shall be terminated with copper compression terminals.

- B. Cast-in-Place Flush Mounted Test Station. Compression-molded fiberglass construction with a flat cover attached with stainless steel screws meeting NEMA 4X exposure rating and UL 508A flammability requirements. The cover shall be provided with a permanently attached label with the words CP TEST. The minimum letter height shall be 1". The enclosure shall be sized to accommodate a 2" diameter conduit entrance and the number and size of cables to be installed but in no case shall the dimensions of the enclosure be less than 7" x 7" x 5". The test station shall be provided with an insulated terminal board with a minimum of 5 terminals consisting of 0.25" diameter nickel-plated brass or stainless steel hardware. All cables terminated in the junction box shall be terminated with copper compression terminals.
- C. At-Grade Test Station. Heavy-duty cast iron cover and collar, exceeding ASTM A48 Class 25 (for roadway installation, AASHTO H-20 classification required). The cover shall be capable of locking to the collar and shall have CP TEST cast in the exterior face. Shaft constructed of ABS plastic exceeding ASTM D1788. The shaft shall be flared at the bottom. The test station shall contain a terminal board constructed of PVC or other insulating product that locks into the cover. The terminal board shall contain a minimum of 5 terminals constructed of 0.25" nickel plated brass or stainless steel hardware. All cables terminated in the junction box shall be terminated with copper compression terminals.

2.6. MASTIC COATING

- A. The field applied external mastic coating shall be cold applied, single component coal tar mastic meeting the requirements of SSPC Paint 33. The external coating shall be applied only where noted herein:
 - 1. Buried bolts, nuts, coupling harness tie rods, saddles, iron and steel anchors, and other connecting hardware.
 - 2. Service clamps other transition fittings between copper services and ductile iron pipe.

2.7. COAL TAR EPOXY COATING

- A. The coal tar epoxy coating shall be a polyamide coal tar epoxy meeting the requirements of SSPC Paint 16 and AWWA C210 for exterior use.

2.8. INSULATED FLANGE AND MECHANICAL COUPLING EXTERNAL COATING

- A. The external surfaces of insulated flanges and mechanical couplings shall be coated with a petrolatum tape coating system that meets the requirements of AWWA C217.

2.9. INSULATED FLANGE, MECHANICAL COUPLING AND ISOLATION JOINT INTERNAL COATING

- A. The coating for the internal surface of potable water pipelines at insulated flanges, mechanical couplings and isolation joints must meet the requirements of NSF 61 and be compatible with any internal lining within the pipeline. For pipelines that do not carry potable water, the internal surface shall be coated with a coating meeting the requirements of AWWA C210 for internal surfaces, and be compatible with

any linings and the product transported by the pipeline. The internal surface of the pipeline shall be coated for a minimum length of 2 pipe diameters on each side of the joint.

2.10. ISOLATION JOINT

- A. Monolithic joints shall be manufactured of API 5L Grade B or Grade X steel and consist of two pipe pups and a forged or pipe steel body that is assembled and welded under a compression load. Isolation shall be accomplished by means of two G-10 or G-11 rings. A double pressure-sealing system consisting of NBR or silicone rubber forming a positive pressure seal shall be incorporated within the body of the joint. A dielectric filler material shall be used between the isolating rings and in the external gap between the body and pipe pup of the joint. The joint shall be provided with a factory applied internal and external dielectric coating. For potable water use, the internal coating shall comply with NSF 61 requirements.

2.11. ISOLATION UNION

- A. Air refined malleable iron complete with brass bearing ring and molded integral one-piece nylon insulating material. The size, temperature, and pressure ratings shall be suitable for the proposed application. For underground installations on water service lines, the union and adjacent piping must be coated for a minimum distance of 3' in each direction to prevent current from traveling through the soil around the union.

2.12. PVC INSERT ISOLATION

- A. A PVC insert isolation joint shall consist of a length of plain-end AWWA C900 PVC pipe. The length of the PVC insert shall be a minimum of one pipe diameter, but in no case less than 1'. The PVC pipe shall be connected to the metallic pipe with the appropriate style mechanical coupling. A PVC insert isolation joint should not be utilized in a location where restrained joints are necessary.

2.13. MECHANICAL ISOLATION FITTING

- A. The coupling shall meet the requirements of AWWA C219. The end rings and center rings shall be cast ductile iron meeting or exceeding ASTM A536. Gaskets shall be constructed of virgin styrene butadiene rubber (SBR) and isolation boots shall be constructed of virgin ethylene propylene diene monomer (EPDM) formulated for water and sewer service in accordance with ASTM D2000. Nuts and bolts shall meet the requirements of AWWA C111. Internal and external metallic surfaces of the fitting shall be shop coated with fusion bonded epoxy.

2.14. FLANGE ISOLATION MATERIALS

- A. Flange isolation materials shall consist of a non-metallic full-face insulating gasket, flange-bolt insulating sleeves and washers that are compatible with the pressure rating of the pipeline and the product being transported. Single or double insulating washer sets shall be installed in accordance with NACE International SP0286. Flanges should not be used in direct burial locations.

2.15. STRUCTURE CROSSING ISOLATION MATERIALS

- A. Electrical isolation materials shall be installed where underground metallic pipelines cross a foreign metallic structure with a clearance of less than 12". The isolation material shall consist of a high-density polyethylene sheet with a minimum thickness of 125 mils and dimensions adequate to

effectively isolate the two structures. Alternately, a non-conductive fiberglass reinforced plastic insulation spacer that extends a minimum of 120 degrees around the pipeline and attached to the pipeline for an adequate length may be utilized for isolation.

2.16. CASING SPACERS

- A. Casing spacers shall be constructed of injection molded virgin polyethylene for pipelines up to 12" in diameter. The runner height shall be sufficient to provide a minimum 1" clearance between the pipe, couplings and hubs as well and the internal casing wall. All bolting hardware shall be stainless steel. For pipelines larger than 12" in diameter, the casing spacers shall be constructed of a stainless steel sleeve with EPDM liner and glass-filled polymer runners. The runner height shall be sufficient to provide a minimum 1" clearance between the pipe, couplings and hubs as well and the internal casing wall. All bolting hardware shall be stainless steel.

2.17. CASING END SEALS

- A. Casing end seals shall be constructed of seamless injection molded EPDM and be able to accommodate a minimum eccentricity of 3". The end seal shall be secured to the pipeline and casing with sealant adhesive and stainless steel band clamps.

2.18. STRAY CURRENT JUNCTION BOX

- A. Compression-molded fiberglass construction with a flat cover attached with stainless steel screws meeting NEMA 4X exposure rating and UL 508A flammability requirements. The cover shall be provided with a permanently attached label with the words SC TEST. The minimum letter height shall be 1". The enclosure shall be sized to accommodate two 2" diameter conduit entrances and the required number and size of cables but in no case shall the dimensions of the enclosure be less than 8" x 10" x 5". The junction box shall be provided with an insulated terminal board and mounting hardware. The mounting hardware shall be silicon bronze or nickel-plated brass. Bus bars shall be constructed of electrolytic copper with a minimum thickness of 0.125". All cables terminated in the junction box shall be terminated with copper compression terminals.

2.19. STRAY CURRENT DRAINAGE CABLES

- A. Stray current drainage collection cables shall be a minimum #1/0 AWG flexible stranded copper cable and in conformance with the specification requirements of Section 16121 Insulated Conductors.

2.20. STRAY CURRENT MONITORING TEST STATIONS

- A. Stray current monitoring test stations shall be constructed of compression-molded fiberglass with a flat cover attached with stainless steel screws meeting NEMA 4X exposure rating and UL 508A flammability requirements. The cover shall be provided with a permanently attached label with the words SC TEST. The minimum letter height shall be 1". The enclosure shall be sized to accommodate the number of 2" diameter conduit entrances and the required number and size of cables but in no case shall the dimensions of the enclosure be less than 8" x 10" x 5". The test station shall be provided with an insulated terminal board and mounting hardware. The mounting hardware shall be silicon bronze or nickel-plated brass. Bus bars shall be constructed of electrolytic copper with a minimum thickness of 0.125". All cables terminated in the junction box shall be terminated with copper compression terminals.

2.21. WIRE AND CABLE

- A. Cable for bonded joints and attachment to collector bars shall be single conductor, stranded copper with high molecular weight polyethylene (HMWPE) insulation. Wire for test stations shall be single conductor, stranded copper wire with 600-volt THWN or HMWPE insulation.

2.22. PRODUCT DELIVERY, STORAGE AND HANDLING

- A. Mark each item with manufacturer's name, brand designation, referenced standard, type, class and rating, as applicable.
- B. Ship each unit securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.
- C. Store equipment in secure and dry storage facility that is maintained within the temperature range recommended by the product manufacturer.

PART 3 - EXECUTION

3.1. RECORD DRAWINGS

- A. General: Document installed location and configuration of each test station, junction box, stray current collection mat and isolation device with an As-Built drawing, including:
 - B. Test station or junction box number per schedule and installed station number.
 - C. Three ties between test station and permanent datum.
 - D. Distance from test station to guard post, where installed.
 - E. Wire routing, size, insulation color and termination configuration on terminal board.
 - F. Station numbers for wire attachments to pipe, stray current collection mat, retaining wall or reinforced concrete structure.
 - G. Anode locations, where installed, including pipeline station number, anode size, anode center-to-center spacing, depth and distance from pipe.
 - H. Pipeline station number and arrangement of interconnecting fittings for each insulating device, including isolation flanges, isolation joints, isolation membranes or shields, unions and mechanical couplings.

3.2. PIPE HANDLING AND STORAGE

- A. Handling of Pipe:
 - 1. At the project site, the pipe shall not be handled with metal chains, cables, unpadded tongs, forklifts or other equipment likely to cause damage to the pipe shop coating or score the pipe surface.

2. Storing of the pipe shall be on padded 12” wide (minimum) skids or select loamy or sand dirt berms, where possible. In urban areas, pipe should be suspended on padded skids. Where skid chucks are used in contact with the pipe, they should be padded with several layers of padding material. Padded chucks should be placed such that pipe is nested on the skid rather than the chuck. The pipe shall not be laid on pavement or stone surfaces without benefit of padding at contact points.
3. If cables or chains are used during transportation, they must be properly padded with approved, suitable material as required to protect the pipe surface from damage while in transit. Use of a padded horizontal separator strip between successive rows of pipe is necessary to prevent damage to the pipe surface.
4. At all times during construction of the pipeline, the DB Entity shall take every precaution to prevent damage to the protective coating and scoring of the pipe surface. No metal tools or heavy objects shall be permitted to come into contact unnecessarily with the pipe surface.
5. Casing pipe shall be handled with extreme care, in accordance with the above procedures to protect the coating.
6. All coated pipe shall be inspected and tested for coating damage prior to lowering into the pipe trench and any damage to the coating due to improper handling shall be repaired at the DB Entity’s sole expense.

3.3. THERMITE WELDING

A. Attach test wires and bond cables to piping and other structures by thermite welding.

1. General: All thermite welds shall be made in accordance with the manufacturer’s recommendations using the proper combination of equipment for the structure and wire size being welded. All welding materials and equipment shall be the product of a single manufacturer.
2. Testing: When the weld has cooled, remove the weld slag and test for mechanical strength of exothermic weld by applying three sharp blows to the side of the weld with a two-pound hammer using 15” strokes being careful not to strike the pipeline or structure. Acceptable welds shall sustain the blows without cracking the weld metal or the bond between the two connecting materials. Remove defective welds and re-weld after cleaning the area to be welded.
 - a. Documentation: Record adequacy of each bond cable and test wire weld based on the above procedure and visual inspection. Data recorded for each bond cable and test wire to include date of inspection, name of inspection personnel, pipeline station number, quantity, and gauge of wire installed, and simple statement (e.g., “satisfactory”) regarding proper installation. Provide field sketches where tabular data alone is not sufficient to document pipe alignment and bonding configuration.
3. Coating Thermite Welds: After soundness of the weld has been verified, thoroughly clean with a stiff wire brush and coat weldment and all bare metal areas around weldment with a coal tar epoxy coating in accordance with the coating manufacturer’s recommendations. The coating should overlap any existing pipe or structure coating approximately 2”. The coating must be adequately cured prior to backfilling.

- B. Bonded Joints: Install bond cables across each joint using the thermite weld process. Use a standard bond cable length of 18” where practical. Document where bond cable length deviates from the standard cable length, including the actual length of the bond cable utilized. A minimum of two bond cables are required per joint.
 - 1. Do not bond across insulating devices.
 - 2. Do not bond between new ductile iron and prestressed concrete pipe.

3.4. TEST STATIONS AND JUNCTION BOXES

- A. Test stations and junction boxes: Include underground utility test stations; reinforced concrete test stations; retaining wall stray current junction boxes and; stray current monitoring test stations. The installation includes placement of anodes, reference electrodes, attachment of test or bond wires to the structure, routing of wires to and terminating on the terminal board, mounting or embedment of the enclosure, guard posts, conduits, utility warning tape and all other materials or equipment necessary for a complete and functional unit.
- B. Test Station Schedule: Type of test station; number, size and color of wires; wire routing and termination shall be included on the Contract Drawings.
 - 1. Test stations for cathodically protected underground utilities shall be located at all insulated fittings, casings, anode installations, foreign line crossings, and intermediate locations such that the maximum spacing between test points does not exceed 500’.
 - 2. Test stations for reinforced concrete structures, retaining walls and other transit fixed facilities where bonding for stray current control is specified shall be installed at the end point of each structure, transitions between structure types, and at intermediate collector bar locations such that the maximum spacing between test stations does not exceed 500’. Intermediate test stations shall be located at expansion joints where practical.
- C. Positioning: The location of all test stations shall be shown on the Contract Drawings. Test stations for pipelines buried under pavement shall be located outside paving limits. Test stations shall be sufficiently set back from vehicle traffic lanes so that they can be accessed for maintenance without extensive traffic control or other special safety precautions. The cathodic protection test station must be rated for AASHTO H-20 loading and positioned in the center of a travel lane if it cannot be located in an area not subject to vehicular traffic. If the test stations cannot be located within 10’ of the location shown on the Contract Drawings, consult the MBTA for additional direction. For test boxes to be embedded in reinforced concrete structures for stray current bonding and monitoring install the test box and associated conduit prior to concrete placement. The test boxes shall be placed such that the test box will be flush with the surface of the concrete and the test box cover can be easily removed and replaced. The test box shall be placed at a height that is between 2 and 5’ above grade level. Test boxes shall not be placed in a location that requires a ladder or personnel lift device for access. Test boxes shall be located outside of the train envelope where practical.
- D. Wire Routing: Install test and monitoring equipment wires in non-metallic conduit. For underground pipelines the wires may be installed in a wiring harness arrangement routed along the bottom of the pipe trench where practical. Install wires leaving the pipe trench in PVC conduit when the test station is not installed over the pipeline.
- E. Utility Warning Tape: Install a maximum of 1’ below grade and directly above PVC conduit or direct buried cables.

F. Guard Post and Concrete Pad:

1. Guard Post: Provide with concrete anchor at locations that may be subject to inadvertent vehicular traffic. Coat portion not buried with two coats of polyurethane or epoxy coating (color-APWA Color Code for Underground Utilities). Surface preparation and coating application shall be in accordance with coating manufacturer's written instructions. The coating should extend a minimum of 3 inches into the concrete.
2. Concrete Pad: Provide for each flush mount test station. Concrete pad formed around test station shall be square and extend a minimum of 12-inches from the test station collar. The concrete pad shall be reinforced with 4" x 4" x 1/4" dia. welded wire mesh and the surface sloped away from the test station.

G. Magnesium Anode Lead Wire Splices, Wire Connectors and Terminations:

1. Magnesium Anode Lead to Header Cable Splices: Splice the AWG No. 12 solid copper wire supplied with the anode to an AWG No. 8 HMWPE stranded copper cable through the use of a copper compression crimp or thermite weld type connector. Center the splice connector inside the three-layer tape splice insulation. Terminate the ends of the AWG No. 8 anode header cable in the test stations.
2. Terminal Board Connectors: Crimp and solder each terminal box wire to one-hole terminal lug. Clean and dry wire and lug connector before soldering.
3. Wire Splicing: No splices are allowed in individual anode wires, reference electrode wires, corrosion rate probe wires, joint bonds or structure wires.

H. Magnesium Anodes:

1. Positioning: Horizontally or vertically to suit field conditions, with closest part of anode a minimum of 3' from the outside edge of the pipe/structure. Minimum spacing between anode centers installed in a group is 10'.
2. Installation in Rock Areas: If solid rock is encountered at a depth which will not accommodate the specified installation of the anodes, the DB Entity is to investigate the immediate proximity to determine if anode(s) can be installed at specified depth at another location in the immediate area. If a suitable location cannot be found within 25' of the original location, consult the MBTA for additional direction.
3. Backfill: Use soil free from rocks and debris. Do not use sand or clay. Compact backfill in 12" lifts. Do not pre-soak the anodes in water prior to installation.
4. Wiring: Unless noted otherwise, connect grouped anodes using an AWG No. 8 stranded copper header cable. Terminate each end of the anode header cable in designated test stations with only splicing of header cable at anode wire attachments. Anode header cables shall be buried a minimum of 2' below grade with warning tape installed above the cable or conduit containing the cable.
5. Documentation: Include location and orientation of each anode on Record Drawings.

- I. Isolation Flanges: Unless noted otherwise, install with a test station and two test wires attached to pipe on each side of flange.

1. Preparation: Clean dust, dirt, grease, oil and other contaminants from flange surfaces. Check flange face and bolt hole tolerances and verify clearances prior to installing isolation materials.
2. Internal Coating: Two coats dielectric internal pipe coating, minimum dry film thickness per coat of 10 mils, or in accordance with manufacturer's recommendations. Surface preparation, coating application and cure times shall be per manufacturer's instructions. Unless noted otherwise, apply internal coating for a minimum length equal to 2 pipe diameters from flange face in both directions. For pipelines transporting fluids with a resistivity less than 2,000 ohm-cm the minimum coating length on each side of the fitting shall be determined by the DB Entity. All internal coatings utilized for pipelines transporting potable water shall satisfy the requirements of NSF-61.
3. Installation: Install isolation flange gasket, sleeves and washers under clean and dry conditions in accordance with manufacturer's written instructions. Two isolating washers are required for each bolt (one for each side of flange) when an isolation flange is installed above ground. One isolating washer is required for each bolt (on the unprotected side) when an isolation flange is installed underground. Properly torque bolts per isolating material manufacturer's instructions to avoid damage to isolating components and otherwise ensure electrical separation between flange faces and between each bolt and each flange. Do not use conductive grease or other material to facilitate flange assembly which could compromise electrical integrity of isolating materials.
4. Initial Testing: After assembly, directly measure electrical resistance between each bolt and one flange face using an ohm meter or other approved low voltage resistance meter. Resistances less than 10 megohms are not acceptable and require isolator replacement, cleaning and drying of isolator surfaces, and/or other corrective action. If any bolt fails the 10 megohm minimum resistance requirement, all bolts must be retested after corrections are made. Tests shall also be performed across the isolating flange to assure that the gasket is providing effective isolation between the flange faces prior to application of the external coating.
5. External Coating: Coat buried isolating flanges with AWWA C217 compliant petrolatum tape. Surface preparation and coating application shall be as specified by manufacturer, including use of filler material to provide smooth contour around bolts and from transition between pipe and flange. The coating system shall include a dielectric outer wrap. The dielectric wrap material shall have a minimum dielectric strength of 2,000 V/mil. The coating shall extend a minimum of 2 diameters from each flange face for buried or submerged locations.

J. Sanitary Sewer Isolation at Manholes:

1. When proposed metallic sanitary sewer pipelines terminate at an existing or new manhole, the pipeline shall be electrically isolated from all contact with metallic components of the manhole or other appurtenances.
2. A minimum separation between the new pipeline and the manhole rebar shall be 6'. Where 6' cannot be attained, a wall sleeve shall be installed for the pipeline penetration.
3. Test station wires shall be attached to the pipeline just outside the manhole.
4. Alternate electrical isolation can be provided by using a 3' long PVC pipe spool from the manhole to the new pipeline and using a compression or bell end pipe to connect to the plastic pipe spool.

K. Fire Protection Piping Systems

1. Buried ferrous fire protection piping shall be electrically isolated from non-buried fire protection piping and/or other electrically grounded facilities, installed with bonded pipe joints and cathodically protected in accordance with this specification. Test stations shall be installed at all underground electrical isolation fitting locations.
2. Non-buried fire protection piping shall be bonded for personnel safety. Bonded fire protection pipe joints shall be tested for electrical continuity.

3.5. CLEARANCE OF PIPING TO OTHER STRUCTURES

- A. Foreign Structures: A minimum of 12” of clearance shall be maintained between the piping and other metallic structures, where possible. When 12” of clearance cannot be maintained, install non-conductive fiberglass shields or a high density flexible polyethylene solid membrane sheet, nominal thickness 0.125”, between the pipe and foreign structure.
- B. Concrete: When placing concrete in direct contact with ductile iron or steel piping, apply mastic coating to the external surface of the ductile iron piping prior to placing the concrete. The mastic coating shall extend a minimum of 6” beyond the interface of the pipe and concrete. Clean all dirt, moisture, oil, grease, and other contaminants from the piping surface. Thoroughly mix the mastic coating and apply a coat of approximately 12 mils of coating to the piping surface. Allow the coating to dry in accordance with the manufacturer’s recommendations and apply a second coat of mastic of approximately 12 mils in thickness. Allow to completely dry before placing the concrete.

3.6. STRAY CURRENT BONDING OF TRANSIT FIXED FACILITIES

- A. Reinforced Concrete Structures: Bare steel reinforcement shall be utilized in locations identified for stray current bonding.
- B. Cast-in-place reinforced concrete structures: All cast-in-place reinforced concrete structures, including: direct fixation and embedded track slabs; retaining walls; cap beams; abutments; and wing walls constructed roughly parallel to and within 30’ of the nearest electrified rail shall have all longitudinal reinforcement in both faces bonded for electrical continuity. The longitudinal reinforcement in the foundation top and bottom layers for retaining walls and abutments shall also be bonded for electrical continuity and bonded to the wall reinforcement. Stray current collector bars shall be installed at all physical breaks in the reinforcement such as expansion and contraction joints. A silver/silver chloride reference electrode shall be attached to the reinforcement and embedded in the concrete on each side of the discontinuity if the bonding cables are routed to a test station. Additional, intermediate collector bars are required at intervals not exceeding 500’ along the structure and at each end of a structure. A minimum of two cables shall be connected to each collector bar and routed to a test station. A silver/silver chloride reference electrode shall be connected to the reinforcement and embedded in the concrete with wires routed to the test station.
- C. Soldier Pile Retaining Walls with Reinforced Concrete Cap Beams: All longitudinal reinforcement in each face of the cast-in-place concrete cap beam shall be bonded for electrical continuity. Stray current collector bar assemblies shall be installed at each end of the retaining wall and at all discontinuities in the cap beam longitudinal reinforcement to create electrical continuity between the longitudinal reinforcement. At approximate 250’ intervals along the wall a physical break in the longitudinal reinforcement of the cap beam shall be installed (expansion joint type break). A collector bar assembly shall be installed on each side of the break. Two cables shall be connected to the collector bar

assemblies on each side of the break and routed to a stray current control junction box. A copper/copper sulfate reference electrode shall be installed below the subgrade at each stray current control junction box.

- D. Sheet Pile Retaining Walls with Reinforced Concrete Cap Beams: Bonding for stray current control of sheet pile retaining walls shall be installed upon completion of the sheet pile installation for the entire length of the wall. At each end of the sheet pile wall and intervals not exceeding 500' a stray current monitoring test station shall be installed. Two cables shall be exothermically welded to the sheet pile and terminated in the test station. In addition, one copper/copper sulfate reference electrode shall be installed below the subgrade on the train-side of the wall and the reference electrode test wire terminated in the test station. The test station shall be mounted on or against the sheet pile wall at a location conveniently accessible for testing and outside of the train envelope, if practical.
- E. Mechanically Stabilized Earth Walls: Mechanically stabilized earth (MSE) walls constructed where the reinforcing elements do not extend beneath the track bed do not require bonding for stray current control. Non-metallic reinforcing strips shall be utilized where practical. Where metallic reinforcing strips are necessary, the reinforcing strips and anchors shall be fusion-bond epoxy or liquid epoxy coated and the reinforcements of adjacent modules shall not be electrically interconnected. Longitudinal reinforcing steel within precast concrete parapets and cast-in-place junction slabs shall not be made electrically continuous. MSE walls constructed where the reinforcing elements extend beneath the track bed require bonding for stray current control if metallic reinforcing strips are utilized. If metallic reinforcing strips are utilized they shall be electrically continuous for the length of the strip, no splicing is permitted. The reinforcing strips of adjacent modules shall be made electrically continuous through bonding along the soil-side face of the wall. At each end of the MSE wall and intervals not exceeding 500' a stray current monitoring test station shall be installed. Two cables shall be exothermically welded to the reinforcing strip bonding elements and terminated in the test station. In addition, one copper/copper sulfate reference electrode shall be installed below the subgrade on the train-side of the wall and the reference electrode test wire terminated in the test station. The test station shall be mounted on or against the sheet pile wall at a location conveniently accessible for testing and outside of the train envelope, if practical.
- F. Soil Nail Walls: Soil nail walls constructed roughly parallel to and within 30' of the nearest electrified rail require stray current control provisions. The stray current control provisions include electrical isolation between the soil nail and the reinforcement of the wall so that electrical continuity between individual soil nails is avoided. The soil nails shall be installed in non-perforated corrugated HDPE sheaths.
- G. Tie and Ballast Concrete Viaduct: Bonding of reinforcement is not required for the concrete viaduct structure. Stray current control for the viaduct structure is provided by the application of a high dielectric strength spray applied waterproofing membrane.
- H. Tie and Ballast Steel Bridge Decks: Bonding of steel elements is not required for the bridge structures. Stray current control is provided by the application of a high dielectric strength spray applied waterproofing membrane to the ballast pan.

3.7. ACCEPTANCE TESTING

- A. General: The DB Entity shall submit a testing plan and testing procedures for all required testing in accordance with this specification. The testing plan shall include theoretical resistance calculations for all electrical continuity testing requirements. The DB Entity shall submit a list of all proposed instruments to be used for the testing in accordance with this specification.

- B. Electrical Continuity: The electrical continuity shall be tested for structures bonded for stray current and corrosion control. The structures include but may not be limited to:
1. Bonded joint utility piping: The electrical continuity of the pipe shall be tested before and after backfilling is completed. The measured resistance shall not exceed 1.10 times the calculated theoretical resistance of the pipeline and bond cables.
 2. Cast-in-place concrete reinforcement: The electrical continuity of the reinforcement shall be tested before and after concrete placement is completed. The measured resistance shall not exceed 1.20 times the calculated theoretical resistance of the longitudinal reinforcement and bond cables.
 3. Soldier pile retaining walls: The electrical continuity of the retaining shall be tested before and after backfilling is completed. The measured resistance shall not exceed 1.20 times the calculated theoretical resistance of the longitudinal reinforcement and bond cables in the reinforced concrete cap beam.
 4. Sheet pile retaining walls: The electrical continuity of the reinforcement shall be tested before and after backfilling is completed. The measured resistance shall not exceed 1.20 times the calculated theoretical resistance of the longitudinal reinforcement and bond cables in the reinforced concrete cap beam, bonding cables, or reinforcing bar utilized for bonding of the sheet pile sections.
 5. Mechanically stabilized earth retaining walls: The electrical continuity of the reinforcement strips and anchors shall be tested before and after backfilling is completed. The measured resistance after backfilling shall not exceed 1.20 times the resistance measured prior to backfilling.
 6. Electrical Isolation: Electrical isolation shall be tested for all installed isolation joints, isolation unions, isolating mechanical couplings and insulated flanges. Electrical isolation shall also be tested for all cased metallic pipeline crossings to ensure the pipeline is isolated from the casing. Acceptance criteria include a current leakage less than 2% or a combination of a native open circuit potential across the fitting greater than or equal to 0.100 volts and when applying a test current to one side of the fitting a voltage shift of zero or in the opposite polarity occurs on the other side due to the test current.
- C. Cathodic Protection: All installed cathodic protection systems shall be tested for effectiveness. Testing procedures shall be in accordance with NACE International Standard TM0497. Cathodic protection system effectiveness shall be determined in accordance with NACE International Standard SP0169.
- D. Track-to-Earth Resistance: Track-to-earth resistance shall be tested in accordance with ASTM G165. Acceptable values of track-to-earth resistance normalized to 1000' of track (2 rails) are:
1. At grade concrete or composite tie and ballast construction – 500 ohms;
 2. At grade wooden tie and ballast construction – 250 ohms;
 3. Aerial concrete or composite tie and ballast construction with electrical isolation/waterproofing membrane – 1000 ohms;
 4. Grade crossings and embedded track – 250 ohms.

3.8. DEFECTIVE OR IMPROPERLY INSTALLED COMPONENTS

- A. The repair or replacement of any defective or improperly installed component of the stray current and corrosion control systems shall be the sole responsibility of the DB Entity. Any and all repairs or replacement of defective or improperly installed components shall be performed by the DB Entity at no additional cost to the MBTA.

END OF SECTION

SECTION 16465

DRAWINGS AND RECORDS FOR THE TRACTION POWER SYSTEM

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This section specifies the production and furnishing of drawings and tracings and describes the general format of drawings, types of drawings, and the manner in which information shall be displayed for submittal drawings, working drawings and As-Built drawings.
1. Design Drawings – Drawings submitted for the development of the design for review by the MBTA for the designated representative. These will become the Design Documents.
 2. Submit Drawings (Shop Drawings) - Drawings displaying systems, subsystems, products, arrangements and layouts.
 3. Working Drawings - Drawings that have been approved for use in the installation of the Contract.
 4. As-Built Drawings - Drawings which show the actual installation of the Contract as approved and accepted.
- B. The accuracy and correction of all drawings are the responsibility of the DB Entity, and the approvals of those drawings shall be granted for format only. The Design Drawings shall show the work in general to be installed under this contract. The DB Entity shall be required to develop the drawings to fit the particular locations or conditions within the Contract Documents. In addition, the DB Entity's attention is directed toward the fact that certain locations may require special layouts. In such cases, the DB Entity shall submit the designs and/or arrangements which he proposes to use to the MBTA for acceptance.

1.2 QUALITY ASSURANCE

- A. The DB Entity shall check drawings and final tracings for both form and content prior to submittal. Points to be checked shall include the following:
1. Conformance to the Mandatory Specifications
 2. Logical grouping and arrangement of subject matter
 3. Accuracy
 4. Legibility
 5. Neatness
 6. Line Quality
 7. Lettering Quality
 8. Reproduction Quality
 9. Inclusion of contract specified interfaces with related contracts

- B. Acceptance of drawings and tracings shall be at the discretion of the MBTA. The MBTA will consider the same points enumerated above, with the basic criteria for obtaining approval being that drawings are easy to read, understand and use.
- C. Drawings shall not be crowded or cluttered, but shall be arranged for easy reading for troubleshooting and maintaining.

1.3 SUBMITTALS

- A. When submitting drawings to the MBTA for initial acceptance of a product, subsystem, or location, DB Entity shall submit all drawings pertaining to the subject at one time. This logical grouping of drawings, sufficient to completely cover the subject concerned, shall be known as a "Submittal Package". Submittals shall be made in accordance with Sections 2.7 and 2.8.
- B. DB Entity shall submit samples of the drawings prepared in AutoCAD software within 30 days after receipt of a Notice-to-Proceed.

1.4 WORKING DRAWINGS

- A. Working Drawings shall consist of the Design Drawings and the DB Entity Submittal Drawings accepted for the installation. The DB Entity shall keep a set of the Working Drawings to mark every field modification for clear indication of the actual installations during construction.

1.5 AS-BUILT DRAWINGS

- A. As-Built Drawings, including the Design Drawings and the DB Entity Submittal Drawings, shall show the actual installation after construction as approved and accepted. These drawings shall be as specified in Sections 2.7 and 2.8. Additionally, the DB Entity shall update the Drawing "INDEX SHEET" to include all DB Entity Submittal Drawings.

PART 2 – PRODUCTS

2.1 BOOKS OF DRAWINGS

- A. The DB Entity shall supply books of specific Electrical System drawings for working and as-built plans as specified herein. These books of drawings shall consist of the following components:
 - 1. Drawings assembled as specified herein.
 - 2. Protective vinylized front and back cover
 - 3. A device for binding the left-hand edges of the drawings firmly, but in such a manner that drawings may be easily added, removed, or replaced without damage to the drawings.

2.2 FINAL AS-BUILT DRAWINGS

- A. Final As-Built drawings shall be printed by automated techniques (CADD) full size and on 11"x17" paper for review prior to final acceptance by the MBTA.

- B. The DB Entity shall coordinate with the MBTA in regards to the development of the final As-Built drawings. Production of final As-Built drawings is the responsibility of the DB Entity and shall be furnished to the MBTA within 30 days of acceptance.
- C. All electronic drawings shall be compiled and placed on a CD, and provided to the MBTA. Two disks shall be provided (i) all drawings and files in pdf format, (ii) all CAD files in native electronic format (AutoCAD).
- D. The DB Entity shall provide electronic files containing all final "As-Built" Drawings prepared on latest version of AutoCAD.

PART 3 – EXECUTION

Not Used

END OF SECTION

SECTION 16806

EXCAVATION FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the furnishing of all labor, material, and equipment required for safe excavation, trenching, backfilling, tamping and grading for cable, conduits, footings, concrete pads, troughs, CIH's, and foundations for signal cases, junction cases, signals, and other facilities at various locations as indicated herein.
- B. Rock excavation, if encountered, shall be included in this Section and is defined as the removal and disposal of materials in-place that cannot be loosened or broken down by ripping, or by the use of modern construction earth excavating equipment.
- C. Materials which require special rock excavation equipment, or blasting for removal, such as boulders measuring one-half cubic yard or more, and all solid rock, masonry, and concrete pavements requiring hand power tools for fragmenting prior to removal shall also be included in this Section.
- D. Sheeting, shoring, and de-watering of excavated areas and trenches shall be included as necessary for the work described herein.
- E. Backfill materials shall consist of suitable on-site earth excavation; crushed stone, sand, and gravel borrow as specified herein.
- F. The DB Entity shall not excavate under or near track so as to adversely affect its integrity without prior approval of construction method and with the MBTA's acceptance.
- G. Work in a manner to prevent soil erosion, washouts, etc.

1.2 QUALITY ASSURANCE

- A. Backfill materials specified shall be accepted by the MBTA prior to placement. The DB Entity shall arrange for material analysis and all certifications as directed by the MBTA, at no additional cost to the MBTA.
- B. Any voids shall be backfilled again until stabilized.
- C. Backfill in a manner to prevent washouts.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following to the MBTA for acceptance:
 - 1. Certified compaction test reports for material required to be compacted, as specified in various Sections of these and the Mandatory Specifications. The percent compaction shall be in accordance with applicable Sections of these Mandatory Specifications.
 - 2. The type of protective covering to be used to prevent contamination of existing ballast during excavation.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Backfill materials delivered to the site and excavated materials suitable for backfill shall be stored in areas designated by the MBTA in neat piles which will not interfere with railroad system operating traffic movements or work being performed by others. Surplus excavated materials not required for backfill shall be removed from the site for disposal as soon as possible.

1.5 JOB CONDITIONS

- A. Sheeting and shoring of trenches shall be in conformance with applicable local and other governmental codes and regulations.
- B. Transportation of backfill materials and dust control on or near the work shall be in compliance with applicable environmental codes and regulations.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. General requirements pertaining to trenching and backfill materials are as follows:
 - 1. On-site materials obtained from trench and other excavation, to be used as ordinary backfill under this Contract shall have physical characteristics of soils designated as group A-1, A-2-4 or A-3 under AASHTO M-145.
 - 2. Crushed stone base for foundations and replacement of excavated ballast shall be AREA size No. 5 having the following gradation:

<u>Size of Opening</u>	<u>Percent Passing by Weight</u>
1-1/2 inches	100
1 inch	90 - 100
3/4 inch	40 - 75
1/2 inch	15 - 35
3/8 inch	0 - 15
No. 4	0 - 5

- 3. Sand for cable bedding shall consist of clean, inert, hard, durable grains of quartz or other hard durable rock, free from loam or clay, surface coatings, and deleterious materials. The allowable amount of material passing a No. 200 sieve as determined by AASHTO T11 shall not exceed 10% by weight.
- 4. Gravel backfill shall consist of inert material that is hard, durable stone and coarse sand, free from loam or clay, surface coatings, and deleterious materials.
 - a. Graduation requirements for gravel shall be determined by AASHTO T-27 and shall conform to the following:

Sieve	Percent Passing
1/2 inch	50 – 85
No. 4	40 – 75
No. 50	8 – 28
No. 200	0 - 8

- b. The maximum size of stone shall not exceed three inches.
5. The DB Entity shall furnish trench marker tape for signal cable, bright yellow, six inches wide and continuously coded in black lettering with the following legend:

CAUTION	CAUTION	CAUTION
BURIED	SIGNAL	CABLE

Tape for “electrical” or “communication” trenches shall be similar except coded within the legend corresponding to the type of cable installed with the trench.

PART 3 - EXECUTION

3.1 CONSTRUCTION

- A. Excavation work shall be conducted as follows:
- Over-excavation shall be kept to a minimum and any over-excavation below the required grades shall be replaced with backfill material meeting the specified requirements, at no additional cost to the MBTA.
 - The DB Entity shall locate, dig, and backfill the trench with minimum disturbance to drainage, electrical, or other existing systems. The DB Entity shall re-establish and/or repair any portion of the drainage system that may have been disturbed. The DB Entity shall immediately notify the MBTA of any breaks or disturbances of the existing cables. Repairs to existing systems disturbed during excavation shall be made at no additional cost to the MBTA.
 - Wherever excavation is required under or adjacent to tracks that are in service, the DB Entity shall provide such sheeting and shoring as is necessary to prevent damage to the track structure and shall complete his excavation and backfill operations within the same workday.
 - A protective covering shall be provided over track ballast to prevent contamination during excavation and backfill operations. Where it is not possible to provide a protective covering, the DB Entity shall remove the contaminated ballast and replace with crushed stone that shall be compacted as described herein.
 - Soft or unsuitable material existing below the required subgrade shall be removed and replaced with gravel, crushed stone, or other suitable material, as directed by the MBTA, and thoroughly compacted. Rock or boulders shall be removed below the subgrade to a minimum depth of one

foot below the bottom of foundations.

6. Excavation required for placement of cable trough and related systems shall be in accordance with manufacturer's recommended installation practices and with methods shown in the accepted DB Entity's submittal for cable trough installation.
7. Subgrades for conduit or cable trenches paralleling the tracks shall not be less than thirty-six inches (minimum) below finished earth or ballast unless otherwise accepted by the MBTA. When passing under tracks, trenches for conduit or cable shall be not less than thirty-six inches below the top of rail. Power cables, where run separately, shall be a minimum of one foot below the signal cable(s).
8. Where cross pipes, drains, cables, or other unforeseen obstacles are encountered or where clearances are not in conformance with national and local codes, the proposed line and grade of the cable trench or foundation may be altered after securing prior acceptance of the MBTA.

B. Sheeting and Shoring

1. When conduit and foundations are being installed in a trench or hole, the DB Entity shall furnish, install, and maintain such sheeting and shoring as may be required to support the sides of such excavations and adjacent structures. Should the DB Entity be permitted to slope the sides of such excavations so that sheeting, shoring, or bracing is not necessary to prevent cave-ins or slides along the excavation, such additional excavation and backfilling shall be done at no additional cost to the Contract.
2. Unless otherwise accepted by the MBTA, all excavation supports shall be removed upon completion of, or during backfill operations.

C. Dewatering

1. The DB Entity shall provide and maintain, at all times during construction, ample means and equipment to promptly remove and dispose of all water from every source entering the excavations or other parts of the work, to ensure dry excavations and the preservation of the lines and grades of bottoms of excavations.

D. Backfill

1. After excavation to subgrade has been completed, the specified fill shall be placed and compacted as described herein.
2. Backfill operations shall not commence without the acceptance of the excavation by the MBTA.

E. Crushed Stone

1. At all locations where pre-cast or cast-in-place concrete foundations or outdoor cable troughs are installed, a crushed stone base shall be placed and compacted on the accepted subgrade to a total depth of not less than four inches after compaction. Crushed stone shall be placed and compacted at locations where track ballast has been removed and/or fouled by the DB Entity's operations and as directed by the MBTA.

F. Sand

1. Prior to the installation of underground cables a bed of sand compacted to a depth of not less than four inches shall be placed on the accepted subgrade. Following the installation of the cables, sand backfill shall be placed and compacted with hand tools around and over the cables in four-inch to six-inch layers, to a uniform depth not less than six inches over the cables without damage to the cables.

G. Gravel

1. In the event that the on-site excavated soil materials, or any part thereof, do not conform to the soil characteristics specified in this Section, gravel material shall be placed and compacted in uniform layers not exceeding eight inches for backfilling trenches beyond the specified limits for crushed stone and sand backfill.

H. On-site Material

1. All suitable soil material, excavated by the DB Entity for cable trenches and foundations conforming to the material requirements of this Section shall be used for backfilling trenches and foundations beyond the specified limits for crushed stone backfill. Material shall be placed and compacted in uniform layers not exceeding eight inches.

I. Compaction

1. Sand, gravel and on-site backfill shall be compacted to not less than 95% of the maximum dry density of the respective materials, as determined by AASHTO Test Designation T-99. Crushed stone shall be compacted with vibratory compactors to distribute the particle sizes and to provide a compact base with free-draining characteristics.
2. All mechanical equipment for compaction of backfill shall be subject to the acceptance of the MBTA.

J. Trench Marker Tape

1. When installing backfill over direct burial cable or conduit runs, the DB Entity shall also install the polyethylene color-coded tape approximately 12 inches below the finished grade for the full length of each run.

K. Two weeks after backfilling, the DB Entity shall perform an inspection to observe settlement. Any voids shall be backfilled and checked again two weeks later until the areas of excavation have stabilized.

L. Clean-up and Disposal

1. Immediately upon completion of the work described herein, or any segments thereof, and as directed by the MBTA, the DB Entity shall remove and dispose of all debris and surplus excavated material away from the site.

M. Safety

1. All excavation areas shall be covered/protected to eliminate any possibility of a tripping or falling hazard. At the end of each work shift, any ground openings shall be safely covered and an approved barrier, snow fence as a minimum, shall be in place at all times to prevent inadvertent passage through the excavation area.

END OF SECTION

SECTION 16807

CONCRETE AND OTHER FOUNDATIONS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing precast concrete foundations, precast concrete or cast-in-place concrete foundations and cast-in-place concrete pads. Foundations to be furnished and installed shall be complete with galvanized anchor bolts, washers, nuts and associated hardware.
- B. Precast concrete shall be furnished and installed for CIHs, wayside cases, junction boxes, and snowmelter control cases.
- C. Precast concrete foundations shall be furnished and installed for ground mast signals as specified herein. At the discretion of the MBTA, approved cast-in-place foundations may be used where conditions prohibit the use of a precast foundation.
- D. All foundations shall include all fastening hardware and associated material.
- E. All general construction effort which includes items such as excavation for foundations, site clearing and restoration shall be the responsibility of the DB Entity.

1.2 QUALITY ASSURANCE

- A. Concrete for precast foundations shall be in accordance with specifications of the AREMA Manual for Railway Engineering Chapter 8, Specifications for Concrete Structures, and shall have a compressive strength of not less than 5,000 psi.
- B. A permanent record shall be kept by the precast fabricator of the date and conditions of casting of each unit.
- C. Test Specimens
 - 1. Representative test specimens of the concrete poured during the fabrication of the precast units shall be tested to determine the compressive strength of the concrete by an "Accredited Authoritative Structural Testing Laboratory" at no additional cost to the MBTA.
 - 2. Proper control of water-cement ratio, vibration frequency, protection and curing processes shall be monitored to provide the minimum strength of concrete as specified herein.

1.3 SUBMITTALS

- A. The DB Entity shall submit the following for acceptance:
 - 1. Catalog cuts and descriptive literature for all material as specified herein and as shown on the Contract Documents.
 - 2. Drawings of the cast-in-place and precast foundations proposed to be furnished and installed. These drawings shall include the following:
 - a. Physical Dimensions

- b. Type of Formwork
- c. Reinforcing
- d. Bolt spacing, size and detail of galvanized bolts, nuts and washers
- e. Depth of foundation from top of finished grade
- f. Cable entry openings
- g. Proposed location

B. Upon the MBTA's request, submit the following for acceptance:

- 1. Drawings of the precast foundations proposed to be furnished and installed. These drawings shall include the following:
 - a. Physical Dimensions
 - b. Reinforcing
 - c. Bolt spacing, size and detail of galvanized bolts, nuts and washers
 - d. Depth of foundation from top of finished grade
 - e. Cable entry opening
 - f. Certification of Compliance
 - g. Proposed location

C. Two copies of the fabricator's records showing the date and conditions relating to the manufacture of each precast unit, which shall include type of fabricator's building or enclosure, form material used, curing procedures, (steam or water), temperature ranges, air entrainment content, water-cement ratio, method of finishing the units, and all other pertinent information.

D. Four certified copies of the tests conducted by the "Accredited Authoritative Testing Laboratory" for approval and acceptance of the precast units.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage throughout delivery, storage and handling. Comply fully with the requirements of Section 16801 - BASIC TECHNICAL REQUIREMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Damage to trough material, resulting from improper handling by the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Precast concrete foundations and piers shall be made of concrete with a compressive strength of not less than 5,000 psi. and be in accordance with the applicable AREMA Signal Manual for the type of precast foundation required.

- B. The pre-cast concrete foundations shall be specifically design for the support of the signal equipment it is supporting.
- C. Precast concrete foundations shall be steel reinforced. Reinforcing steel shall be placed not less than one inch from any outside surface.
- D. Finish and Curing of Precast Foundations. Proper control of the water-cement ratio, high frequency vibration and controlled curing shall be used. An air entraining agent shall be used to increase the resistance to weathering. All outside surfaces shall present a flat smooth and finished appearance.

2.2 BOLTS, NUTS AND HARDWARE

- A. Bolts, nuts and washers shall be galvanized. Nuts and threads shall be in accordance with AREMA Specifications for Bolts, Nuts and Threads.
- B. Plain washers shall be in accordance with AREMA Specifications for Plain and Spring Lock Washers.
 - 1. Steel shall be in accordance with AREMA Specifications for Various Types of Steel.

2.3 CAST-IN-PLACE MATERIAL

- A. Concrete Formwork
 - 1. Concrete formwork shall conform to the requirements of Section 03300 - CAST-IN-PLACE CONCRETE.
- B. Concrete Reinforcement
 - 1. Concrete reinforcement shall conform to the requirements of Section 03300 - CAST-IN-PLACE CONCRETE.
- C. Cast-In-Place Concrete
 - 1. Cast-in-place concrete shall conform to the requirements of Section 03300 - CAST-IN-PLACE CONCRETE for ASTM C150, Type 11 portland concrete cement.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Prior to placing precast concrete foundations, cast-in-place concrete foundations or pads the excavation(s) and installation of crushed stone base shall be placed and compacted as specified in Section 16806 – EXCAVATION FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Foundations and piers shall be buried to a minimum depth of 60 inches below top of finished grade, unless otherwise accepted by the MBTA. Top of final grade to top of foundation shall be as shown on the Contract Documents.
- C. When placing foundations or pads, exercise care to ensure that anchor bolts are not bent or

threads damaged. All anchor bolt threads, washers and nuts shall be protected by applying friction tape, or other approved method satisfactory to the MBTA, until the unit to be supported is installed. Anchor bolts requiring leveling nuts shall be of sufficient length.

- D. Foundation(s) and pad(s) shall be installed level and plumb.
- E. If the surfaces of all foundations exposed to view do not present a uniformly clean surface of even texture and appearance, the surface shall be treated and rubbed to obtain a satisfactory finish, subject to acceptance by the MBTA.

END OF SECTION

SECTION 16808

EXTERNAL SIGNAL CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies requirements for furnishing, installing and testing of a new external signal cable system.
- B. The DB Entity shall furnish and install new signal cables, conduits and raceways required for the complete signal cable system necessary to support the GLX Project. All cables shall be installed in conduit, cable tray, prefabricated cable trough, or aerially on messenger wire.
- C. Material and workmanship shall be of the highest quality to ensure durability for a minimum life expectancy of forty years. The cables shall be suitable for use in the environment to be encountered and shall be certified for continuous operation at 90 degrees C in wet or dry locations with no conductor failing in continuity or with loss of insulation to cross or ground less than fifty meg-ohms.
- D. Express cables are defined as those cables that run between CIH locations.
- E. Local distribution cables are defined as those cables that run from CIH's and cases to wayside equipment. Such as CIH to signal, track circuit, switch machine, main CIH to east CIH etc.
- F. Wire and cable to be furnished for this Project shall meet the requirements of the MBTA's wire and cable requirements as stated herein and as listed in the Technical Appendix A of this section.
- G. The DB Entity shall assure wire and cables are of adequate size and quantity for the system prior to installation.

1.2 QUALITY ASSURANCE

- A. Rejected Wire and Cable – Wire and Cable that does not meet the requirements of this Mandatory Specification shall be rejected. Wire and cable which shows defects or non-compliance with the requirement after delivery at destination may be rejected and the DB Entity shall, on request, advise disposition of the wire and cable in question and pay all related transportation charges for the rejected and replacement material.
- B. Approval of Signal Wire and Cable
 - 1. All wire and cable manufacturers supplying cable for this Contract must be accepted by the MBTA. The DB Entity shall provide all of the data required for the MBTA's evaluation and shall arrange for wire and cable samples, demonstrations and test, if requested.
 - 2. Approval shall be based on the following criteria:
 - a. Past performance and experience: The wire and cable manufacturer(s) must demonstrate previous successful experience in supplying wire and cable to the railroad or transit industry for use as vital signal control, communication cable and electrical. A list of such installations shall be provided for each cable manufacturer under consideration.

- b. Quality assurance program: The manufacture of wire and cables in accordance with the requirements of this Mandatory Specification shall be accomplished in compliance with a quality assurance program that meets the intent of ANSI/ASQC C1-1996 (ANSI Z1.8-1971): Specifications of General Requirements for a Quality Program. Such compliance shall promote a thoroughly tested wire and cable that will render long service life to the user. Prime concern must be focused on the necessary formal assurance requirements to insure that wire and cable failure cannot be attributed to actions or lack of actions by the manufacturer.
- c. Technical data: The DB Entity shall provide full technical data demonstrating compliance with the requirements of this Mandatory Specification for each specified wire and cable.
- d. Demonstration tests: The DB Entity shall make arrangements with the prospective cable manufacturer(s) to perform demonstration tests as required by the MBTA.
- e. Sample specimens. The DB Entity shall, if requested by the MBTA, furnish sample specimens in four-foot lengths for each type of wire and cable specified herein. Sample specimens shall remain the property of the MBTA.
- f. The manufacturer shall certify that he shall comply with the following warranty clauses:
 - 1) The manufacturer warrants that design, material and shall be of the highest quality and consistent with the established and generally accepted industry standards for wire and aerial and underground cable for vital railroad signal, communication, and power circuits; and that each such item and every part and component thereof shall comply with this specification.
 - 2) The manufacturer agrees that this warranty shall commence with the acceptance of each item of wire and cable, whether the defect be patent or latent, and shall apply for a period of two years after initial satisfactory operation or four years after acceptance, whichever is shorter.
 - 3) The warranty covering any length of wire and cable replaced by the manufacturer under the above conditions shall be reinstated for a period of two years effective the date of replacement is affected. If failure is found to be of major significance and affects other wire and cable, the reinstatement of the warranty shall then be extended to cover the item so affected as well, and shall start as of the date of such replacement. The warranty reinstatement provided for in this subparagraph (3) shall apply only to the first replacement or repair of any such item and, in the case of failure of major significance, to the first extension of the said warranty to said affected items.
 - 4) The foregoing warranties are exclusive and in lieu of all other warranties, written, oral, implied or statutory (except as to title and freedom from lien). In no event shall the Manufacturer be liable by reason of breach of warranty for special or consequential damages.
 - 5) Wire and cable furnished shall be traceable to the test data on file for each step in its manufacturing process.

3. Cable Inspections

- a. Inspection:
- b. The MBTA, or its authorized representative, shall have the right to make inspections and tests to determine if the wire and cable meets the requirements of this Mandatory

Specification. The inspector for the MBTA shall have the right to reject wire and cable that is found defective.

- c. The MBTA shall be given a ten-day advance notice of final wire and cable testing, so that the MBTA may witness the tests, if it so elects.
- d. Physical tests shall be made on samples selected at random at the place of production. Each test sample shall be taken from the accessible end of different reels. Each reel selected and the corresponding sample shall be identified. The number and lengths of samples shall be as specified under the individual tests. All applicable tests for the cable materials and cable construction specified shall be performed.
- e. The manufacturer shall provide, at the point of production, apparatus and labor for making any or all of the following tests under the supervision of the MBTA's inspector; to include:
 - 1) Conductor size and physical characteristics,
 - 2) Insulation HV and IR tests,
 - 3) Physical dimension tests,
 - 4) Special tests on materials in coverings,
 - 5) Final HV, IR, and conductor resistance tests on shipping reels.
- f. Certified electrical and physical test reports shall be furnished for the finished multiple conductor cables no later than the time of shipment. Each test document shall, in addition to the test results, indicate the date the tests were performed and the signature of the manufacturer's authorized representative.
- g. The MBTA reserves the right to conduct itself, or by its duly authorized representative, those tests it so elects to further satisfy itself that the cable is manufactured in accordance with the requirements of this Mandatory Specification.

C. Signal Wire and Cable Termination – Quality Assurance Program

1. The DB Entity shall develop a Quality Assurance program to assure that the proper procedures are followed to prepare and terminate signal cables on this contract. All work shall be performed using the highest quality of workmanship possible in a railroad signal, communications and electrical systems environment. This procedure covers supervision, training and implementation of that program.
2. An “assembly line” approach shall be used to strip the outer jackets; pothead the cables; affix eyelets to wire ends; terminate the conductors and perform megger tests. The DB Entity shall inspect and maintain documentation on the various segments of the work. Under no circumstances shall the cables be unraveled or connected prior to visually inspecting for cuts, nicks or abrasions to conductors. The DB Entity shall submit, for acceptance, Cable Termination Report Forms that shall be used to report the work and document/record inspections. These forms shall be submitted within five (5) days of an inspection. Every cable shall be inspected both prior to and after connection; the MBTA shall be notified 48 hours prior to each inspection, and reserves the right to witness the inspection.
3. Wiremen shall be pre-qualified in the use of the approved tools to perform the various functions to which they are assigned. Wiremen shall be trained on the use of proper tools. Wiremen engaged in tagging and termination shall also receive a short training on how to read cable wiring diagrams. The MBTA shall be notified 48 hours prior to each training session and reserves the right to witness and inspect the samples of work.

4. The requirements for pre-qualification are:
 - a. Wiremen engaged in stripping the outer jackets shall demonstrate their ability to properly remove the outer jackets using T-CA Magic Cable Strippers as manufactured by DLW Industries without damaging the inner conductors.
 - b. Wiremen stripping wire ends shall demonstrate their ability by using Ideal Stripmaster Wire Strippers 45-092 (for #14-#16-#10 AWG wire) and Ideal Cable Strippers (for #6 AWG wire) to properly remove the required amount of insulation without nicking the copper conductor.
 - c. Wiremen installing wire eyelets shall demonstrate their ability to properly install the eyelets by using new factory calibrated AMP crimping tools designed for the particular eyelet used.
5. All cable and wire strippers shall be purchased new and shall of be the highest quality available on the market. Ten percent (10%) spare tools shall be available in case of damage to the tools in daily service. These tools shall be factory calibrated and shall be checked periodically in accordance with manufacturer's recommendations for wear or damage.
6. Tools for crimping on the eyes shall be new and factory calibrated at least every six (6) months. Calibration stickers shall be required on each tool.
7. To ensure that the proper tools are used, kits will be set-up and identified by kit number. All tools in each kit must also be numbered. Each wireman shall be assigned a number kit. The kit number and employee's name shall be recorded on a Cable Termination Report and submitted to the MBTA. The DB Entity shall inspect these kits daily, prior to the start of cable termination work, and shall immediately remove the kit from service if a discrepancy is found.
8. The DB Entity shall not proceed with any wiring work if there is a noticeable problem with the tools or cable.
9. Any tools referenced above may be substituted with approved equals upon receiving written acceptance from the MBTA.
10. The conductor terminations shall be made by experienced personnel and be in conformance with the cable manufacturer's recommendations. Submit for approval the cable manufacturer's termination recommendations.
11. Splices in signal cables are not allowed.
12. The MBTA has the right to inspect any tools, materials or work, in conjunction with or independently of the DB Entity. The MBTA has the right to stop work should any deficiencies be found and to only allow work to continue once the deficiencies have been resolved to his sole satisfaction.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8, the DB Entity shall submit the following for acceptance:

- A. Signal Wire and Cable:
 1. List of each cable manufacturer's railway signal installations;
 2. Each cable manufacturer's Quality Assurance Program, including the manufacturer's testing procedure;

3. Manufacturer's technical information describing the cable and its electrical and mechanical characteristics including a cross-section drawing to include cable shape, construction, number of conductors, size, insulation thickness and type, jacket thickness and type, approximate weight per foot and outside diameter for each type of cable the DB Entity proposes to use.
4. The DB Entity shall furnish sample specimen of a four-foot length, if requested, for each proposed cable type. The samples shall remain the property of the MBTA;
5. Certified factory cable test reports which shall include:
 - a. Report Number,
 - b. Date and location of test,
 - c. Description of test, including the testing conditions,
 - d. Complete cable or wire description,
 - e. Lot, batch, and reel identification number,
 - f. Quantitative test results including a completed, signed and notarized standard wire and cable test report sheet,
 - g. Summary of the test results,
 - h. Information on the components of the cable tested to include batch numbers and physical and electrical properties.
6. The DB Entity shall submit two certified copies of the following for acceptance:
 - a. Cable test reports for all demonstration tests required by the MBTA,
 - b. Cable test and inspection reports for tests and inspections required and described by these Mandatory Specifications,
 - c. Test reports of cable tests conducted in the field in accordance with accepted testing procedures,
 - d. Certification that each cable supplied complies with the requirements of these Mandatory Specifications.
7. The DB Entity shall submit two copies of complete, signed and notarized standard Wire and Cable Test Report Sheet as part of each cable test report.
8. The DB Entity shall furnish to the MBTA ten copies of the cable manufacturer's instructions and procedures together with one sample end seal specimen for pot heading of each type of cable to be furnished and installed for this Project.
9. Cable jacket removal and termination procedures;
10. Sample sheet showing format for Cable Termination Report Forms;
11. Cable Termination Report Forms when work is completed;
12. Cable pot heading method and product manufacturer;
13. Submit five copies of detailed installation plans, showing all hardware to be used, methods of attachment, cable routing through conduits, troughs and pull boxes, etc. and including fill percentages, for approval prior to construction/installation, including but not limited to:
 - a. Detailed cable routing plans.
 - b. Pulling plans, including pulling tension calculations and DB Entity's proposal for

monitoring pulling tension during wire and cable installation.

- c. Cable bending radius plans demonstrating minimum bending radius compliance during installation and after installation is complete.
14. Submit for approval messenger attachment, size, usage, sag and tensions and cable pulling calculations for each individual cable run. The maximum pulling tensions shall be recorded for each cable pull and submitted to the MBTA.
15. Provide a final as built copy in the case adjacent to the cable run. Submit to MBTA Final as-builts in electronic format.
16. Splicing of signal wire and cable will not be allowed.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Ship all wire and cable on reels, adequately protected by heavy wrapping or wood lagging from damage during shipment. The DB Entity shall be responsible for any defect in wire or cable occurring in transit. External protective wrapping shall be secured to reels to protect cable during shipment.
- B. Provide reels designed and constructed to withstand handling and so both ends of wire or cable are secured and accessible but protected from injury. If the inner end of the wire or cable projects through the flange of the reel, protect the inner end with a suitable cover of metal with rounded ends and sides and securely fastened in place to protect the wire or cable end. Secure both ends of wire or cable on the reel in place, to prevent their becoming loose in transit or during handling of the reel.
- C. Provide reel drums with a radius larger than the minimum bending radius of the cable to prevent damage to wire or cable during reeling. The arbor hole shall admit a spindle 2-1/2 (two and one-half) inches in diameter without binding. Ship wire and cable in non-returnable reels.
- D. After acceptance of factory tests, seal wire or cable against the entrance of moisture. Protect both ends of each length of wire or cable with wrappings of rubber tape and plastic tape, or an effective boot taped or sealed into place, or by other suitable means accepted by the MBTA. The use of friction tape, other than as an external mechanical protection over an adequate rubber and/or plastic tape, will not be accepted. The wire or cable end protection shall be adequate to protect wire or cable in shipment and for prolonged external storage.
- E. Wind each layer of wire or cable closely and tightly on the reel in a uniform manner.
- F. Paint an arrow on one head of each reel pointing to the opposite direction from the outer end of the wire or cable, with the words "Roll This Way", using letters not less than 3/4-inch in height and arrow not less than six inches in length and 1/2-inch in width.
- G. Requirements for shipping, storage, and handling shall also be in accordance with AREMA C&S Manual, Parts 10.4.1, Recommended Instructions for Wire and Cable Installation and Maintenance and 10.3.16, Recommended Design Criteria for Signal Cable, Non-Armored as well as other provisions established throughout these Mandatory Specifications.

PART 2 - PRODUCTS

2.1 SIGNAL WIRE AND CABLE

- A. Provide the wire and cable for this Project for signal, communication and electrical applications to meet the requirements of the MBTA wire and cable specifications contained within the Technical Appendix A of this section.
- B. The standard cable make-ups shall be as follows:
 - 1. Generally, No. 14 AWG solid used as line circuits between points, to junction boxes and snowmelter control/indication cable to heater cases.
 - 2. Electric Switch Machines: 15 conductor composite cable consisting of (3) #6 AWG stranded and #14 AWG stranded, installed between CIH to the switch machine junction box.
 - 3. Wayside Signals: 12 conductor #14 AWG solid installed between CIH to signal.
 - 4. Track Circuits: 2 conductor #6 AWG stranded twisted from CIH or junction box to track.
 - 5. AVI: 2 conductor #12 AWG solid shielded from CIH to tuning unit (if not located in CIH); #8 AWG stranded twisted from tuning unit to track.

2.2 CABLE MAKE-UP

- A. General
 - 1. If any cables are required beyond those shown above, the DB Entity shall determine size of conductors and cable make-up to meet design requirements. DB Entity shall also increase conductor sizes, as necessary, to be in accordance with the National Electrical Code requirements.
 - 2. If the DB Entity's proposed signal system equipment requires use of shielded cable, the price of such shielded cables shall be included in the bid. Provide shielded cables meeting all requirements of these Mandatory Specifications.
 - 3. The DB Entity will be required to supply all cables, wires and ancillary materials and equipment for this project in sufficient quantities and qualities as prescribed by the MBTA Cable Specification Technical Appendix A of this section.
- B. Spare Requirements
 - 1. The DB Entity shall provide spare conductors in all multi-conductor cables. Express cables originating at a CIH shall contain a minimum of 20 percent spare conductors. Local distribution cables shall contain a minimum of ten percent spare conductors or minimum of one spare conductor.
- C. Where more than one cable is used between the same locations, the quantity of spare wires/pairs shall not be less than 20 percent of the total number of working wires/pairs, but in no case shall the total quantity of spare wires/pairs be less than the quantity of spare wires/pairs required in the largest cable in the group.

2.3 SEALING OF CABLE ENTRANCES

- A. Any voids remaining, where cables enter housings, cases, junction boxes, signals, switch machines, or any other apparatus, shall be made water-tight with cold sealing compound in accordance with AREMA C&S Manual, Part 15.2.15, Recommended Functional Guidelines for Cold Application Sealing Compound

- B. After cable installation, seal all conduit ends, whether above or below ground with “Duxseal” as manufactured by OZ Gedney, “Flame-Safe” as manufactured by T&B, or any approved expanding foam filler.
- C. All cable entrance openings in equipment enclosures and junction boxes shall be sealed with either a compression type fitting or pliable sealing compound after the cable is in place. Dry sand shall be used to fill openings, chutes, risers. (Digging below the riser will release the sand) Sealing compound shall be used to seal the area around cable where the cable emerges from the end of a conduit, pipe, or duct bank. All spare conduits shall be sealed or plugged in an approved manner. Spare conduits will have a pull string installed and taped off on both ends for future use.

2.4 WIRE – INTERNAL

- A. Internal wire and cable shall be as required in specification Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM.

2.5 TAGS

- A. Tags for identification of individual wires and cable conductors and field-installed wire shall be the sleeve type as manufactured by TYCO Electronics, RAYCHEM RPS-1K-8-4/2.0-9, or approved equal. Sleeve size shall vary as required for different wire sizes.
- B. Tags for cables shall be the PANDUIT flag type, or approved equal.
- C. Back-wired terminal boards in CIHs, and cases shall be provided with factory-printed strip tags with wire nomenclature adjacent to the wire entrance hole on the terminal board. Front-wired terminal boards in junction boxes shall have sleeve tags affixed to each individual conductor. Plastic cable tags as described in Section 16897 - MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM shall be supplied to identify individual cables entering each house, case or junction box in accordance with the DB Entity’s installation drawings, as accepted by the MBTA. All wires and cables shall be equipped at both ends with an approved tag.
- D. All strip and sleeve tags shall be machine printed.
- E. Three-line sleeve type tags shall state the conductor identification with "FROM", "NOMENCLATURE", and "TO" destinations
- F. Spare conductors shall also be identified as “Spare” in the “NOMENCLATURE” line of the tag.
- G. Submit catalog cuts or samples of each type of cable, wire, and equipment identification tags to be installed.
- H. Additional information regarding tagging is presented in Section 16897 - MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

PART 3 - EXECUTION

3.1 WIRE AND CABLE INSTALLATION

- A. General

1. The installation of wire and cable shall conform to AREMA C&S Manual Part 10.4.1, Recommended Instructions for Wire and Cable Installation and Maintenance, except as modified herein.
2. The DB Entity shall give the MBTA 24 hours' notice prior to installing cables.
3. Cables shall not be bent to a radius less than 10 times the diameter of the cable during installation or as finally installed. Express cables and fiber optic shall be installed with a minimum radius of curvature of 25 feet.
4. All signal cable runs shall be continuous without splices between cable terminating locations. Every effort shall be made for continuous runs without breaks. Junction boxes are required where a continuous length exceeds the reel length obtainable and all terminated cable wires within junction boxes will be identified by tags as previously explained within the section and requires the MBTAs acceptance. If it is determined that junction boxes are required for this purpose the DB Entity shall design furnish and install these junction boxes at no additional cost to the MBTA.
5. Inspect wire and cable carefully prior to installation to be certain that the wire and cable is free from defects. It is suggested that the DB Entity megger test the cable on the reels prior to installation for continuity and cross-meggering. This does not relieve the DB Entity from final cable testing and results when both cable ends are dressed within their final terminating points.
6. Any instance of damage to existing, operating wire and cable facilities which occurs during construction, or is discovered subsequent to construction activities, shall be immediately reported to the MBTA. MBTA personnel will promptly make necessary repairs with all necessary assistance by the DB Entity. All additional costs are the responsibility of the DB Entity. All MBTA related costs incurred for the repairs are to be paid by the DB Entity to the MBTA within 60 days. In the case of damage to any new wire and cable facilities installed for this Project, the DB Entity shall be solely responsible to provide repair or replacement of such wire and cable, depending on the nature of repair and correction of any damage shall be as prescribed by written instruction from the MBTA.
7. When pulling cable, an approved wire cable grip, extending not less than 18 inches back from the end of the cable, shall be used. Clutch on the pulling device shall be set to slip at 50 percent of the cable manufacturer's allowable maximum. The equipment used for pulling cable shall be equipped with a dynamometer, which shall continuously indicate the pulling force in pounds. The maximum pulling tensions shall be recorded for each cable pull and submitted to the MBTA.
8. A suitable lubricating medium, non-injurious to the cable insulation, shall be used when pulling cables into conduit, pipe, or duct bank.
9. Cables shall not cross one another when they are placed in a trench, or pulled into a conduit or pipe and care shall be taken not to have the conductors pulled tight or kinked. All cables to be installed in the same conduit shall be pulled and installed simultaneously.
10. The track bed and ballast shall be protected from contamination during cable installation, and shall be restored to the existing condition after cable installation. Plastic tarps and plywood shall be used to prevent ballast contamination. Comply with Section 16806 - EXCAVATION FOR THE LIGHT RAIL SIGNAL SYSTEM of the Mandatory Specifications.
11. Where buried cables enter a concrete foundation, junction box, signal house, or case, five feet of slack for each cable shall be left in the trench below the foundation or pedestal. Do not coil the cable slack used with electronic equipment. The conduit end shall be sealed to

prevent water penetration and the cable shall be encased in a minimum of four (4) inches of sand. Cable marker tape shall also be installed over top of the cable coil at a depth of one (1) foot below the finished grade.

12. Where signal, communications or track cables are installed in the same trench as, or are required to intersect low voltage power cables, these cables shall be installed such that the distance between such cable and the low voltage power cable shall not be less than 12 inches, while maintaining the cover depth of not less than 36 inches for the cable. The 12 inches between any intersecting direct burial cables of different voltages as specified herein shall be filled with sand to a distance of two feet from each cable from the point of intersection.
13. Cable carrying 480V or more shall not be installed in the same trench, conduit, trough, or other raceway as signal cable.
14. The DB Entity shall provide appropriate special protection for wire and cable in areas where the cables are unavoidably exposed to hazardous conditions such as vibration or sharp corners on equipment. The DB Entity shall be responsible for the replacement, at no additional cost to the MBTA, for any cable that is subsequently damaged as a result of a failure to provide such special protection.
15. Cables shall be protected by conduit across bridges, culverts, thru rock cuts, under tracks, where minimum cover depths cannot be maintained, where minimum side clearances cannot be maintained. DB Entity shall provide drawings indicating where minimum cover depth could not be achieved and cables are protected in conduit.
16. Where cable leaves the ground at other than buildings or in foundations, it must be protected by a bootleg or other covering extending above the ground line. Top of such protective coverings shall be filled with a sealing compound.
17. Restoration of backfill and ballast shall be in accordance with the construction methods outlined in Section 16806 - EXCAVATION FOR THE LIGHT RAIL SIGNAL SYSTEM.
18. Cable marker tape shall be installed over top of all underground cables at a depth of one (1) foot below finished grade for the length of the entire run.
19. Where cable transfers from trays or troughs into a conduit, the ends of the conduit shall be fitted with bell ends to prevent damage to the cable.
20. Cables shall enter equipment and foundations through cable entry openings, chase ways, etc. that have been specifically designed and approved for cable entrance or through cable entrance pipes, as specified in 16897 - MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
21. All wires shall be terminated in conductor order. Individual cable conductors shall be identified at each cable termination with plastic tags as specified above. All spare conductors in each cable shall be terminated and identified as spare.
22. All cable entrance openings in equipment enclosures and junction boxes shall be sealed with either a compression type fitting or pliable sealing compound after the cable is in place. Dry sand shall be used to fill openings, chutes, and risers. (Digging below the riser will release the sand) Sealing compound shall be used to seal the area around cable where the cable emerges from the end of a conduit, pipe, or duct bank. All spare conduits shall be sealed or plugged in an approved manner.
23. All cables shall be potheaded, tagged and terminated. Tags to identify cables shall be of plastic material. Tags shall be lettered to correspond with the cable destination and number of conductors in the cable. The tag shall be applied at the cable entrance in a manner to be

easily read. In addition, all cables shall be tagged within each manhole, each enclosure, and on each side of any barrier the cable passes through. Cables shall also be tagged at aerial exits from conduit risers. The type of tag to be used shall be as described in Section 16897 - MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

24. Wherever multiple conductor cables are terminated, the outer jacket of the cable shall be carefully removed to the point of cable entrance. Only approved cable jacket cutting tools, specifically designed for the purpose, with a positive means of setting and controlling the depth of cut into the jacket will be permitted. Razor instruments shall not be used. All conductors shall be inspected for damaged insulation immediately after removal of outer jacket and before tape is applied.
25. Cables shall be potheaded at termination points. The outer sheath shall be carefully removed to within 3"-12" of the cable entrance. Any bronze or metal type shielding, not used for grounding shall be nipped off and the edges bent outward away from the conductors. This shall be followed with several wrappings of 30 mil rubber tape (Scotch 130C) and two layers of 8.5 mil vinyl tape (Super 88) as manufactured by the 3M Company or an approved equal.
26. Excess cable slack shall not be left at terminal boards. Cable shall be cut so any wire within the cable can reach the furthest terminal designated for that cable then neatly trained back into its allotted terminal. Provide sufficient slack in wire or cable conductors at all terminating posts to enable three re-terminations of the conductor due to broken eyelets without re-servicing or re-potheading the cable.
27. In certain types of installation, the cable cannot be constrained; therefore, ample cable slack shall be provided for additional flexibility due to vibration of such equipment.
28. Wires and cables shall be installed (Dressed) in a neat, workman-like manner. Wires and cables in trays or in troughs shall be laid therein and not pulled into same. The cables shall be arranged to allow free access to all cables for maintenance. Wires and cables shall be installed with a minimum amount of cross-over in the trays and troughs and shall not be pulled tightly around bends. All wires and cables shall be protected from abrasion and sharp edges.
29. All conductors shall be eyed (solid only), or terminated as specified in Section 16897 - MISCELLANEOUS COMPONENTS FOR THE LIGHT RAIL SIGNAL SYSTEM insulation shall be removed carefully to ensure the conductor is not nicked or damaged.
30. All conductors including spares shall be identified (tagged) and terminated. The type of tag used for identification shall be as described in Section 16897 - MISCELLANEOUS COMPONENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
31. Fiber optic cable shall be looped behind the main terminal board for future termination into a fiber slack enclosure located on the adjacent wall - leave sufficient slack of at least 50 feet. The inner duct shall be cut within 3-12 inches of the cable entrance.
32. Seal all openings in equipment housings during construction and upon completion to prevent weather and rodents from entering.

B. Underground Buried Installation

1. Underground cable installation shall be in FRE conduit, buried a minimum of 36 inches below top of tie and 36 inches minimum cover depth outside of the tie area.
2. Cables shall not cross one another when they are pulled into a conduit or pipe and care shall be

taken not to have the conductors pulled tight or kinked in conduit fittings or boxes. All cables to be installed in the same conduit shall be pulled and installed simultaneously.

3. The track bed and ballast shall be protected from contamination during cable installation, and shall be restored to the existing condition after cable installation. Comply with specification Section 16806 – EXCAVATION FOR THE LIGHT RAIL SIGNAL SYSTEM.
4. Where buried cables enter a concrete foundation, junction box, or case, the DB Entity shall coil five feet of slack for each cable below the foundation or pedestal. The conduit end shall be sealed to prevent water penetration and the cable coil shall be encased in a minimum of four (4) inches of sand. Cable marker tape shall also be installed over top of the cable coil at a depth of one (1) foot below the finished grade.
5. Where signal, communications or track cables are installed in the same trench as, or are required to intersect low voltage power cables, these cables shall be installed such that the distance between such cable and the low voltage power cable shall not be less than 12 inches, while maintaining the cover depth of not less than 30 inches for the cable. The 12 inches between any intersecting direct burial cables of different voltages as specified herein shall be filled with sand to a distance of two feet from each cable from the point of intersection.

C. Non-Buried Installation

1. Installation in Cable Trays or Prefabricated Cable Troughs - Cable installed in cable trays or prefabricated cable troughs shall be laid and not pulled in place. Cables installed in trays and troughs shall have a minimum amount of crossover and shall not be pulled tightly around bends.

D. Above Ground Installation

1. All above ground conduit shall be galvanized rigid steel (GRS). When GRS conduit risers transition into the ground, GRS to FRE conduit adapters are to be installed 3-inch (minimum) to 5-inch (maximum) above grade.
2. Cables shall not cross one another when they are pulled into a conduit or pipe and care shall be taken not to have the conductors pulled tight or kinked in conduit fittings or boxes. All cables to be installed in the same conduit shall be pulled and installed simultaneously.

3.2 TESTS

- A. All installed external cable shall be tested in accordance with requirements of Section 16898 - SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM of these Mandatory Specifications.

END OF SECTION

APPENDIX A

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY (MBTA)

Power and Signals Department SIGNALS AND

COMMUNICATIONS DIVISION

Specification S—114—B

Date: May 13, 2009

SPECIFICATION FOR LOW SMOKE, NO HALOGEN, SIGNAL WIRE AND CABLE

I

1. GENERAL

This Mandatory Specification shall be in accordance with AREMA C&S MANUAL PARTS 10.3.13, 10.3.16 AND 10.3.22 that establishes the criteria for low smoke, no halogen ethylene propylene rubber insulated and low smoke no halogen cross—linked flame retardant polyolefin jacketed wire and cable.

This Mandatory Specification is for the purpose of providing for cables of high quality and long life, which are to be installed under adverse conditions of direct burial in earth, in ducts, or by aerial suspension, in circuits subjected to voltages of 0 to 1000 volts.

- (a) The wire and cable shall be in accordance with the requirements of the current AREMA C &S MANUAL 10.3.16 AND 10.3.23
- (b) When there is a difference between the requirements of this Mandatory Specification and other specifications mentioned herein, the requirements of this Mandatory Specification shall govern.

2. CONDUCTORS

- (a) The conductors shall meet AREMA 10.3.16 Type I to V.
- (b) Unless otherwise specified in-the purchase order, conductor sizes No. 9 AWG and smaller shall be meet AREMA 10.3.16 IV. Conductors larger than No. 9 AWG shall meet AREMA 10.3.16 type 1,2,3,5.

3. INSULATION

- (a) Conductors insulation shall meet AREMA 10.3.16. E. Type 1
- (b) The insulation shall also meet AREMA 10.3.19. B
- (c) The thickness of the insulation shall be in accordance with AREMA 10.3.16 TABLE 10316-2
- (d) The average thickness shall meet AREMA 10.3.16. E.5
- (e) The insulated conductors intended for assembly, into multi—conductor

cables shall be color—coded by means of printed color, name, and number according to ICEA Method 1 or 3 color coding. Printed legend shall be duplicated on Opposite sides of each conductor.

- (f) In addition, the low smoke EPR Insulation when tested at the thickness of 100 mils, for smoke generation, shall not exceed the value in Table III.
- (g) Testing voltages for the conductors shall be in accordance with Table 1 and Table 2 herein.

TABLE I

Insulation Thicknesses and Test Voltages for Single Conductor Wire Prior to Sheath Application

Rated Size of Circuit <u>Voltage</u>	Insulation Conductor- <u>A.W.G.</u>	<u>Test Voltages</u> Thickness <u>64th Inch</u>	<u>AC Volts,</u>	<u>DC VolTS,</u>
			<u>5 Minutes</u>	<u>5 Minutes</u>
0—1000	14 to 8	5	8,000	25,000
	7 to 2	6	10,000	30,000
	1 to 0000	7	11,000	33,000

The test voltages for Tandem Extruded insulation and jacket for Single Conductor wire are as follows:

Test Voltage for Composite Thickness — Table 1 Modified

Insulation <u>mils</u>	Thickness	AC (1) <u>Test Voltage</u>	DC <u>Test Voltage</u>
62.5	(4/64)	9.5kV	26kV
78.0	(5/64)	12.0kV	31kV
94.0	(6/64)	13.0kV	34kV

TABLE I-A

Insulation Thicknesses and Test Voltages for Individual Conductors of Multi—conductor Cable

Rated Circuit <u>Voltage</u>	Size of Conductor <u>A.W.G.</u>	Insulation Thickness <u>64th Inch</u>	<u>Test Voltages</u>	
			AC Volts, <u>5 Minutes</u>	DC Volts, <u>5 Minutes</u>
0—1000 19	to 16 3	6,000	18,000	
	16 to 8	5	10,000	30,000
	7 to 2	6	11,000.	33,000
	1 to 0000	7	12,500	37,500

- (h) A.C. Test — Each length of conductor, insulated with prime insulation, prior to application of any outer jacket and prior to cabling or twisting, shall be random—wound on spools and immersed in water for a minimum of twenty—four (24) hours, then subjected to test voltages given above for five (5) minutes, without showing signs of puncture, overheating, or self— healing of punctures. Voltage to be applied between conductor and water (ground).

- (i) Insulation Resistance Test — Immediately after the AC test specified above and while still submerged, an insulation resistance test shall be made on each length of conductor. The insulation resistance constant shall not be less than 25,000 megohms — 1000 ft when corrected to 60°F.
- (j) D.C. Test — the D.C. test may be done either following an insulation resistance test or at least eight (8) hours prior to the A.C. test, providing the insulated conductor has been continuously immersed for a period not less than sixteen (16) hours prior to the D.C. voltage application. Each length of insulated conductor, while submerged, shall withstand, without failure, the high voltage D.C. test for five (5) minutes at the potentials given in Tables I and I—A.
- (k) Single Conductor Sheaths — Individual insulated conductors not intended for assembly into multiconductor cables shall be covered with a low smoke cross—linked polyolefin compound sheath in accordance with the properties in Table III, applied over the primary thickness of insulation specified above and after the tank—testing of the primary insulation. The average thickness of sheath compound shall be not less than the value specified for single conductors in Table II of Paragraph 5.
- (l) Single Conductor Identification — The sheath of single conductor cables shall be surface—printed with a legend identifying the manufacturer, year of manufacture, conductor size, and voltage rating in a contrasting ink; durable surface colors are required.
- (m) In addition, the low smoke cross—linked Polyolefin sheath when tested at the thickness of 100 mils, for smoke generation, shall not exceed the values in Table III.

4. ASSEMBLY OF MULTI—CONDUCTOR CABLES

- (a) Multiple conductor cables shall be made by assembling individually insulated, printed conductors into a tight cylindrical form. Individual conductors in a cable having two (2) or more conductors shall be assembled helically and with adjacent layers wound in opposite directions.
- (b) When fillers are required to make the cable round, they shall be non—hygroscopic and flame retardant. Cable tape shall be applied round the cable core of multiple—conductor cables, and shall also be non—hygroscopic and flame retardant.
- (c) Cable tape shall conform to Section 4.4 of ICEA, except that compound—filled tape shall be treated on both sides and thoroughly filled with a rubber compound. Where colored tapes are called for, the colors shall be clear, durable, and of easily distinguishable shades; they shall have no harmful effect on any part of the cable.
- (d) A waterproofed marker tape indicating the name of the manufacturer and year of manufacture shall be inserted in cables for identification purposes. The information shall be present at no less than one—foot intervals. The marker tape shall be so located as to be readily identifiable.

5. **OUTER SHEATH**

- (a) A continuous tubular sheath of high tensile strength moisture and flame—resistant properly cured base product of low smoke cross—linked polyolefin compound shall be tightly formed around the insulated conductor(s) to provide protection against mechanical damage and the entrance of moisture, earth acids, and alkalis into the cable. It shall not adhere to the insulated conductors of multiple—conductor cables and shall conform to Table III. It shall be applied by the continuous tube method, without joints, and shall be properly cured to meet test requirements.
- (b) Average thickness of sheath compound for single conductor and multi—conductor cables shall be not less than values specified in AREMA 10.3.16 Table 10316-4.
- (c) In addition, the low smoke, cross—linked polyolefin sheath, when tested at a thickness of 100 mils, for smoke generation, shall not exceed the values in Table III.
- (d) The Minimum thickness of the sheath shall meet AREMA 10.3.16.E.5
- (e) Manufacturer’s Identification Marker

A waterproofed marker tape bearing the name of the manufacturer and year of manufacture shall be inserted in wires and cables for identification purposes. The identification marking shall be placed at such intervals that all information may be obtained without destroying more than one foot of cable. This information shall be inserted as follows:

- 1. Multiple—conductor cables shall have the marker tape so located as to be readily identified.
- 2. For all cables not included in Item 1, above, the manufacturer’s color tracer threads shall be inserted between the conductor and the insulation or among the strands of a stranded conductor.

(f) Outside Diameter

The maximum outside diameter or finished wire and cable shall not exceed the nominal outside diameter by more than the following tolerances:

Nominal Diameter — Inch	Tolerance— Inch
0 to 0.600	0.030
0.601 to 2.000	5%

TABLE III

Properties of Cross—Linked Polyolefin

	<u>Property</u>	<u>Test Method</u>	<u>Value</u>
Original	Tensile Strength PSI	ASTM D 412	1500 Min
	Elongation %	ASTM D 412	150 Min

Air Oven Aged	<u>168 hours @ 100C</u>			
	Tensile Str % Original	ASTM D 573		100 Min:
	Elongation %	ASTM D 573		75Min
	<u>168 hours @ 125C</u>			
	Tensile Str % Original	ASTM D	573	75Min:
	Elongation % Original	ASTM D	573	60Min
	<u>168 hours @ 150C</u>			
	Tensile Str % Original	ASTM D	573	50Min
	Elongation % Original	ASTM D	573	50Mix
ASTM #2 Oil	<u>22 hours @ 125C</u>	-	-	
	Tensile Str % Original	ASTM D 471	50	Min
	Elongation % Original	ASTM D 471	50	Min
Durometer	Shore A	ASTM D 2240	85 ±	
Low Temp. Flex.	Pass °C	ICEA S—19—81	-40	
Water Absorption	168 hours @ 70C mg/in ²	ASTM D 470	30 Max	
Oxygen Index	% Oxygen	ASTM D 2863	30 Min	
Smoke Generation	Flaming Avg. Ds 4 mm	ASTM E	662	150Ma,
	Flaming Avg. 0cm	ASTM E	662	250Ma,
	Non—flaming Avg. Ds 4 min.	ASTM E	662	150Ma)
	Non—flaming Avg. dm	ASTM E	662	300MA)
Ozone		ASTM D 470	Pass	

* Note: Smoke Generation values also apply to the EPR Insulation. All smoke tests are on 3-inch x 3-inch square slabs of material having a thickness of 100 rails.

6. **FINISHED CABLE TESTS**

Except as otherwise stated herein, tests shall be in accordance with AREMA 10.3.16 AND 10.3.22

- (a) Each completed multiconductor cable, when on the shipping reel, shall be subjected to and successfully pass 2.0 times the AC test voltage levels given in Table I—A for one minute. This voltage to be applied to each conductor against all others grounded, or between conductors utilizing a mid—point grounded test transformer to assure that each conductor is tested against each adjacent conductor in its layer and conductors in adjacent layers. This required repeat application of test voltage should be done by reversing voltage combinations between layers. Cable shield, if any, shall be connected to ground.
- (b) The insulation resistance test shall be made in accordance with Section 6.23 of ICEA, using a well—insulated and sensitive galvanometer. When the temperature at which the cable is tested differs from 60 F, the insulation

resistance shall be corrected to that at 60°F.

The insulation resistance constant shall not be less than 25,000 megohms—
—1000 feet when corrected to 60°F.

- (c) Tests shall be made at point of production. The manufacturer shall give notice when cable is ready for test, and the purchaser shall have the option to witness the tests.
- (d) All completed cable must pass the IEEE — 383 70,000 BTIJ/Hr. Vertical Tray Flammability Test.
- (e) Certified copies of all test results, both electrical and physical, which are required to assure compliance with this Mandatory Specification, shall be furnished to the MBTA. A Certificate of Compliance certifying that the cable has been manufactured in accordance with this Mandatory Specification must be included with the certified test results. Two (2) copies of each of the above documents must be signed by the manufacturer's chief engineering officer, notarized and forwarded, for acceptance by the MBTA, prior to the shipment of any cable.

7. PACKING

Packing shall be in accordance with AREMA 10.3.10

Cable shall be shipped on reels per AREMA 10.3.10 G, and H, and AREMA 10.3.16. H. All reels shall be numbered and lengths to be shipped on each reel shall be worked out in advance, subject to approval by the DB Entity.

**MASSACHUSETTS BAY TRANSPORTATION AUTHORITY (MBTA)
SIGNALS AND COMMUNICATIONS DIVISION
SPECIFICATION S-115
Date: September 15, 2000**

**SPECIFICATION FOR LOW SMOKE, NO HALOGEN, TWISTED PAIR SIGNAL
WIRE AND CABLE**

1. GENERAL

This Mandatory Specification establishes the criteria for low smoke, ethylene propylene rubber insulated and low smoke, no halogen; cross-linked flame retardant polyolefin jacketed wire and cable.

This Cable shall be a twisted pair suitable for the transmission and reception of electrical signals from DC to 10KHz.

Twisted pairs shall be formed from two individually insulated conductors, suitably marked for identification, cabled with a length of lay as short as good construction will permit but no longer than six (6) inches. Multiple pairs shall be constructed such that the length of lay of adjacent pairs shall differ by at least one-half (1/2) inch.

The cables provided for under this Mandatory Specification shall be of high quality and long life. This cable will be installed under adverse conditions of direct burial in earth, in ducts, or by aerial suspension, in circuits subjected to voltages of 0 to 1000 volts DC or AC.

(a) The wire and cable for this Mandatory Specification shall be in accordance with the requirements of the current AREMA (AAR), Signal Manual Part 10.3.17, where applicable, and shall conform to the latest editions of ICEA 5-68-5 16 Standard Publication Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy except where otherwise specified herein.

(b) When there is a difference between the requirements of this specification and other Mandatory Specifications mentioned herein, the requirements of this specification shall govern.

(c) Pair counts will be covered by the purchase order starting from one twisted pair.

2. CONDUCTORS

(a) The conductors shall be annealed copper; concentric stranded bare or coated and conforming to the requirements of the latest issue of ASTM B-8.

(b) Unless otherwise specified in the purchase order, all conductors shall be concentric lay, Class B or C stranding. Conductors shall have no welds of any kind.

3. INSULATION

- (a) Conductors shall be insulated with a highly moisture and ozone-resistant low smoke EPR compound, which has demonstrated, either through actual field experience and/or through comparable valid aging tests, that the cable offered shall have a minimum life expectancy of forty (40) years. Substances which are injurious to the conductor or insulation shall not be included in the compound.
- (b) The insulation shall be properly vulcanized, homogeneous in character, tough, elastic, and applied concentrically about the conductor, and shall fit tightly thereto. The insulating compound shall be clean and free stripping, leaving the coated conductor, upon stripping, unimpaired and ready for soldering.
- (c) The minimum thickness of the insulation shall conform to Tables land 1-A.
- (d) The average thickness of insulation shall be no less than the specified thickness. The minimum thickness at any point shall not be less than 90% of that specified.
- (e) The insulated conductors intended for assembly into a twisted pair multi-conductor cables shall be color coded by means of printed pair numbers, printed color, (i.e. 1black, 1 white, 2 black, 2white...) All print to be white ink on neutral color compounds. This is a variation of ICEA Method 3 color-coding.
- (f) In addition, the low smoke EPR insulation when tested shall meet the physical characteristic in Appendix A.

4. INSULATION QUALIFICATION TEST:

The insulation shall be consistently uniform, and established suitable for service at potentials to 15,000 volts.

Voltage aging: The dielectric strength stability shall be demonstrated by voltage-aging a minimum often feet between terminals of a single conductor #14 AWG or larger size with 80 mil or thicker insulation, suitably finished. The cable shall be tested in free air with the ends appropriately terminated.

The Laboratory qualification tests must include one of the following stresses to the voltage aged sample:

- (a) 225 V/mil for two years.
- (b) 180 V/mil for three years.
- (c) 135 V/mil for five years.

A sixty (60) Hz voltage in 10kV steps for 5 minutes at each step until breakdown. This test must be started immediately after the voltage aging test above.

No cable breakdown shall occur during the voltage-aging test and the same sample shall withstand

the voltage aging test minimum test stress of 350 Volts/mil on the thermal aging test.

Thermal Aging: The insulation shall be tested in a circulating air oven on 80 mil thick slabs and shall have an elongation not less than 50% after a minimum; aging time of 25 hours at 136°C and 100 hours at 121°C.

Moisture Resistance: A single conductor #14 AWU or larger size with 80 mils or thicker insulation wall, shall have at least 10 feet immersed in water at room temperature. The insulated conductor without any coverings over insulation shall be continuously energized with dc voltage as follows; 325 V/mil for two months, or 280 V/mil for 3 months, or 240 V/mil for four months, or 200 V/mil for six months. No insulation failures shall occur during the test period. The manufacturer must certify that there was no water infiltration during this test.

5. ASSEMBLY

5.1. The insulated conductors shall be twisted into pairs. The average twist length of any pair in the finished cable shall be designed to meet ICEA S56-434 Fifth Edition and shall not exceed six inches

5.2. The insulated pairs shall be twisted into specified combinations to provide pair identification as well as low susceptibility to noise pick-up, and, with varying lay lengths to minimize cross-talk.

6. ARMOR TAPE

The assembled core shall be covered with a rubber impregnated fabric tape to hold the assembly together and to provide a protective bedding for the overlying metallic armor. A waterproof marker tape indicating the name of the manufacturer and year of manufacture shall be inserted in cable for identification purposes. The information shall be present at no less than one-foot intervals. The marker tape shall be so located as to be readily identifiable.

A 1 0-mil bronze tape shall be applied over the bedding tape.

7. COMMUNICATION CHARACTERISTICS

The manufacturer shall certify that the proprietary pair lay-up used shall not exceed the following crosstalk parameters:

<u>CABLE MAKE-UP</u>	<u>ALLOWABLE MUTUAL CAPACITANCE</u>	<u>MINIMUM CHARACTERISTIC IMPEDANCE.+ -20%</u>	<u>CROSSTALK ATTENUATION</u>
2C Twisted #16	.065 MFD/mile	180 ohm @2khz 125 ohm@10hz	Per A below
2CTwisted #14	.065MFD/Mile	180 ohm @2khz 124ohm@10khz	Per A below
Multi conductors	.065 MFD/Mile	160 ohm @2khz 105 ohm @ 10khz	Per B below

Configuration A

Minimum crosstalk attenuation between adjacent pairs or between two individual pair cables, shall not be greater than 90dB per one thousand (1000) feet for all frequencies between 2 kHz and 10khz. The crosstalk attenuation between adjacent pairs will apply to a multipair cable except only one pair will be allowed to have a lower crosstalk attenuation equal or greater than 80dB per one thousand (1000) feet for all frequencies between 2 kHz and 10khz

Multi-conductors of this configuration shall be one hundred (100) percent tested for crosstalk attenuation on all pairs with data supplied indicating crosstalk attenuation and pair identification.

Configuration B

The MBTA can request cables to satisfy configuration B, where the cable shall be twisted and designed to minimize crosstalk between pairs with a crosstalk attenuation between adjacent pairs of multi-pair cable shall be 75dB per 1000ft. nominal for all frequencies between 2khz and 10khz.

8. PRELIMINARY TESTS:

AC Test: Each length of conductor, insulated with prime insulation, prior to application of any outer jacket and prior to cabling or twisting, shall be random-wound on spools and immersed in water for a minimum of twenty-four (24) hours, then subjected to test voltages given in Table 1 for five (5) minutes, without showing signs of puncture, overheating, or selthealing of punctures. Voltage to be applied between conductor and water (ground). Each length of insulated conductor, while submerged shall withstand, without failure, the high voltage AC test for five (5) minutes and the potentials given in Tables I and I-A.

Insulation Resistance Test: Immediately after the AC test specified above and while still submerged, an insulation resistance test shall be made on each length of conductor. The insulation resistance constant shall not be less than 35,000 Megohms -one thousand (1000) feet when corrected to 60° F.

DC Test: The DC test may be done either following an insulation resistance test or at least eight

(8) hours prior to the AC test, providing the insulated conductor has been continuously immersed for a period not less than sixteen (16) hours prior to the DC voltage application. Each length of insulated conductor, while submerged shall withstand, without failure, the high voltage DC test for five (5) minutes and the potentials given in Tables I and I-A.

Insulation Thickness and Test Voltages for Single Conductor Wire Prior to Sheath Application

Rated Circuit Voltage	Size of conductor A.W.G.	Insulation Thickness 64th Inch	Test Voltages	
			AC Volts 5 Minutes	DC Volts, 5 Minutes
0-1000	14 to 8	5	8,000	25,000
	7 to 2	5	10,000	30,000

The test voltages for Tandem Extruded insulation and jacket for Single Conductor wire are as follows:

Test Voltage for Composite Thickness. Table 1 Modified

Insulation Thickness Mils	AC (1) Test Voltage	DC Test Voltage
62.5 (4/64)	9.5kV	26kV
78.0 (5/64)	12.0KV	31KV
94.0(6/64)	13.0KV	34KV

TABLE I-A

Insulation Thickness and Test Voltages for Individual Conductors of Multi-conductor Cable

Rated Circuit Voltage	Size of Conductor A.W.G.	Insulation Thickness 64th Inch	Test Voltages	
			AC Volts 5 Minutes	DC Volts 5 Minutes
0-1000	19 to 16	5	6,000	18,000
	14 to 8	5	10,000	35,000

In addition, the low smoke cross-linked Polyolefin sheath when tested at the thickness of 100 mils, for smoke generation, shall not exceed the values in appendix B.

9.0 OUTER SHEATH:

The outer covering shall be a Crosslinked Polyolefin (XLPO) low smoke compound, a mechanically rugged, thermosetting low-smoke compound which is resistant to most oils, acids and alkalies. It is flame and moisture resistant. The jacket shall meet the physical and electrical properties shown in Appendix B. The overall jacket thickness shall be in accordance with AREMA (AAR) Manual part 10.3.17 as shown in Table 2 below. The minimum thickness at any one point shall not be less than

90% of the minimum average value.

Common Overall Jacket of Twisted Pair Cable

Calculated Diameter of Cable Under Jacket Inches	Jacket Thickness Mils ^(64th~5)
0.425 or less	62 (4)
0.426 .0.700	78 (5)
0.701 .1.050	94(6)
1.051 .1.500	109 (7)
1.501 -2.000	140(9)
2.001 —3.00	156 (10)

10.0. IDENTIFICATION

Following is an example of how the identifying legend shall be printed on the outer jacket, with contrasting ink repeated every two feet:

- (A) (N)/PR #C AWG CU EPR 1000 Volts (Year)
- (A) =Manufacture and Plant Number.
- (N) = Number of Pairs
- (C) = Wire size

11.0. FINISHED CABLE FINAL TEST:

Except as otherwise stated herein, tests shall be in accordance with AAR Signal Specification 240-58.

(a) Each completed multi-conductor cable, when on the shipping reel, shall be subjected to and successfully pass two (2.0) times the AC test voltage levels given in Table I-A for one minute. This voltage to be applied to each conductor against all others grounded, or between conductors utilizing a mid-point grounded test transformer to assure that each conductor is tested against each adjacent conductor in its layer and conductors in adjacent layers. This required repeat application of test voltage should be done by reversing voltage combinations between layers. Cable shield, if any, shall be connected to ground.

(b) The insulation resistance test shall be made in accordance with Section 6.23 of ICEA, using a well-insulated and sensitive galvanometer. When the temperature at which the cable is tested differs from 60°F. the insulation resistance shall be corrected to that at 60°F.

The insulation resistance constant shall not be less than 35,000 Megohms .1000 feet when corrected to 60°F.

(c) Tests shall be made at point of production. The manufacturer shall give notice when cable is ready for test, and the purchaser shall have the option to witness the tests.

(d) All completed cable must pass the IEEE .383 70,000 BTU/Hr. Vertical Tray Flammability Test.

12.0. QUALITY ASSURANCE

The manufacturer shall function under a nationally recognized Quality Assurance Program. Independent audits demonstrating compliance with programs such as; IOCFRSO Appendix B or ANSI N45.2 or an ISO 9000 system shall be certified to prior to production.

Certified copies of all test results, both electrical and physical shall be furnished to the MBTA. A Certificate of Compliance stating the cable has been manufactured in accordance with this Mandatory Specification must be included with the certified test results. Two copies of each of the above documents must be signed by the manufacturer's Chief Engineering Officer, notarized and forwarded, for acceptance by the MBTA, prior to the shipment of any cable.

APPENDIX A EPR Insulation

PHYSICAL AND ELECTRICAL CHARACTERISTICS When tested per ICEA S-68-516, Part 6, where applicable the (EPR) insulation shall meet the following guaranteed values:

Properties tested for control of product.

Physical Requirements before Aging	Guaranteed Value
Tensile Strength, mm. psi	1000
Tensile Stress at 200% Elongation, mm., psi	600
Elongation at Rupture, mi. %	300

Physical Requirements after Aging

After 168 hours in Air oven Test at 121°C

Tensile Strength, % of Unaged Value	90
Elongation, % of Unaged Value	85

Properties demonstrated by qualification testing, that are inherent to the formulation. Physical Requirements after Aging

After 168 hours in Air Oven Test at 150°C

Tensile Strength, mm. % of Unaged Value	85
Elongation, mm., % of Unaged Value	60

Ozone Resistance

168 hours at 0.025% concentration	No Cracks
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Accelerated Water Absorption

Electrical Method EM 60 @ 75°C

Dielectric Constant

(Composite insulation & jacket)
 After 1 Day, max. 4.5
 Increase 1-14 Days, max. % 3.5
 Increase '7-14 Days, max. % 2.0

Power Factor
(Composite insulation & jacket)
 After 1 Day, max., % at 80 V/Mil 4.0
 Stability Factor after 14 Days, max. % 1.0

Long Term Water Stability
Electrical Method EM 60 except water shall be maintained at 90°C
Dielectric Constant, SIC at 80V/Mil
 After 2 weeks immersion, max. 3.9
 After 36 'weeks immersion, max. 4.5

Power Factor % at 80V/Mil
 After 2 weeks immersion, max. 2.6
 After 36 'weeks immersion, max. 1.2

Stability Factor (SF) = 80-40 V/Mg power factors
 After 2 weeks immersion, max. 0.06
 After 36 weeks immersion, max. 0.15

Mechanical Water Absorption
 7 days, 70°C, mg/sq.in. 8.0
Insulation Resistance Constant: (K) at 156°C 35,000
Oxygen Index: per ASTM D2863 1 20
Halogen Content: calculated 0
Cold Bend: After 1 hr. at -65°C No Cracks
Heat Distortion: After 1 hr. at 12 1°C, 2000 gr % decrease 10

Appendix B

**PHYSICAL CHARACTERISTIC OF CROSS-LINKED POLYOLEFIN
LOW SMOKE. ZERO HALOGEN JACKET**

When samples are treated in accordance with ICEA requirements the low smoke, non-halogenated crosslinked polyethylene (XLPO) jacket shall meet the guaranteed values below: Properties tested for control of **product**. **Guaranteed Values**

A. Physical Requirements Unaged

Tensile Strength, Minimum	1700 psi (1 1.8 N /mm2)
Elongation at Rupture, %, Minimum	150

B. Aging Requirements

Air Oven Test at 121°C for 168 hours	
Tensile Strength, % of unaged value, Minimum	60
Elongation, % of unaged value, Minimum	60
Oil Immersion, at 121°C for 18 hours (IRIVI 902)	
Tensile Strength, % of unaged value, Minimum	60
Elongation, % of imaged value, Minimum	50

Properties, demonstrated by qualification testing, that are inherent to the **formulation**.

C. Aging Requirements Minimum % of Unaged, Retained

	Tensile	Elongation
Air Oven Test at 100°C for 168 hours	100	75
Air Oven Test at 150°C for 168 hours	60	60
Gasoline, at 25°C for 24 hours	50	50
Oil Immersion, at 70°C for 4 hours (IRM 90)	80	80
Oil Immersion, at 125°C for 22 hours	60	50
Methanol, at 25°C for 24 hours	50	50
MIL-A-17672, at 50°C for 24 hours	50	50
MIL-I-23699, at 100°C for 24 hours	50	50
<u>Oxygen Index</u> , ASTM D-2863 Minimum		35
<u>Ozone Resistance</u> , 24 hours @ 1 S0ppm Ozone		No Cracks
<u>Tear Strength</u> , Minimum	35Lbs. /in. (6.25 kgs. /cm.)	
<u>Cold Bend</u> 1 hour at —40°C, Minimum		No Cracks
<u>Durometer</u> , Shore A, Minimum	90	
<u>Gravimetric Water Absorption</u> , 7 days at 70°C, Maximum	20 mg./in.2 (3.08 mg./cm.2)	
Acid Gas Equivalent MIL-C-24643, %, Maximum		0.2
Toxicity Index NEW 713, Maximum	2	
Smoke Index NES 711, Maximum	25	

***Smoke Generation, ASTM E662
Ds4 Min. Uncorr. (max.) Dm Corr. (max)***

Flaming Non-Flaming
25 50

Flaming Non-Flaming
150 250

John C. Lewis
Acting Director
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SMI

Walter A. Reed
Senior Project Manager
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John Recinito
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SECTION 16811

POWER SWITCH AND LOCK MOVEMENT LAYOUTS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the procuring and installing of 110 volt DC dual control power switch-and-lock movement layouts including all required hardware to form a complete track switch layout as shown on the Contract Documents.
- B. Power switch-and-lock movement layouts shall include an electric switch-and-lock movement, pedestal mounted junction box, throw rod, insulated hinged front rod, point lug, lock rod, detector rod, shims, identification numbers and letters, all required screws, nuts, washers, pins, grease fittings, cotter keys, plates, adjusting brackets, extension plates, saddle plates, and all hardware to mechanically couple the power switch-and-lock movement layout to the track switch points and to mount the movement on the ties.
- C. The DB Entity shall be responsible for providing miscellaneous items such as flexible conduit, fittings, etc., to facilitate a complete layout for installation. The DB Entity shall also furnish and install tie straps, gauge, extension, and saddle plates for each power switch-and-lock movement layout as indicated on the Contract Documents and the accepted layout drawings.
- D. The DB Entity shall mount adjust, and maintain the complete power switch-and-lock movement layout as hereinafter described until accepted by the MBTA.

1.2 QUALITY ASSURANCE

- A. Power switch-and-lock mechanisms shall meet the requirements established by AREMA C&S Manual, Part 12.2.1 where the AREMA requirements do not conflict with any requirement specified in this Section.
- B. The DB Entity shall inspect each power switch-and-lock movement layout after it has been installed and correct any deficiencies. This inspection shall be conducted in conformance with the requirements of the DB Entity's installation inspection procedure as accepted by the MBTA.
- C. The DB Entity shall coordinate with the MBTA and perform final operational tests of the switch-and-lock movements that shall be performed as described in Section 16898 – Signal System Tests for the Light Rail Signal System. The DB Entity shall also have the required personnel on-site to make adjustments and modifications as directed.

1.3 SUBMITTALS

In accordance with the requirements of Section 2.7 and 2.8, the DB Entity shall submit a description of materials and methods of installation to be furnished under this section. This shall include but not be limited to:

- A. Assembly (product) drawings of each type of power switch and lock movement identifying all the components required for a complete layout. Also provide installation drawings showing the mounting details of the layout including the connections to the track switch points.
- B. Factory test procedures and manufacturers certification of factory tests prior to shipment

- C. Installation Inspection and Test procedures
- D. Field testing procedures and completed Field Test Reports

1.4 DELIVERY, STORAGE AND HANDLING

- A. Prior to shipment, all parts of the power switch-and-lock movement layout that are not painted, or made of non-corroding material, shall be coated with an approved grease to prevent corrosion. All unused threaded outlets shall be suitably plugged or capped.
- B. Switch-and-lock movements and their component layout parts shall be protected against damage during handling and shipment, and shall be secured against loss during storage.

PART 2 - PRODUCTS

2.1 MATERIAL

- A. Power Switch-and-Lock Movements
 1. Power switch and lock movements shall be gear driven from the motor. Movements shall be furnished with double adjustable type lock rods and detector rods. Movements shall be provided with dual operation hand throw lever capable of being locked at the “power/hand” selector lever.
 2. Power switch-and-lock movements shall be as manufactured by Alstom (GRS), Model 5F, or equivalent.
 3. Power switch-and-lock movement motors shall be suitable for continuous normal operation at 90 to 130 volts dc and shall not be damaged when operated intermittently at 130 to 150 volts dc. Each switch-and-lock movement shall sustain a 150 volt factory test operation without damage to diodes or other components.
 4. Power switch-and-lock movements shall throw from normal to the reverse position, or vice versa, within the time specified by the approved technical manuals while driving a load meeting the requirements shown on reference drawing from AREMA C&S Manual, Part 12.2.5.
 5. The hand throw selector lever, when in the hand throw position, shall disengage the clutch assembly and all energy from the motor for hand throw operation of the switch-and-lock movement in either direction and provide indication of the disengagement.
 6. Fifteen watt internal heaters shall be provided in the contact compartment and in the motor compartment of each power switch-and-lock movement.
 7. Heater type, location, and mounting details shall be included as part of the submitted layouts.
- B. Rods and Hardware
 1. The power switch-and-lock movement layouts shall not require offsets in the track connecting rods.
 2. Ample threaded area, equal on either side of the adjusting nut(s) shall be provided on each rod to accommodate wide latitude in operating adjustments.
 3. All front rods shall be of the vertical, hinged type, insulated and adjustable.

4. Two malleable cast metal letters, "N" and "R", at least three inches high, painted white, shall be furnished to denote the normal and reverse position of the switch points for each layout. Each letter shall have four holes drilled to receive No. 12 brass wood screws.
 5. Four, one and one-half inch No. 12 brass, flathead wood screws shall be furnished for each letter.
 6. Each power switch-and-lock movement mechanism shall be supplied with identification letter-numbers 6" high stenciled with white paint on the switch and lock movement cover. Where two switches are operated by one lever, the number of the switch will be supplemented by the letter "A" or "B" centered on the mechanism cover.
 7. Switch tie rods shall be drilled in place during installation at the location of final placement.
 8. The DB Entity shall install extension or saddle plates and tie straps for each power switch-and-lock movement layout.
- C. Junction Box - Each power switch-and-lock movement layout shall include a cast iron, pedestal mounted junction box, suitable for terminating the interconnecting wires and cable. Junction boxes shall be manufacturer's standard for use with layout.
- D. Electrical Fittings - The DB Entity shall furnish all connectors, and electrical fittings, as required for each power switch-and-lock movement layout.
- E. Hose and Clamps - Hose and clamps shall be provided to form a complete layout.
- F. Switch Adjustment Wrenches – DB Entity shall provide a complete set of adjustment wrenches for each interlocking location.
- G. Painting - All equipment described in this Section shall be painted in accordance with requirements of AREMA. The finish color shall be black.
- H. Security – DB Entity shall provide all proprietary and standard signal padlocks of appropriate design as follows:
1. To restrict entry to the inside of the power switch-and-lock movement;
 2. To restrict entry to the inside of the motor compartment;
 3. To restrict entry to the inside of the hand crank selector lever, where applicable;
 4. To secure the selector lever and the hand-throw lever.
 5. The DB Entity shall ensure pad locks are applied.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. New switch timbers shall be installed as part of each switch installation. The DB Entity shall verify that the track switch layout is in accordance with the dimensions indicated accepted installation drawings prior to commencement of installation work.
- B. Prior to mounting the power switch-and-lock movement the DB Entity shall align the switch headblock ties (T1 and T2) at right angles to the straight stock rail, and space the ties in accordance

with the accepted installation drawing, and condition the switch points to move without binding. The DB Entity shall install the tie straps as indicated and in accordance with the accepted installation drawing.

- C. Whenever the DB Entity drills, adzes, or daps ties, the cut surfaces shall be thoroughly saturated with copper naphthenate, or other type of wood preservative, as accepted by the MBTA. Limit of cutting or dapping shall not exceed two inches.
- D. The DB Entity shall be responsible for removing any stone ballast necessary for the installation of each power switch-and-lock movement layout and for replacing and tamping the ballast after the installation has been completed. Excess ballast shall be spread evenly between ties in the vicinity of the power switch-and- lock movement layout. The DB Entity shall take care not to contaminate the ballast in the area of his work.
- E. The DB Entity shall be responsible for any costs incurred by the MBTA in restoring track alignment and surface as a result of the DB Entity's work on track switches.
- F. The DB Entity shall assist the MBTA in making a preliminary adjustment of the power switch-and-lock layout at the time of installation and a final adjustment when placing in service, which shall result in the adjusting nuts being centered on the threads, plus or minus 30% of the thread length.
- G. The adjustment shall be such that when the switch point is obstructed 1/4-inch or more and the switch and lock movement is manually or electrically operated, the obstruction will not allow the switch-and-lock movement to lock up. The DB Entity shall also verify that the power switch-and-lock movement circuit controller contacts will be made when the switch point is within one-eighth inch closed. Measurements shall be made over the No. 1 switch rod for both the normal and reverse positions of the track switch points. The DB Entity shall use the MBTA standard (floating the lock rod method) for adjustment of mechanical and electrical locking when making these adjustments.
- H. Underground cables terminating in the switch junction box shall be dressed as specified in Section 16808 – EXTERNAL SIGNAL CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM. The individual conductors shall be fanned, tagged and terminated. Wiring between the switch junction box and the power switch-and-lock movement shall be accomplished using insulated flex wire, No. 14, 19-strand minimum and No. 10 27-strand minimum. These wires shall also be tagged and terminated. The wires between the switch junction box and the power switch mechanism shall be installed in an appropriate length of approved flexible hose. The hose shall be fastened to the switch junction box and switch mechanism with two, three-inch stainless steel hose clamps, as approved. The maximum length of the hose shall not exceed 21-inches unless otherwise accepted by the MBTA.
- I. Once the DB Entity receives the power switch-and-lock movement layouts, and after installation, the power switch-and-lock movement layouts shall be properly lubricated and maintained by the DB Entity on a regular timed program until accepted by the MBTA.
- J. The DB Entity shall exercise care that the switches, including switch tie plates, are thoroughly lubricated at all lubricating points, that all machined surfaces susceptible to rusting, both external and internal, are thoroughly coated with an approved grease, and that threaded portions of switch rods and nuts are similarly coated and protected.
- K. The switch tie plates shall be lubricated with an approved lubricant used by the MBTA. The DB Entity shall periodically renew the protective coating until such time as the MBTA assumes responsibility for maintenance of the equipment.

3.2 IDENTIFICATION

- A. Each power switch-and-lock movement shall bear a number corresponding to the number of the controlling operation number of the switch. (IA, IB, 3A, 3B, 5 etc.) These identifications shall be 6” high, stenciled with white paint on the switch and lock movement cover per the MBTA Standards.
- B. The DB Entity shall install, for each layout, the letters "N" and "R" for the purpose of identifying the position of the switch points. The "N" shall be placed on the normally closed point side as shown on the Contract Documents. These letters shall be attached to the first tie adjacent to, but not supporting the switch points, using the four, one and one-half inch No. 12 brass flathead wood screws provided.

3.3 FIELD TESTS

The DB Entity shall assist in testing all functions of each power switch-and-lock movement layout in accordance with the requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

3.4 PAINTING

All equipment described in this Section shall be painted in accordance with AREMA section 1.5.10, Recommended Instructions for Painting and Protective Coatings. The finish color shall be flat black.

3.5 HEATERS

Heaters for the switch points shall be installed in accordance with the requirements of Section 16850 – SNOW MELTER HEATING SYSTEMS FOR THE LIGHT RAIN SIGNAL SYSTEM.

END OF SECTION

SECTION 16817

SIGNAL, BUS HOLD, START LIGHT, AND TRAIN INDICATOR LAYOUTS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing color light signals, bus hold, start light, and train approach indicator light (TAK) layouts.
- B. The color light signal layouts shall be both wall mount and pedestal mount type. Each signal layout shall be provided with appropriately colored LED lighted lens units, junction boxes with terminal boards, wiring, number plates, hood, padlocks, and mounting hardware. Pedestal mounted signal layouts shall include a foundation, split-base junction box, mast and ladder.
- C. The bus hold light unit, located at Lechmere station, shall be furnished and installed by the DB Entity. The bus hold light will provide a “wait” indication to the bus operators in the station to allow the patrons disembarking from the train enough time to transfer to the bus. The bus hold light layouts shall be of the same material and design as a single signal light unit and be suitable for wall and (under) canopy mounting.
- D. The start light units, located at College Ave and Union Square stations, shall be furnished and installed by the DB Entity. The start light will provide an illuminated “START” indication with associated bell that will light and ring when a train is to depart inbound. This command will be derived from commands given by the OCC scheduling software. The start light layouts shall be of material and design be suitable for wall and (under) canopy mounting.
- E. The DB Entity shall conduct a survey of the entire contract limits and confirm that the signal and TAK layouts proposed for the project do not intrude into the dynamic clearance envelope of the Green Line car equipment. The DB Entity shall modify the proposed layout, in a manner accepted by the MBTA, for any signal that infringes on the dynamic clearance envelope of the vehicle.
- F. All lights, specified in this section shall be internally wired at the factory insofar as practicable and possible.

1.2 QUALITY ASSURANCE

- A. The DB Entity shall inspect each unit prior to shipment. This inspection shall conform to the DB Entity's Factory Inspection Procedure as accepted by the MBTA. Signal, bus hold and TAK layouts and light units shall be in compliance with these Specifications prior to delivery to the MBTA. The DB Entity shall inspect each signal, bus hold and TAK unit prior to accepting delivery. The DB Entity shall be responsible for promptly notifying the MBTA of damaged or unsuitable material. Once accepted, the DB Entity shall be responsible for storage and handling until final installation and acceptance.
- B. The DB Entity shall inspect each layout after it has been installed in the field. This inspection shall conform to the DB Entity's Installation Inspection Procedure as accepted by the MBTA. Installation will not be considered complete until the DB Entity has corrected all installation defects to the satisfaction of the MBTA.

- C. Signals shall meet the requirements of AREMA C&S Manual, Part 7.1.1, Recommended Design Criteria and Functional/Operating Guidelines for a Color-Light Signal, Doublet-Lens Type, where the requirements of the AREMA Specifications do not conflict with these Specifications.
- D. The final operating tests to determine the acceptability of each complete signal layout shall be performed as described within Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM of these Specifications.

1.3 SUBMITTALS

- A. Prior to the manufacture or procurement of the signal, bus hold, start light, and TAK layouts, the DB Entity shall submit complete drawings for each type of layout and configuration for each location. A complete keyed parts and material ordering reference number list shall be provided for each type of signal, bus hold, start light, and TAK layout.
 - 1. Submit specifications and other product information for all components of the layout(s).
 - 2. Provide information for all relevant lighting applications, e.g: LED units for under canopy vs. outdoors and the use of additional lenses or roundels.
- B. The DB Entity shall submit a Factory Test and Inspection Procedure for each type of signal layout prior to factory test.
- C. Prior to the installation, the DB Entity shall submit a complete set of installation drawings for each type of signal, bus hold or TAK layout, unit, and configuration, for all locations. The drawing(s) shall indicate that each layout does not infringe upon the dynamic clearance envelope of the vehicle and include site specific mounting details and installation dimensions for each different type of location.
- D. The DB Entity shall submit an Installation Inspection Procedure for each type of layout prior to installation.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Signal, bus hold, start light, and TAK layouts and their component parts shall be properly crated at the manufacturer's point of shipment. The DB Entity shall be responsible for all damage incurred in transit and/or caused by mishandling or improper storage. Comply with all provisions of Section 16801 – Basic Technical Requirements.

PART 2 – PRODUCTS

2.1 MATERIALS

- A. Signal Units - Signals shall be color light type as manufactured by Alstom (GRS), Ansaldo-STC (US&S), or approved equal for transit application with the capability of LED lighting. Signal housings shall be manufactured so that all light compartment doors of each layout permanently operate as a single door.
- B. Bus hold, start light and TAK light units shall be as described above. It is the MBTA's preference to utilize LED lighting. The color for bus hold, and TAK application shall be clear or lunar white and will be subject to acceptance of the MBTA.

C. Lenses and Hoods

1. Signal lenses shall meet AREMA Signal Section standards for performance with regard to sighting and chromatic properties.
2. Lenses shall be uniform in shade and density for the respective color. Lenses shall be provided with neoprene gaskets to provide a weatherproof and dust-proof seal between the lenses and signal housing.
3. Lenses that have hot spots or “cat’s eyes” will not be acceptable. The DB Entity shall submit the type of lens proposed for MBTA acceptance.
4. Each signal unit lens opening, for signals to be installed outdoors, shall be equipped with a nine inch hood. Shorter hoods will be acceptable for “under-cover” locations.

D. Lamp (Lens Unit) Compartments

1. The housing for each signal shall be made of cast aluminum and shall have individual lamp (lens unit) compartments. The lamp compartments shall be separated from each other by partitions that shall prevent the passage of light between the compartments.
2. Each signal shall have a single cast aluminum hinged, removable door, which provides access to all lamp compartments simultaneously. The door shall also be provided with two ventilating openings, top and bottom, which shall be covered with fine mesh stainless steel, copper or brass screen on the inside and protected with hoods to keep precipitation out. Doors shall have gaskets as specified in AREMA C&S Manual, Part 15.2.10, Recommended Functional Guidelines for Gasket Material Suitable for Circuit Controllers, Signal Cases and Other Signal Apparatus Housings.
3. Doors shall be secured by standard MBTA hex-keyed padlocks. The locking arrangement of the doors shall be so arranged that the door cannot be locked until fully closed. All doors for lamp compartments shall have a stop at 90 degrees that shall prevent them from swinging out into the train’s dynamic clearance envelope.
4. Each lamp compartment shall be provided with means to pass wiring between units.
5. Each lamp compartment shall be of proper size to provide ample space for LED lens units, terminals and such adjusting devices as are necessary.
6. Provide for a “backlight” indication on the rear of each signal compartment. The backlight shall provide the ability to determine which lamps are illuminated from behind the unit. The indicator light shall appear as clear or white when used with any aspect other than red. With a red aspect the backlight indicator shall also appear as red.

E. LED Light/Lens Units

1. LED light/lens units shall be available in all required colors and be of the same type and available from the same manufacturer. GE Lighting Solutions (Gelcore), Alstom, Ansaldo-STS, Siemens (Safetran), and others may be approved as suppliers provided they satisfy the required criteria and can provide all the colors as required.
2. LED light/lens units shall operate on nominal voltage 115V AC.
3. LED light/lens units have a rated life of 35,000 hours or more.
4. LED light/lens units shall be mounted so that a proper display of the aspect for optimum preview can be readily made and maintained. Mounting within the signal head shall be of a standard arrangement consistent with lens unit manufacturer’s requirements and as accepted by

the MBTA. No customized mounting/assembly arrangements shall be allowed.

F. Painting

1. The inside of the lamp compartment(s) shall be painted non-reflective black.
2. Each signal, bus hold, and TAK layout shall have one primer coat of rust preventive paint and one finish coat of paint at the point of assembly prior to shipment. The finish coat of paint for the exterior of the lamp compartment housing shall be dull (non-reflective) black.

G. Signal/TAK Number Plates

1. Number plates for signals and TAK lights shall be enameled sheet steel. The enamel shall be baked on the sheet steel in such a manner as to ensure that every part of the metal has a smooth, durable, and permanent covering, free of any imperfections.
2. All number plates shall have black synthetic enamel lettering on a white reflex-reflecting background.
3. The number plate shall be bracket mounted under the lowest signal lens in the assembly and shall be fastened by four brass screws, with lead and brass washers under the screw heads and under the enameled plate. The lead washers shall be installed adjacent to the enamel.
4. Each number plate shall meet the requirements of AREMA C&S Manual, Part 14.6.1, Recommended Design Criteria for Signs Other Than for Highway-Rail Grade Crossings where the requirements of the AREMA C&S Manual do not conflict with the requirements established in this Section.

H. Signal, Bus Hold, Start Light, and TAK Mounting

1. Wall mounting

- a. Wall-mounted signals, bus hold, start light, and TAK lights shall be provided for locations as required by the DB Entity's design.
- b. Mounting design shall conform to the DB Entity's accepted submittal.
- c. The DB Entity shall measure all proposed locations where wall mounted signal units are to be installed, prior to submitting details or ordering equipment, to ensure that the train's clearance envelope is not adversely impacted.

2. Pedestal Mounting

- a. Pedestal-mounted signals and TAKs shall be provided for locations as required by the DB Entity's design. A mast for a pedestal-mounted signal or TAK shall consist of a four- inch aluminum pipe post suitably equipped at the top to accommodate the light unit and provided at the bottom with an approved junction box base. The dimension of the bolt hole centers in this base shall be eleven and eleven-sixteenth inches by eleven and eleven-sixteenth inches.
- b. The base shall be a split base junction box type with AREMA terminals for all pedestal mounted signals and TAKs. The terminals are to be made accessible by a cover or door, with provisions for padlocking, without removing any other part of the signal assembly.
- c. The DB Entity shall provide foundations for all pedestal mounted signals and TAKs as shown on the Contract Documents. Foundations shall conform to the requirements of Section 16807 – Concrete and Other Foundations.

I. The DB Entity shall provide access to all pedestal-mounted signals. Ladders shall be furnished by

the DB Entity if the height of the signal is such that there is more than six feet - six inches between the center line of the uppermost lens and top-of-rail. Ladders shall have horizontal (flat bar) rungs and be complete with an approved ladder base, all required bolts, nuts, washers and associated mounting hardware.

PART 3 – EXECUTION

3.1 INSTALLATION

- A. All signal, bus hold, start light, and TAK layouts shall be installed in accordance with installation drawings accepted by the MBTA. All units shall be installed with a hood of an appropriate size unless otherwise directed by the MBTA. The DB Entity shall show proposed locations of all layouts on the design plans and the installed layouts on the as-built plans.
- B. Each signal lens configuration must be distinct and unmistakable when viewed with the centerline of the bottom red aspect 7' above the top of rails at a minimum distance of 1,000'. The DB Entity shall furnish all labor, equipment, and material, including shims or special tools, required to properly focus and align the signals both horizontally and vertically to obtain specified sighting distance.
- C. Lens/light unit voltage shall be set at manufacturer's recommended voltage level for optimum viewing and maximum life expectancy.
- D. All equipment described in this Section shall be painted in accordance with AREMA C&S Manual, Part 1.5.10, Recommended Instructions for Painting and Protective Coatings. One coat of paint shall be applied after installation and prior to placing in service. The paint shall be of the same quality and texture as the manufacturers finish coat.
- E. The DB Entity shall provide 10% spare for each lens/light unit utilized.

3.2 FIELD TESTS

- A. For proper operation and setting of LED/lamp operating voltages and sighting shall be performed in accordance with Section 16898 - Signal System Tests of these Specifications. The DB Entity shall assist in the testing as directed by the MBTA.

END OF SECTION

SECTION 16818

NEXT TRAIN SIGNS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies basic requirements applicable to furnishing and installing next train signs.
- B. Next Train signs will indicate the approach of a train and the track or platform it is to arrive on and be located at all turn back stations.

1.2 RELATED WORK SPECIFIED ELSEWHERE:

Section 09900 – PAINTING

Section 16742 – VARIABLE MESSAGE SIGN SYSTEM

1.3 SUBMITTALS

- A. Shop Drawings:
 - 1. Submit shop drawings of all work of this Section. Do not order materials or begin fabrication until obtaining MBTA's acceptance.
 - 2. Show sizes and thicknesses of all members, types of materials, methods of connection and assembly, complete dimensions, hangers, brackets, anchorage, relationship to surrounding work by other trades, shop finishes, sign designs, layouts, and lettering, and other pertinent details of fabrication and installation.
- B. Samples: Submit samples in duplicate of all materials under this Section, as follows:
 - 1. Samples of bronze color opaque back-lit panel.
 - 2. Samples of chimes proposed with different sound for each track.
 - 3. Samples of all colors proposed for use on signs, and lettering.
 - 4. Full-size paper proofs of all signs, with proposed colors marked thereon.
 - 5. After approval of color match and lettering proofs, submit for MBTA's acceptance one full-size sign, as selected by the MBTA, complete in all respects and ready for installation. Submit as many times as necessary until obtaining MBTA's acceptance. Sample sign, upon approval, shall serve as a standard to be equaled by all other work.
- C. Submit design plans showing proposed locations of all next train signs and as-built plans that detail installed locations.

PART 2 – PRODUCTS

2.1 SCHEDULE OF SIGN

- A. Next Train signs shall be installed on both platforms at all turn back stations.

2.2 FIELD MEASUREMENTS

- A. The sign fabricator shall obtain all measurements in the field required to fabricate the work to proper dimensions. See Section 16742.

2.3 BACK-LIT ELECTRONICALLY ACTIVATED NEXT TRAIN SIGN

- A. Next train signs shall be a factory-fabricated single-sided unit.
- B. Materials
 - 1. Sign face materials
 - a. ¼” translucent mar-resistant polycarbonate sheet plastic in colors as indicated.
 - b. Porcelain enamel on 16-gauge steel laminated to polywood backing as indicated.
 - 2. Sign frame: all exposed steel shall be painted as specified in Section 09900 - PAINTING.
 - 3. Illumination: Provide an LED type lamp with illumination capacity at least equivalent to a 120V 60 Watt incandescent lamps.
 - 4. Audible Warning: Provide an audible warning chime device with differing sounds for inbound and outbound train arrival.
 - 5. Lamp and chime device shall be wired in accordance with the Next Train Sign circuit drawings developed for each location.
 - 6. All electrical components shall be UL approved.

2.4 FASTENINGS AND ANCHORS

- A. The sign fabricator shall design a complete system of fastenings and anchorage devices for the various signs, as required for attachment to the various supporting structures. These may include, but are not limited to, concealed clip systems, face screws, epoxy adhesives, etc. Wherever reasonably possible, fastenings and anchorage devices shall be fully concealed, and shall be vandal proof. The DB Entity is responsible to provide safe and secure installations in strict conformance to the governing laws and building code.
- B. Fully describe proposed fastenings and anchorage devices for each sign type on the shop drawings.

PART 3 – EXECUTION

3.1 PROTECTION AND TEMPORARY COVERS

- A.** Completed sign panels shall be properly protected and maintained in good condition, free from dirt, scratches, hand marks or other blemishes. The panels shall be shipped in such a manner as to insure their arrival on the job site in an undamaged condition.
- B.** Subsequent to erection, if directed by the MBTA, any exterior signs may be required to be covered until the actual use thereof is desired. Material used to temporarily cover any sign panel shall effectively conceal the message and be non-injurious to the panel, its finish, or its structural integrity.

3.2 INSTALLATION

- A.** Erection of all work under this Section shall be performed by experienced sign erectors. Signs shall be installed true, plumb and level, located as shown on the Drawings. No field cutting of any sign work will be allowed. Exercise extreme care in all handling and stacking of signs to avoid chipping. The DB Entity shall approach the MBTA to determine exact location of signs in the field.
- B.** All work shall be rigidly anchored to the supporting construction, as indicated on the accepted shop drawings. Fastenings, except those for the anchorage of supporting members to the structures, shall be concealed.

3.3 CLEAN-UP

- A.** Surfaces of sign work shall be cleaned as recommended by the sign manufacturer after installation and left in a condition satisfactory to the MBTA.
- B.** All defective work, including that exhibiting cracked, chipped, scratched, abraded, or otherwise damaged finishes, shall be removed and replaced with work conforming to the specified requirements.

END OF SECTION

SECTION 16819

TRAIN DETECTION FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The work to be done under this Section consists of providing 100Hz, steady energy, single rail and double rail Track Circuits.
1. Track Circuits shall be Siemens SE-3 or approved equal.
 2. Track Circuits shall provide immunity to both conductive and inductive vehicle electrical emissions.
 3. Track circuits shall be single or double rail as shown on the Contract Documents.
 4. Track circuits shall be designed to detect insulated joint failure and to tolerate the effects of current imbalance without reliability failure.
- B. Insulated Joints and Rail Bonding
1. The work defined under this section also includes furnishing and installing all necessary material for signal and power bonds on the track running rails for proper operation of the train detection and traction negative return systems.
 2. The requirements for running rail bonding for rail joint, rail expansion joints, frog and switch fouling connections, track cross bonding and yard track bonding connections are further described in Section 16829 – INSULATED JOINTS FOR THE LIGHT RAIL SIGNAL SYSTEM and Section 16830 – RUNNING RAIL BONDING FOR THE LIGHT RAIL SIGNAL SYSTEM of these Specifications.
 3. The requirements for impedance bonds are further described in Section 16823 – IMPEDENCE BONDS FOR THE LIGHT RAIL SIGNAL SYSTEM.

1.2 QUALITY ASSURANCE

- A. Track circuit equipment shall be provided in accordance with the applicable requirements and recommendations of the AREMA C&S Manual, Section 8 – Track Circuits, where the manual does not conflict with these Specifications.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”, the DB Entity shall submit the following for approval:
1. Mechanical and circuit drawings for track circuits;
 2. Complete performance data of each track circuit based on actual cut-over test values. In addition to actual test data provide nominal values and operating ranges/limitations for each type of track circuit.
 3. Factory test procedures;

4. Field Test Procedures including any schemes to facilitate phased testing and/or cut-over method;
5. Installation drawings;
6. System Failure Modes and Effects Analysis, Quality Control standards for inspectors and system components including pass/fail criteria for the system. Manufacturers assurance of testing to maintain quality standard.
7. Ten (10) copies of product information and service manuals for each type of track circuit;
8. For Insulated Joints and Rail Bonding:
9. Material composition, electrical and mechanical characteristics for power bonds, signal bonds, and track circuit connectors;
10. Mechanical and operating data for the tool(s) required to install the track circuit connections;
11. Field installation & test procedures for insulated joints, welded signal and power bonds;
12. All mechanical devices for securing and protecting running rail bonding;
13. Installation drawings showing/verifying final layouts for bonding of special trackwork to ensure that all pieces of the special trackwork are properly connected electrically.

PART 2 – PRODUCTS

2.1 MATERIALS

A. General Track Circuit Requirements

1. Single and double rail, 100 Hz, steady energy, power frequency track circuits shall be SE-3 as manufactured by Siemens (Safetran) or approved equal.
2. Circuits shall operate on ungrounded, 105 - 125 Volts, AC 100 +/- 2 Hz power. This power shall be phase synchronized between adjacent CIH's to ensure polarity staggering for failed insulated joint detection.
3. Single and double rail circuits shall be vital and applied as indicated on the Contract Documents.
4. Track circuits shall be immune to 600V DC traction power and shall not require external filters for operation.
5. The design of power frequency track circuits shall ensure that any single failure shall not result in an indication of false unoccupancy in any track circuit. Insulated joint failures shall be self- detecting. The failure of an insulated joint shall cause adjacent track relay(s) to give indication of track circuit occupancy.
6. Track circuits shall be totally immune to improper operation due to crossed or grounded wires or any other influences such as capacitive and inductive coupling or stray currents.
7. With the exception of cabling, junction boxes, matching transformers and associated fuses, all track circuit elements shall be located in the Central Instrument Houses (CIH).
8. Track circuits shall have a rated shunting sensitivity of 0.25 to 0.5 ohms at any point in the circuit. Final adjustments shall be performed with a 0.06 ohm shunt.
9. Track circuit components shall consist of a tapped feed step-down transformer and series feed reactor at the transmit end, with a track transformer, receiver and a biased-neutral track relay at

the receive end. The use of matching transformers to overcome line impedance shall be as required by the DB Entity's design.

10. All components shall be rack or wall mountable and utilize AREMA binding posts for terminations.
11. The track circuit product shall have an in service history on the MBTA or similar transit lines in a similar application for a minimum of 5 years.
12. Circuit components shall have a dielectric breakdown rating (circuit to chassis, circuit to circuit) of 3000V AC, 60Hz.
13. All circuit components shall be rated to perform in an environment consistent with the AREMA C&S Manual part 11.5.1, Recommended Environmental Requirements for Electrical and Electronic Railroad Signal System Equipment, for a Class C environment.
14. Track circuit shall provide broken rail detection on all rails with the exception of the negative return rail on the single rail applications. Broken rails shall be indicated by the de-energizing of the track relay for the track circuit containing the broken rail.

B. Power Bonds

1. All power bonding shall be bonded to the web of the rail. Bonding material shall be manufactured to use the exothermic process, Cadweld or approved equal. Bonding material and molds shall be MBTA accepted.
2. All non-insulated joints in single or double rail track circuit territory including guard-rail joints in curved track areas, shall use 250 kcmil size, 14" bonds, two for each joint, as manufactured by Erico Products, Inc.; Dwight and Wilson Company; United States Steel; or approved equal.
3. Power bonds for frog and switch fouling connections and expansion joints shall be made up with 2-500 kcmil extra flexible bonds.

C. Guardrail Bonds and Signal Rail Bonds

1. Guardrail bonds and signal rail bonds on the signal rail side in single rail track circuit areas shall be rail-head type manufactured bonds prepared for welding. The bonds shall be 7/32" by 6-1/2" and two for each joint, as manufactured by Erico Products, Inc.; Dwight and Wilson Company; United States Steel; or approved equal.
2. These bonds shall be manufacturer's bonds prepared for welding by the exothermic process. Bonds, bonding materials and types of molds shall be as accepted by the MBTA.

D. Other Bonds

1. Impedance bond connections to the rail shall be welded to the base of the rail as accepted by the MBTA. The cable for these connections shall be 2-500 kcmil extra flexible conductors as shown on the Contract Documents and specified in Section 16808 – External Signal Cable of these Specifications. 2-1000 kcmil extra flexible conductors shall also be used for impedance bond connections at traction power substation negative return connection locations as shown on the Contract Documents.
2. Frog jumpers, switch jumpers, and end-of-storage-track cross-bonds shall be welded to the base of rail as accepted by the MBTA. The cable for frog and switch jumpers, and end of storage track cross-bonds shall be 2-500 kcmil extra flexible as shown on the Contract Documents and specified in Section 16808 – External Signal Cable of these Specifications.

PART 3 – EXECUTION

3.1 INSTALLATION

- A. Track Circuits – power frequency track circuit components and track relays shall be rack mounted and factory tested prior to delivery of the CIHs to the job site. Upon delivery to the final location, the DB Entity shall re-insert relays and components and make connections, adjustments and test, as required, to effect a working field installation.
- B. Rail Bonding
1. Power bonds shall be installed at non-insulated rail joints as specified herein.
 2. Guardrail bonds shall be installed at all guardrail joints in curved track areas.
 3. Frog, switch jumper, and cross-bonding shall be installed at locations as required by the DB Entity's design. All pieces of the special trackwork shall be bonded in accordance with the accepted plans in order to establish electrical continuity and conductive capacity for traction power return and signal track circuits.
 4. Signal rail bonds in single rail track circuit areas shall be installed at locations as required by the DB Entity's design.
 5. For all rail-joint bonds, impedance bond connections to the running rails, switch and frog bonds, and expansion joint bonds, the surfaces of the rails where the bond is to be applied shall be ground clean with a reinforced grinding wheel, of a type as recommended by the bonding material manufacturer. The use of vitrified grinding wheels will not be allowed. After grinding, the surface shall be cleaned with an approved non-toxic solvent to remove all traces of grease and dirt.
 6. After the surface has been ground and cleaned, the surface shall be heated to drive out any moisture. The cable bond shall then be welded by exothermic process in such a manner as to ensure a thorough mechanical and electrical connection.
 7. The welding material shall consist of a copper exothermic mixture employing tin in an amount to effectively constitute 4.5 percent to 5.5 percent of the resulting weld metal. The resulting weld metal shall be of high electrical conductivity and shall have a minimum tensile strength of 39,000 pounds per square inch. The tensile strength shall be determined by tensile tests performed on ½" nominal diameter tensile specimens (without flaws) cast in graphite molds.
 8. The casting of test specimens shall be by the direct reduction of the exothermic mixture and the flowing of the weld metal into a graphite mold to form the ½" diameter specimens.
 9. Before beginning work on these bonds, the DB Entity, at his expense, shall require each welder to weld in the field under conditions similar to those of regular installation, not less than three complete rail connections, and as many more as the MBTA considers necessary to determine that the welds are being made satisfactorily. Such welds shall be subject to inspection and test by the MBTA, and his approval as to method and quality of workmanship will depend on the results of these inspections and tests.
 10. It is of great importance that each rail connection be thoroughly welded to the rail and, to reduce the possibility of any of these welds breaking while in service, the MBTA reserves the right to require a test of each weld by hammer and striker, or in any other manner which in the opinion of the MBTA is reasonable.

3.2 TESTS

- A. Track Circuit and Rail Bonding tests shall be performed in accordance with the manufacturer's approved factory and field test procedures and with requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

END OF SECTION

SECTION 16821

AUTOMATIC VEHICLE IDENTIFICATION AND PUSH BUTTON SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies basic requirements to provide Automatic Vehicle Identification (AVI) equipment for the MBTA's Green Line light rail system.
- B. This Section also specifies the requirements for application of Motorperson's Push Button boxes for the MBTA's Green Line light rail system.
- C. The AVI equipment will provide train routing requests at certain locations as well as augment the train tracking capability of the OCC systems by providing information from new locations installed as part of this contract. The locations for new AVI equipment are detailed in the project technical requirements. The DB Entity shall provide AVI equipment from an established supplier of AVI systems or equipment, and shall develop 'as-built' final drawings and design documentation based on the design philosophy of these Specifications and the Contract Documents.
 - 1. The AVI equipment will communicate with the existing operations control center (OCC) via the new fiber optic backbone being installed under this contract.
 - 2. The AVI equipment shall be functionally equivalent to the existing AVI equipment, and will be able to replace existing equipment without requiring changes to any equipment on board the Light Rail Vehicles (LRVs) or the Green Line wayside signal system, and without requiring changes to the existing OCC software and message formats.
 - 3. The AVI antenna equipment shall interoperate with existing AVI interrogator units, and existing AVI antennas shall interoperate with AVI interrogator logic units (ILUs) provided under this Contract.
 - 4. AVI antennas provided shall be fully interoperable with existing AVI antennas. Supplemental antennas shall be able to communicate with existing AVI interrogator units without imposing intermediate devices or modifying the existing interrogators units. Existing antennas shall be able to communicate with the supplemental AVI ILUs without imposing intermediate devices.
 - 5. The AVI equipment shall not affect or interfere with the operation of any existing MBTA systems or equipment.
 - 6. AVI route numbers required for use in non-vital application logic shall be supplied by the MBTA during construction.
- D. The DB Entity shall provide ancillary equipment such as junction boxes for the termination of antenna leads, bandpass filters, cables, and cases.
- E. The Motorperson's Route Select Push Button boxes will provide train routing requests, from the train operator, at certain Home Signal locations, and installed as part of this contract. The DB Entity shall provide all equipment from an established supplier of wayside signal system equipment, and shall develop 'as-built' final drawings and design documentation based on the design philosophy of these Specifications and the Contract Documents.

1. Furnish and install Motorperson push buttons at locations as required by the DB Entity's design. Locate train Operator's pushbuttons at home signals approximately eight feet in approach of the home signal. Train Operator's push buttons shall provide capability of selecting all routes which can be obtained at a particular Home Signal location.
 2. Install Motorperson's push buttons at a height of 5' measured between the base of rail and the bottom of the push button unit. Push Button Boxes shall be of adequate size for the equipment contained therein without crowding, and include a full complement of AREMA Standard terminal posts for terminating cables. Train Operator's push button boxes shall be NEMA 4X with padlock hasp sized for standard MBTA's hex keyed lock, and manufactured of type 304 stainless steel as shown on the Contract Documents. All Train Operator push button boxes shall be the same size. The mounting bracket or cantilevered support shall be rated to withstand 600 pounds of load.
 - a. The Push Button Boxes shall be furnished with push buttons in a vertical row and route indication lights mounted in a vertical row directly across from the corresponding route request Push Button. The box shall be hinged at its side with a 180-degree locking point.
 - b. Pedestal mounted Push Button boxes shall be as shown on the Contract Documents and accommodate a pedestal having a 4" diameter.
 - c. The pedestal unit shall have a 4" inside diameter and fit properly with pedestal junction box.
 3. The push button panel, push buttons, illuminating light and LED shall be vandal-resistant and vibration proof. All mounting hardware shall be secured by application of "Lock-tite" or product accepted by the MBTA.
 4. Locate the push buttons so as not to block any signal indications, and install at a height and distance to permit operation by the train operator without leaving the cab.
 5. Furnish and install laminated phenolic plastic tags indicating the button required for the route path desired and the lamp indicating the approved route. All characters on the tags shall be WHITE letters or numbers on a BLACK background, and be a minimum of 8 mm in height and 6 mm spacing between letters. A similar laminated phenolic plastic nameplate shall be provided identifying the Push Button name and location.
 6. Within the request circuitry that will be inputted to the NVMIS, the design shall ensure that the train operator has held the push button for sufficient time to initiate the routing feature.
 7. Each push button shall have an LED that illuminates when the push button is operated.
 8. The LED within the request Push Button shall be GREEN in color, or white with a green lens. The LED within the route indication shall be WHITE in color.
 9. If required for trackside visibility, the push button should be illuminated by method and location as accepted by the MBTA. In outdoor areas, the illumination light shall be lit at night only. In subway areas, the illumination light shall be on continuously.
- F. Furnish and install various arrangements of push button mounting for the layouts, as indicated on the Contract Documents, and as specified herein.
- G. Push Button Mounting
1. Outdoor Type - Pole-mount push buttons on split-base pedestals fastened to concrete foundations. Support for pedestal mounted push buttons shall consist of an approved 4" mast

suitably equipped at the top to accommodate the push button box and provided at the bottom with an approved split-base pedestal.

1.2 SITE CONDITIONS

- A. Dust, dirt, and electrical interference shall be considered and reflected in the design of all equipment provided. Equipment shall be able to operate as required either in the Green Line's underground sections or under prevailing exterior climatic conditions.

1.3 QUALITY CONTROL

- A. Material and equipment provided under this Contract shall be produced subject to a formal Quality Assurance Program, for which the DB Entity will provide certificates as requested by the MBTA.
- B. The DB Entity shall comply with the requirements of Volume 1 DB Contract Terms and Conditions Section 4 "Quality Control and Quality Assurance" and Volume 2 Technical Provisions Subsection 2.5 "Quality Management"
- C. The DB Entity shall inspect all AVI antenna site equipment prior to shipment. This inspection shall be conducted in conformance with the requirements of the DB Entity's Factory Inspection Procedure as accepted by the MBTA.
- D. DB Entity shall inspect each AVI wayside equipment unit prior to assembling it and installing it in a CIH.
- E. The DB Entity shall perform a Factory Acceptance Test of the AVI ILU, UPS system in conjunction with the factory test of the CIH system.
- F. All AVI antenna site equipment shall be inspected after it has been delivered and the DB Entity shall correct any deficiencies noted. This inspection shall be conducted in conformance with the requirements of the DB Entity's Delivery Inspection Procedure as accepted by the MBTA.
- G. The DB Entity's Delivery Inspection Procedure shall require the DB Entity to provide the MBTA with a written report upon receipt of all materials and equipment and shall note the condition of the shipment including any deficiencies.
- H. Only equipment that has passed the associated Factory and Integration tests shall be installed.
- I. The DB Entity shall inspect all Motorman's Route Select Push Button equipment prior to shipment. This inspection shall be conducted in conformance with the requirements of the DB Entity's Factory Inspection Procedure as accepted by the MBTA.
- J. DB Entity shall inspect each Motorman's Route Select Push Button unit prior to assembling it and installing it in its designated wayside location.
- K. All Motorman's Route Select Push Button equipment shall be inspected after it has been delivered and any deficiencies noted shall be corrected by the DB Entity. This inspection shall be conducted in conformance with the requirements of the DB Entity's Delivery Inspection Procedure as accepted by the MBTA.
- L. The DB Entity's Delivery Inspection Procedure shall require the DB Entity to provide the

MBTA with a written report upon receipt of all materials and equipment and shall note the condition of the shipment including any deficiencies.

M. Only equipment that has passed the associated Factory and Integration tests shall be installed.

1.4 SUBMITTALS

A. Unless expressly specified otherwise, submittals shall be made in accordance with the requirements of Volume 2 Section 2.7 and Section 2.8.

B. The DB Entity shall submit the following:

1. Drawings showing the typical layout, construction, mounting and grounding arrangement of the AVI antenna equipment at a surface (outdoor) location.
2. Drawings showing the cabling arrangements for each of the antenna sites including locations of junction boxes and cable routes between the antennas and junction boxes.
3. Drawings showing installation details for all AVI antenna site equipment. These drawings shall include, but not necessarily be limited to, layout of antenna loops, antenna lead configuration relative to track structures, junction box installation details, cable connections and terminations; and locations of any bandpass filters that may be necessary.
4. Schematic diagrams showing the manner in which AVI wayside equipment components are to be connected to each other internally, to the AVI antenna equipment, and to field communications externally.
5. Drawings showing the location, type, and arrangements of all interface terminations to Wayside Equipment, Antenna Site Equipment, external 120V AC 60Hz power, and the patch panels for the two network switches and terminal servers for the fiber optic backbone communication system.
6. Sizes and types of internal and external wire proposed for use.
7. Manufacturers' specifications for AVI ILU and supporting equipment.
8. Manufacturers' specification of UPS system's components including, but not limited to, AC to DC converter, charger, DC to AC inverter, transfer switch and batteries.
9. Power calculations demonstrating the proposed UPS system's ability to adequately serve the load demands of solid state equipment for each system with the required additional operating margins.
10. Schematic diagram of UPS system components including, but not limited to, AC to DC converter, battery charger, inverter, and transfer switch. Also include schematic diagrams showing manner of connection between components, including batteries, to form a viable UPS system.
11. A Factory Inspection Procedure for the AVI Antenna, and for the ILU and the UPS prior to assembly. Following approval of the Factory Inspection Procedures, furnish six certified copies upon satisfactory completion of the inspections.
12. A Factory Acceptance Test Procedure for the AVI antenna, and for the ILU, UPS system, and supporting hardware installed in the CIH's.
13. Following approval of Factory Acceptance Test procedures, six certified copies upon satisfactory completion of the Factory Acceptance Tests.

14. A Delivery Inspection Procedure to assure that all furnished equipment meets the requirements of these Specifications.
 15. Installation test procedures.
 16. An Antenna Interface Test Procedure.
 17. A Proof of Performance Test Procedure.
 18. A Site Integration Test Procedure.
 19. Ten (10) copies of all maintenance manuals.
 20. Drawings showing the typical layout, construction, mounting and grounding arrangement of the Motorman's Route Select Push Button equipment at a surface (outdoor) location.
 21. Drawings showing the cabling arrangements for each of the Motorman's Route Select Push Button sites including locations of junction boxes and cable routes between the boxes, and CIH locations.
 22. Drawings showing installation details for all Motorman's Route Select Push Button site equipment. These drawings shall include, but not necessarily be limited to, layout of positioning configuration relative to track structures, junction box installation details, cable connections and terminations.
 23. Schematic diagrams showing the manner in which Motorman's Route Select Push Button wayside equipment components are to be connected internally, and to CIH locations.
- C. All drawings submitted by the DB Entity shall be in conformance with Section 16804 – DRAWINGS FOR THE LIGHT SIGNAL RAIL SYSTEM, and shall include the drawing number, title, issue date, revision number or letter, date of revision, the initials of the DB Entity's responsible MBTA authorizing and checking the revision, a description of the change, the reason for making the change, contract number, reference to next higher assembly, and relevant DB Entity's approval signatures.

1.5 DELIVERY, STORAGE AND HANDLING

- A. The DB Entity shall provide all equipment and accessories specified herein and all accessories not specifically identified but which are necessary or reasonably required for the AVI and Motorperson Route Selection Push Button equipment to perform its functions when connected to the OCC via the new fiber optic backbone.
- B. The DB Entity shall comply fully with the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- C. The DB Entity shall assure that all equipment is protected from damage during shipment.
- D. Shipment of all equipment shall be trackable and the MBTA shall be provided the ability to monitor the status of the shipment.
- E. The DB Entity shall provide identification nameplates, tags and/or markings for items as specified in this Section.
- F. The DB Entity shall replace any equipment damaged in transit or caused by mishandling by the DB Entity at no additional cost to the Contract.

1.6 TESTING

- A. The DB Entity shall provide testing of equipment as specified herein and in Section 16898, Signal System Tests.

1.7 WARRANTY

- A. The DB Entity shall provide warranty on equipment provided under this Contract, in accordance with Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

PART 2 – MATERIALS

2.1 EQUIPMENT

- A. All equipment provided by the DB Entity shall be new and free of manufacturing defects. The equipment will consist of:
 - 1. AVI Antenna Site Equipment, including AVI antennas, bandpass filters as warranted and interconnection cables.
 - 2. AVI Wayside Equipment, including ILUs, uninterrupted power supply (UPS), AVI support equipment, and connections to patch panels for the new fiber optic backbone.
 - 3. Motorman’s Route Select Push Button wayside site equipment, including split base junction boxes, masts, mast caps, and box mounting hardware.
 - 4. Any and all equipment and accessories required to make the furnished equipment meet the requirements of these Specifications.
- B. All equipment provided by the DB Entity, including cables, connections, and accessories, shall be able to operate as required outdoors in weather conditions, including precipitation and temperature and humidity variations according to data published by the National Oceanic and Atmospheric Administration for Boston and surrounding areas. Equipment shall operate as required in an outdoor environment without requiring protection other than enclosure in the CIH itself. Comply and adhere to AREMA Class C.
- C. All original equipment provided by the DB Entity, including cables and connections, shall be accepted by the MBTA prior to procurement or use. For this purpose, the DB Entity shall provide to the MBTA satisfactory evidence that the equipment is appropriate for the intended use, including manufacturer’s specifications or other technical characteristics.

2.2 AVI ANTENNA SITE EQUIPMENT

- A. Provide AVI antennas consisting of a double loop of wire, in a ‘figure 8’ configuration, to be installed between the running rails.
- B. The loops shall be formed of #8 stranded, insulated wire.
- C. The antenna(s) shall be designed to reflect an RF field upward as installed.
- D. The AVI antennas shall be provided pre-installed in frames fabricated of Cordura hose or an approved equal, compatible with the existing AVI antenna location support structures.

- E. The outside dimensions of the antenna loop frame shall be approximately 4' by 16'.
- F. The antenna loops shall have a mean time between failures (MTBF) no less than 40,000 hours.
- G. Junction Boxes
 - 1. The DB Entity shall furnish junction boxes to terminate the leads from individual antennas and effect links to the associated ILU in the CIH.
 - 2. Junction boxes shall satisfy the NEMA 3R standard, and shall be watertight and provide for the intended connections to be made reliably in the EMI conditions prevalent in the Green Line's Central Subway.
- H. Interconnecting Cables at Antenna Sites
 - 1. The DB Entity shall furnish and install the interconnecting cables as specified herein. The following cable interconnections are required at each AVI antenna site:
 - a. Antenna leads from individual antenna loops to junction boxes;
 - 2. All interconnecting cables will run in trough or conduit. The DB Entity shall provide conduit sufficient for the length of all interconnecting cables, and such that each connection can be made without requiring mechanical connections. These conduits shall be metallic and shall shield the interconnecting cables against RFI/EMI interference, shall be grounded appropriate to provide such shielding, and shall be of waterproof construction.
- I. All conduits shall be of an ANSI-approved type and shall be classified by UL as suitable for the purpose specified.
- J. All conduits shall be free of burrs and projections, circular in cross-section, of uniform wall thickness, and shall conform to the requirements of ANSI Standard C-80.1.
- K. Grounding
 - 1. The DB Entity shall furnish equipment necessary to ground the antennas in accordance with Section 16871 – GROUNDING FOR THE LIGHT RAIL SIGNAL SYSTEM, and Section 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHTH RAIL SIGNAL SYSTEM.

2.3 Wayside Equipment

A. AVI Interrogator Logic Unit (ILU)

- 1. The DB Entity shall provide ILUs compatible with the MBTA's existing or "legacy" Green Line units as manufactured by Vapor Corp.
- 2. The function of the ILU shall be as follows:
 - a. Upon activation by the approach of an LRV, continuously interrogate each connected antenna loop for transponder messages. Every 24 millisecond (ms), output a 100KHz signal of 2 ms duration, and wait for a response from a transponder;
 - b. Process all messages received from up to four (4) connected antennas in such a way as to have output indistinguishable from the 'legacy' units, without requiring any additional external processing;
 - c. Format and output the messages for transmission to the OCC at 45 High Street via the

fiber optic backbone communications. The MBTA will develop code at the OCC to interpret the DB Entity's data format.

- d. As required by its configuration, decode the route number in a message from an LRV and operate interface relays to initiate a corresponding route request with the existing wayside signal system. This functionality shall interface with the VMIS to the wayside signal system for route requests.
3. The ILUs shall be installed in the CIH prior to factory integration testing and delivery.
 4. The ILUs shall be configured so that the route selection capability can be enabled, disabled, and properly set in the field without requiring the unit to be removed from the CIH.
 5. The ILUs shall be configured so that the route decoding can be modified to accept new or changed route codes from LRVs in the field without requiring the unit to be removed from the CIH.
 6. ILUs shall operate on 120V AC or at a common voltage with all other devices in the CIH requiring electric power. Any other voltage shall be accepted by the MBTA. ILU's shall be fed by the CIH signal power, not utility power.
 7. Each ILU shall have two serial data ports receiving/sending the same data concurrently through redundant fiber optic links with the OCC. In the event that control is switched from one ILU to the other within the CIH, the two serial data connections will be switched to follow the ILU in control. The ILU shall have a mean time between failures (MTBF) no less than 40,000 hours.
- B. AVI Supporting Equipment
1. The DB Entity will provide a bandpass filter device where necessary to suppress any interference signals which may be present in the antenna loops. The DB Entity shall install these filters in the correct AVI equipment cases for the required locations, in such a way that the antenna leads terminate directly in the equipment case.
 2. The DB Entity shall furnish and install termination points for the fiber patch cables between the CIH and the fiber patch panels of the fiber optic backbone.
 3. The DB Entity shall furnish and install termination points for cables originating from the AVI antenna site, which includes the potential for four (4) antenna loops connected to the equipment in each CIH.
- C. Interconnecting Cables at AVI Sites
1. The DB Entity shall furnish and install interconnecting cables and wires as specified in this Section and as required to form a complete and operable system. The following cable interconnections are required at all AVI sites:
 - a. Four (4) fiber patch cables to run from the CIH to a fiber patch panel, the interface point for communications to the OCC at 45 High Street.
- D. Grounding and Lightning Protection
1. Internal ground bus arrangement shall be as specified in Sections 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM and 16871 – GROUNDING FOR THE LIGHT RAIL SIGNAL SYSTEM.
 2. The DB Entity shall design and make provisions to minimize the susceptibility of equipment to lightning strikes, including provisions to equalize or discharge the resulting energy.

E. Labeling

1. The DB Entity shall install a laminated phenolic plastic nameplate on each AVI antenna and junction box. The nameplate shall be 450 mm x 70 mm with white lettering 50 mm high on a black background. The lettering shall have an 8 mm letter stroke width and 6 mm spacing between letters. Letters shall be generated by an engraving machine. The nameplate shall be fastenable with four stainless steel self-tapping screws, with 'Robertson' No. 2 (red) heads.
 - a. All labels mounted on equipment installed outdoors shall be treated to prevent degradation from sunlight.
 - b. The information content of the required labels shall be as accepted by the MBTA for each type of component, and the DB Entity shall confirm the nameplate information with the MBTA prior to manufacturing the labels.
2. Labeling for connecting cable shall be mechanically printed. Painting, stenciling or hand printing is not acceptable. Cables shall be labeled on each end and labeling shall repeat no greater than every thirty (30) linear feet where cable is exposed. Except for cable ends which are to have plastic labels with a mechanical strap, adhesive backed labels are acceptable, but only if the label wraps around the entire circumference of the cable and adheres to itself. Otherwise, mechanical fastening with a strap is required.

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS

- A. The DB Entity shall fabricate all AVI equipment according to the MBTA accepted fabrication drawings and factory test according to the MBTA accepted factory Inspections and test Procedures. The DB Entity shall progress and update, as required, the development of all required drawings into a final “as-built” package that is consistent with the equipment provided. The DB Entity shall be responsible for providing final as-built drawings incorporating all changes and all revisions.
- B. The DB Entity shall thoroughly review the Contract Documents and shall resolve any questions with the MBTA prior to initiating the development of design documents.
- C. AVI wayside equipment will be installed in the CIHs by the DB Entity prior to on-site delivery in accordance with this Section.
- D. The DB Entity shall furnish and install mounting and fastening hardware, insulating covers, cable lugs, conduit, copper grounding strips, grounding, and miscellaneous hardware required for the AVI wayside equipment components and AVI Antennae.
- E. The DB Entity shall monitor the installation of each AVI location and each antenna location and shall certify that each installation has been performed correctly.
- F. The DB Entity shall perform field testing in accordance with the requirements of Section 16898 - SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

16821 APPENDIX A: DESCRIPTION OF EXISTING MBTA GREEN LINE SYSTEM

- A. The MBTA's Green Line (shown schematically in Figure 1) consists of the following portions or 'territories':

The 'Central District' which combines underground (Central Subway) and surface portions, and extends from Lechmere Station in the northwest to subway portals on Commonwealth Avenue ('B' branch west of Kenmore Station), Beacon Street ('C' branch west of Kenmore), Fenway ('D' branch west of Kenmore Station), and Huntington Avenue ('E' branch west of Symphony Station).

The surface routes from the portals running out to Boston College ('B'), Cleveland Circle ('C'), Riverside (D), and Heath Street ('E').

FIGURE 1: GREEN LINE MAP



- B. The Green Line does not have a consistent operating environment across the different territories described above. The following are the different operating environments on the Green Line:
1. In the Central District and on the Riverside 'D' branch operational control is achieved by a wayside Automatic Block Signal (ABS) system.
 2. Operations along the surface portions of the Boston College ('B'), Cleveland Circle ('C'), and Heath Street ('E') branches are subject to on-street traffic signal control with safe train separation being the responsibility of the train operator.
- C. Throughout the Green Line, each track used in revenue operation has a normal direction of travel, and operations almost always follow this convention. Trains can change tracks at control points (CPs) where track switches are located. Merging or diverging train movements at junctions in the Central District and on the 'D' branch occur at interlocking CPs, where the wayside signal system prevents the display of signals permitting conflicting routes, and requires the power-operated switches to be lined and locked in the correct position before a signal indication for the corresponding route can be displayed.
- D. Centralized dispatching and operations control over the MBTA rapid transit system (Red, Blue and Orange lines), and the MBTA's light rail system (Green and Mattapan- Ashmont lines) is

maintained from the OCC at 45 High Street, Boston. Green Line dispatchers at the OCC track the real-time movements of Green Line trains mainly with the help of train passage and route selection indications received from an Automatic Vehicle Identification (AVI) system. Additional information on train movements is available in the OCC via voice communications received from field officials and operators, and from CCTV coverage of certain key locations.

- E. The existing AVI system was introduced in 1992 to replace overhead pan contacts as a means of route selection by Green Line vehicle operators. As part of this system, a number of CPs are equipped with AVI trackbed loop detector antennas and associated wayside interrogators, with a capability to request route selection from the wayside signal system. AVI devices are also deployed at other locations to improve vehicle tracking. Eleven of the total of thirty-nine existing AVI sites (antenna loops and associated interrogators) are deployed at wayside locations where there is no route selection, and serve only to facilitate vehicle tracking.
- F. Each Green Line light rail vehicle (LRV) is equipped with an AVI Code Control Box and two transponders, one at each end (designated 'A' and 'B'). The transponders transmit the following information to the wayside AVI interrogator through the AVI antenna loop when they pass over a keypoint:
 - 1. LRV ID.
 - 2. Route identifier (set by operator in the lead LRV).
 - 3. Coupling status of the LRV end (coupled or uncoupled).
 - 4. LRV orientation (A or B end leading).
- G. The information read by the interrogators is used by the wayside AVI equipment to convey route selection requests to the wayside signal system (where so equipped), and is also conveyed from all AVI sites to the OCC, where it is used for monitoring train locations.
- H. At points where route selection is to be accomplished, the routing received by the wayside AVI interrogator from the lead transponder unit on the lead LRV is used locally to request the wayside signal system to set the switch in accordance with that routing, and to display a signal for the corresponding route.
 - 1. All the information received by wayside interrogators at all keypoints is brought into the OCC using modems and leased lines. Software at the OCC compiles this information and uses it to:
 - a. Derive the train consist (as a sequence of LRV identifying numbers).
 - b. Derive the sequence of trains that have passed over keypoints.
 - c. Track the location of trains as they pass over keypoints.
 - d. Calculate vehicle mileage.
 - e. Run reports against train data.

END OF SECTION

SECTION 16823

IMPEDANCE BONDS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies furnishing and installing impedance bond layouts and cross bonding layouts, complete with all associated mounting hardware and all connecting cables.

1.2 QUALITY ASSURANCE

- A. Impedance bonds shall comply with the applicable requirements and recommendations of Section 8.4.5 of the AREMA C&S Manual where the manual does not conflict with these Specifications.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 Construction Submittal Requirements”, the DB Entity shall submit the following for approval:
 - 1. Impedance bond layout installation drawings showing the physical dimensions of the bond, associated mounting hardware, mounting ties, and cables.
 - 2. Impedance bond electrical characteristics.
 - 3. Factory test procedures.
 - 4. Installation test procedures.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage throughout delivery, storage and handling. Materials shall comply fully with the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Damage to material resulting from improper storage or handling by the DB Entity shall result in replacement of all damaged material with new material by the DB Entity at no additional cost to the Contract.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. All impedance bonds shall be tuned to operate specifically with 100 Hz double rail steady energy AC track circuits. The DC resistance of the impedance bond, from track lug to track lug, shall not be less than 1 ohm.
- B. The track winding of each impedance bond shall be rated to carry 2500 amperes per rail continuously. The impedance bond shall function properly with a traction current imbalance of up to at least 12 percent.
- C. Two track winding terminal lugs shall be provided on each impedance bond. Each track winding lug shall accept two 500 kcmil cables or two 1000 kcmil cables. One center tap terminal lug shall be provided on each impedance bond. The center tap lug shall accept up to four 1000 kcmil cables.

- D. When it is necessary to terminate cross bonding cables, substation return cables, or DC negative returns from other equipment to the center connection between two impedance bonds, the DB Entity shall provide a copper plate of sufficient physical size and electrical capacity to accommodate all terminations necessary, including all center tap cables between the bond pair, to be installed in the middle of the center tap cables. The copper bus plate shall be mounted on ties between adjacent impedance bonds and shall be insulated from the ties.
- E. The size of the impedance bond shall permit mounting on the ties between the rails as shown on the Contract Documents. Mounting height shall be at least one-half inch below the plane of the top of rails.
- F. Side lead, center tap cables, and exothermic connections to the rails shall be as specified in Section 16830 – RUNNING RAIL BONDING FOR THE LIGHT RAIL SIGNAL SYSTEM and as shown on the Contract Documents.

PART 3 – EXECUTION

3.1 INSTALLATION

- A. The DB Entity shall relocate and space crossties at locations where bonds are to be installed in accordance with the accepted installation drawings.
- B. Following installation, the DB Entity shall re-tamp and redress the ballast in the area of the new impedance bond installation to restore the pre-installation quality of the track structure and tolerances.
- C. The impedance bond shall be mounted on the ties between the rails as shown on the Contract Documents and in accordance with the accepted installation drawing. Mounting height shall be at least one-half inch below the plane of the top of rails.
- D. Impedance bonds shall be shock mounted to effectively isolate them from the shock and vibration normally encountered in the area in which they are mounted.
- E. Impedance bonds mounted between the rails shall be protected against dragging equipment in both directions by steel ramps.

3.2 TESTS

- A. Impedance bond layouts shall be tested per the accepted installation test procedure as specified in Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

END OF SECTION

SECTION 16826

CABLE RACEWAYS AND AERIAL CABLE SUPPORT SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies requirements for design, furnishing and installation of cable raceways, outdoor cable tray, outdoor cable trough (polymer concrete or stainless steel), conduit and aerial cable support systems.
- B. The DB Entity shall furnish and install all new cable raceways, outdoor cable trough, pre-cast concrete vaults, polymer concrete pullboxes, conduit and aerial cable support systems for the Green Line Extension Project.
- C. The DB Entity shall develop work plans for the installation work covered in this Section. These plans shall detail the period of work, number and size of crews, anticipated work hours, and number of track shutdowns. The work plan shall conform to all other Contract requirements and limitations such as quantity and type of flagperson. The work plan shall be submitted to the MBTA for acceptance and updated periodically as specified elsewhere in these Specifications. Reference the Volume 1 DB Contract Terms and Conditions Subsection 2.3 "Commencement of Work" and Subsection 4.4 "Completion Milestones, Project Schedule" and Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM, Section 16803 - STAGING AND IMPLEMENTATION FOR THE LIGHT RAIL SIGNAL SYSTEM, and other applicable sections for detail reporting and phasing requirements.
- D. Installation of all cable raceway, conduit, outdoor trough and aerial cable support systems shall be in accordance with requirements listed in the latest revision of the National Electrical Code (NEC) and National Electric Safety Code (NESC).
- E. The prefabricated cable trough system provided shall be complete with all necessary right angle corners, single "T" intersections, horizontal and vertical deviations, cable exits, lockable cover system, special junctions, end plugs, heavy load covers and other special fittings as required to permit proper cable installation and to provide secure protection of installed cables.

1.2 QUALITY ASSURANCE

- A. Material, equipment and systems provided for this Contract shall be produced under control of a formal Quality Assurance Program to ensure an acceptable level of quality for the equipment provided.
- B. Comply with the requirements of Volume 1 DB Contract Terms and Conditions Section 4 "Quality Control and Quality Assurance" and Volume 2 Technical Provisions Subsection 2.5 "Quality Management".

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements", the DB

Entity shall submit the following to the MBTA for acceptance:

- A. Outdoor Cable Trough Systems, including pre-cast concrete cable vaults and polymer concrete pullboxes
 1. Submit certification that manufactured materials meet specification requirements;
 2. Manufacturer's drawings and catalog cuts of all trough system components to be installed on the project (including special vertical and/or horizontal offset fittings, special junctions, end plugs, adapters, covers, etc.);
 3. Detailed installation/routing drawings and installation procedures for the cable trough system components. The drawings shall include:
 - a. Physical layout of new cable trough, cable vaults and pullboxes, dimensioned to the gauge, or centerline, of adjacent track(s) and wayside structures.
 - b. Installation details showing the transition between trough and other raceways, such as conduit penetrations and vault/pullbox installations.
 - c. Provide detailed steel fabrication and installation drawings for any specialized steel support members, and associated materials, that may be required. Steel support members shall be galvanized.
 4. Provide percent fill calculations, cable bend radius determination for all trough, pullboxes and hand holes.
 5. Following acceptance of the installed cable trough system, as-built tracings of the cable trough routing signed and stamped by the registered land surveyor, shall be submitted as part of the DB Entity's final as-built drawing submittal.
- B. Outdoor Cable Tray, Accessories and Associated Hardware.
 1. Catalog cuts and product data for all types of cable tray to be provided, cable tray shall be ladder type;
 2. Catalog cuts for all cable tray support system components and accessories;
 3. Detailed installation plans for tray routing system, including tray fill calculations and cable installation methods. Plans shall show location, size, fasteners, connections, grounding, and general configurations of tray installation. Plans shall also include installation details for the transitions between cable tray and any other cable routing system for both typical and particular or special applications
- C. Stainless Steel Pull Boxes and Fabricated Steel Supports.
 1. Stainless steel pullboxes and associated hardware, if required, shall be fabricated of 304 stainless. Detailed fabrication and installation drawings shall be provided by the DB Entity.
 2. The DB Entity shall provide detailed fabrication and installation drawings of all galvanized support steel member and materials that are need to secure the stainless steel pullboxes.
- D. Stainless Steel Cable Trough and Associated Materials.
 1. Stainless steel cable trough if required shall be provided with detailed fabrication and

installation drawings. The trough shall be constructed from new 304 stainless steel.

2. Detailed fabrication and installation drawings of all galvanized support steel member and materials that need to be attached to support the trough system shall be provided.
3. Detailed installation methods for field drilling existing structures for mounting, field-galvanizing procedures, support steel installation and stainless steel trough installation.

E. Conduit and Associated Materials:

1. Catalog cuts and product data for galvanized rigid steel (GRS), fiberglass reinforced (FRE), flexible metallic conduit and proposed fittings;
2. Catalog cuts and product data for galvanizing repair compound;
3. Catalog cuts for all conduit support system components and accessories;
4. Detailed installation plans for conduit, including conduit fill calculations and cable pulling calculations. Plans shall show location, size, fasteners, connections, grounding, and general configurations of conduit installation. Plans shall also include installation details for the transitions between:
 - a. Conduit to wayside junction boxes;
 - b. Conduit to overhead cable tray;
 - c. Conduit to aerial messenger;
 - d. Exposed GRS conduit to underground FRE;
 - e. Conduit installation details to all wayside equipment.

F. Aerial Cable Support System:

1. Installation drawings showing the number of messengers at specific stationing location, as well as indicating all cables that are supported on each messenger.
2. Messenger wire, automatic compression fitting, preformed wire fitting, dead-end materials, messenger clips, cable straps, strain insulators, and all other proposed aerial cable support hardware for the project.
3. Sag and tension calculations for messenger's initial and final loaded conditions per the National Electric Safety Code (NESC).
4. All wood pole and pole line materials and installation details for all wood pole construction.
5. Installation drawings and procedures for all messenger attachments and aerial cable installations. The installation plans may include cable placement and details with bill of materials. Typically, shall show, as a minimum, cable attachments, mounting height, and cable clearances. Special areas or construction not covered by typical drawings shall have site specific pertinent clearance details.
6. Installation drawings showing transitions from aerial messenger to conduit risers and cable tray.
7. Fabrication drawings for messenger dead-end structural steel.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage during delivery, storage and handling. Comply fully with the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Damage to material, resulting from improper handling by the shipper or the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the Contract.

PART 2 - PRODUCTS

2.1 CABLE TROUGH, AT-GRADE PULLBOXES, CABLE VAULTS AND COVERS

- A. Prefabricated Outdoor HDPC Cable Trough
 - 1. Traversable Cable Trough
 - a. Traversable Cable Trough shall be utilized as a pedestrian egress path and installed at the locations indicated on the Contract Documents.
 - b. Non-traversable Cable Trough shall be utilized in areas not accessible to pedestrians where a smaller trough is specified at locations indicated on the Contract Documents.
 - c. Traversable cable trough unit shall consist of (1) 10’ HDPC body and (3) HDPC dielectric 39” covers. Reference Oldcastle Enclosure Solutions – Synertech Plastibeton Model 2012 or approved equal.
 - d. Non-Traversable cable trough unit shall consist of (1) 10’ HDPC body and (3) HDPC dielectric 39” covers. Reference Oldcastle Enclosure Solutions – Synertech Plastibeton Model 1216 or approved equal.
 - e. HDPC trench and body shall meet the material of construction and performance specifications detailed below.

TABLE 1: HDPC Cable Trough Cover Dimensions & Weight

Type	Width (in.)	Length (in.)	Depth (in.)	Maximum Cover Weight	
				LB	KG
Model 1216	14”	39 ¼”	2 ¼”	82	37.2
Model 2012	22”	39 ¼”	2 ¼”	115	52.2

TABLE 2: HDPC Cable Trough Body Dimensions & Weight

Type	Width (in.)	Length (in.)	Height (in.)	Maximum Body Weight	
				LB	KG
Model 1216	17 ¼”	118 1/8”	19 3/8”	813	368.8
Model 2012	25 ¼”	118 1/8”	15 ¾”	821	372.4

- f. HDPC cable trough shall have the following internal dimensions:

Nominal Sizes	Model 1216	Model 2012
Interior Height under cover	16"	12”

Interior Width

12"

20"

- g. HDPC cable trough system provided shall be complete with all leveling blocks, protection rods, cover plugs, end plates, internal dividers (as required), attachment plates as required to permit proper cable trough installation and provide secure protection of installed cables.
- h. HDPC cable trough systems shall be sized by DB Entity to accommodate 20% future expansion.
- i. HDPC cable trough shall afford cable installation through laying cables into trench without any interference or the need to thread cable through supportive cross supports or other interfering trench structural support components.
- j. HDPC cable trough body side wall shall be set at finish grade to avoid creation of a tripping hazard.
- k. HDPC cable trough bodies shall come in standard 10' sections.
- l. The interior of HDPC cable trough body shall be factory formed as a smoothly finished, U-shaped channel, which is free of burs, sharp edges and shall have no interior angles that increase the pulling resistance on cables.
- m. HDPC cable trough sidewalls shall be a minimum 1.25" thick HDPC across the full side wall area. No cored-out sidewall areas less than 1.25" thick will be accepted.
- n. HDPC cable trough shall have a solid bottom provided with conduit access holes. Bottom conduit openings shall be cast within the trench during manufacture.
- o. SMC dividers may be required and should be installed at the factory at time of trough body manufacture. Field installation of dividers will not be accepted.
- p. HDPC cable trough flush covers shall sit inside the trough to allow flush to grade installation. No T-Cover designs will be accepted.
- q. HDPC cable trough covers shall be provided with a means for manual lifting.
- r. Any special tools required for lifting HDPC cable trench & covers shall be the
- s. DPC cable trough covers shall be manufactured with an anti-skid surface. Addition of an anti-skid surface coating or treatment after manufacturing is not acceptable.
- t. HDPC cable trough covers shall resist ice formation on cover top and sides.
- u. Non- metallic, light weight carbon fiber "protection rods" shall be provided to protect against covers falling into trough during cover removal. Protection rods cannot have a structural lateral load support role in the integrity of the trench body. The protection rods cannot be used to aid in the elevation of cover vertical load capacity. Rebar shall not be used.
- v. If locking covers are required, locks shall utilize L-Bolt anchor design for keyed or standard style locks. No threaded nuts or bolts will be accepted on HDPC cable trough.

2. Cable Trough Performance Requirements

- a. HDPC cable trough and covers shall be suitable for both indoor and outdoor placement.
- b. Trench covers and bodies shall conform to all applicable AASHTO, ASTM, NFPA and OSHA standards as detailed below.

- c. HDPC cable trough shall be of the self-supporting type equipped with easy access flush covers. No T-Cover designs shall be utilized due to the potential for inadvertent dislocation or removal due to heavy tire or snow plough horizontal shear force.
- d. HDPC cable trough and covers shall be compliant with the AASHTO HS20-44 – Standard Specification for Highway Bridges, Sixteenth Edition, Section 3, Loads, Service Factors and their Application. (Per ASTM C-857 & C-497 Section 5).
- e. Proof of trough Body/Cover Design Load compliance shall require manufacture to demonstrate through testing, ability for trough and cover (unit) to meet a 20,800# (design load w/impact factor) load cycled 50 x (10"x 10" 1" thick plate) with the 51st cycle taken to failure. A minimum failure load of 40,000 pound is required.
- f. No internal supports or cross-braces may be used during testing.
- g. Proof of trough Body/Cover Lip Strength compliance shall require manufacture to demonstrate through independent testing, ability for trough and cover lip area to meet a 20,800 lb. (design load w/impact factor) load cycled 10 x (10"x 10" 1" thick plate) with the 11th cycle taken to failure. A minimum failure load of 40,000lb is required.
- h. Proof of trough Body Lateral Load compliance shall require manufacturer to demonstrate through independent testing, ability of trench body side wall to meet 800lb./sq.ft. cycled 10 x (18" x 24" x 1" thick plate) with a minimum of 1200 lb./sq.ft. failure load. This test confirms trench body's ability to handle vehicular and mechanical lateral loads typically seen during installation and maintenance operations. Testing shall be done free-standing without cover installed and no secondary cross supports to simulate an opened trough.
- i. Proof of trough Body/Cover Fit compliance shall require manufacture to demonstrate through independent testing, ability for cover insertion and removal with 440lb. dead weight loaded onto the first 2" of the cover/body lip sidewall. This test insures the lid will fit inside the trough and will not be locked in or out of position during installation, after maintenance of way operations.
- j. HDPC cable trough cover weight shall not exceed OSHA's allowable handling weights as specified in the OSHA Technical Manual, Volume 1, Section 7, Appendix VII: 1-2, Evaluation Of Lifting Tasks.
- k. HDPC cable trough shall comply with confined space (building area, tunnel) use in accordance with ASTM C-542 Flame Propagation & NFPA 130, Chapter 2-1, Standard for Fixed Guideway Transit and Passenger Rail System – 2006 Ed.).
- l. HDPC cable trough shall comply with ASTM E-662 & NFPA-258 Non-Flaming (no flaming drips) standard, no smoke generation per performance ratings detailed in material specification chart below.
- m. HDPC cable trough, covers shall be suitable for both indoor & outdoor confined space (tunnel) use in accordance with ASTM E84-99 "Standard Test Method for Surface Burning characteristics of Building Materials".

3. Cable Trough Material Specifications

- a. HDPC cable trough, covers and related hardware shall be made from materials that are low-smoke, zero-halogen, and are in compliance with approved noncombustible construction as defined in NFPA 220, as specified in 2-2, Construction and 2-4.2.

- b. Material used for the manufacture of HDPC cable trough body & cover shall be minimum 18,000 PSI – compressive strength - High Density Polymer Concrete (HDPC).
- c. HDPC cable trough and cover material is nonporous (closed cell) and shall resist the degrading action of freeze/ thaw cycles. The material shall also resist degradation from acids, hydrocarbons, and salts.
- d. HDPC cable trough body shall be compression molded high density polymer concrete reinforced with welded wire.
- e. HDPC covers shall be compression molded high density polymer concrete reinforced with Sheet Molding Compound (SMC).
- f. HDPC cable trough covers shall resist Ultra Violet deterioration and be tested in accordance with ASTM G154.

HDPC cable trough and covers shall comply with ASTM C 267 for chemical resistance and shall demonstrate no significant change when exposed to:

- a) Sulfuric acid (50%) b) Sodium Hydroxide (5%)
- c) Sodium Sulfate (10%) d) Sodium Chloride (26%)

TABLE 3: HDPC Cable Trough Body and Cover Material Specifications

Characteristic	Performance Rating	Testing Standard
Compression Strength	18,000 PSI minimum	ASTM C 170
Direct tensile strength	1,800 PSI minimum	ASTM D 2936
Modulus of rupture	6,400 PSI minimum	ASTM C 99
Impact strength	34 in-lb.	ASTM F 736
Modulus of elasticity in flexure	4.2x10 ⁶ PSI	ASTM C 120
Water absorption maximum	0.15%	ASTM C 97
Density	153 lb./ft ³ minimum	ASTM C 128
Fire resistance max	10	ASTM E 84
Freeze/Thaw resistance	2,500 cycles of no change	ASTM C 666
Flame Spread Index	4	ASTM E 162
Flame Propagation	Pass No Flaming Drips	ASTM C 542 (NFPA-130 2006)
Smoke Generation (Non-Flaming)	Ds 1 @ 1.5 min Ds 8 @ 4.0 min (No Flaming Drips)	ASTM E 662 (NFPA-258)

B. Stainless Steel Cable Trough and Associated Materials

- 1. The stainless steel cable trough and all integral components shall be fabricated from 12 gauge, type 304, stainless steel. It shall have minimum internal dimensions of 8” x 8” and a hinged cover. Stainless steel trough shall have a ¼” thick x 2” wide x 11”+/- long integral mounting plate to secure the trough to the new fabricated steel supports.
- 2. The stainless steel shall be supported by new fabricated, hot-dipped galvanized, steel angles. These new steel supports are to be secured to the existing structures. New steel supports shall be factory fabricated in accordance with American Welding Society (AWS) standards and hot-dipped galvanized in accordance with ASTM- 123.
- 3. The DB Entity is required to perform detailed measurements and installation layout of the

existing field conditions and detail all stainless steel trough sections and galvanized steel supports.

4. DB Entity shall install suitable bolts, washers, lock washers and LockTite 271 to all bolted connections used to support the fabricated steel supports to the existing structures and the stainless steel cable trough to the support steel.

C. Polymer Concrete Pull Boxes

1. Pull boxes and cable vaults shall be constructed of polymer concrete consisting of an aggregate matrix bound together with a polymer resin. Internal reinforcement may be provided by means of steel, fiberglass, or a combination of the two. The use of chopped fiberglass strands applied with a "chopper gun" or the use of high density polyethylene or high density polystyrene is prohibited. To assure consistent production from part to part, only matched metal tooling is to be used to manufacture the product.
2. Pull boxes, vault and covers shall be gray and of the sizes required by the DB Entity's design. Covers shall be provided with stainless steel bolts. The logo shall be permanently recessed in the cover.
3. The installed enclosure shall be rated for a minimum test load of 33,852 lbs., and be suitable for installation in railroad environment.
4. Pull boxes shall be equipped with pulling eyes.
5. Boxes may be stackable to achieve depth indicated on the Contract Documents. All pull boxes shall have a solid bottom.
6. All pull boxes installed at grade level shall be heavy-duty Quazite Style PG boxes, as manufactured by Strongwell, or MBTA accepted equal. Covers for the pull boxes and vaults shall be the heavy duty variety with 2 bolts (Strongwell/Quazite HA00 series for PG style pull boxes or MBTA accepted equal).
7. Imprinted logos shall be provided that properly reflect the respective cables that they house/protect.

D. Pre-Cast Concrete Cable Vaults

1. Pre-cast concrete cable vaults shall have minimum inside dimensions of 36"W x 60"L x 48"D. Cable vaults shall be provided with a base, along with a recessed area for a sump. The DB Entity may provide the pre-cast concrete cable vaults in sections, such as base section, layer 1 section, layer 2 section and cover section, to facilitate installation. Sections shall be properly water proofed to prevent water ingress into the cable vault.
2. Cable vaults shall be provided with pulling eyes on each wall, and located in an area that will not be adversely affected by future conduit penetrations.
3. Pre-cast concrete cable vaults shall be capable of withstanding soil surcharges from a loaded MBTA Green Line Transit Vehicle (100,000 lbs. (total weight), representing a 25,000 axle load). The DB Entity shall submit a pre-cast cable vault that is suitable for these loads.
4. Cable Vaults shall have steel covers with hinges as shown on the Contract Documents. (minimum H20 loading).

2.2 OUTDOOR CABLE TRAY

- A. Cable Tray shall be 304 type stainless steel ladder with 9" rung spacing, have a width of 24" with side rail height of 5". Tray shall be B-Line # 358-SS4-09-24-144 or approved equal.
- B. All cable tray vertical and horizontal offset fittings shall have a minimum 24" radius and also be 304 type stainless steel.
- C. All cable tray support systems and associated hardware shall be stainless steel.

2.3 CONDUIT AND ASSOCIATED MATERIALS

A. Galvanized Rigid Steel (GRS) Conduit

- 1. Galvanized rigid steel conduits (GRS) shall be used where conduits are exposed except as below:
 - a. EXCEPTION: FRE conduit shall be used for all 600V DC circuits.
- 2. Conduit, couplings, elbows, offset and nipples shall be UL approved and meet requirements of ANSI C80.1.
- 3. For conduit trade sizes 2" and below, conduit elbows shall have a minimum 30" radius, all others shall have a minimum radius of 36". Field-made conduit offsets shall conform to the same minimum radius requirements as noted above.
- 4. Provide fittings and accessories as follows:
 - a. Galvanized rigid steel conduit hubs, with gasket and separate nylon insulated throat and a case hardened locknut;
 - b. Nylon insulated metallic type bushing;
 - c. Conduit clamps with back spacers shall be made of galvanized malleable iron;
 - d. Conduit with standard pipe thread, along with coupling and ship with thread protector;
 - e. Compound for field galvanizing repairs shall be Subox, Galvanox or other approved equal.
- 5. All strut type conduit support hardware shall be 304 type stainless steel (Strut, nut, bolts, washers, strut conduit clamps, etc.).
- 6. All other conduit materials/fittings shall be suitable for outdoor use.

B. Fiberglass Reinforced Epoxy (FRE) Conduit

- 1. FRE conduit shall be suitable for direct burial, concrete encasement, suspended from walls or ceilings without regard to outdoor environment.
- 2. FRE Conduit and fittings shall bear nationally accepted testing laboratory approval from C.S.A. (C22.2 No.211.3-M1984) and Underwriters Laboratory (E53373N, 44G7).
- 3. All conduit shall be manufactured to the dimensions and tolerances listed in the ANSI/NEMA Standards Publications TC-14B. The thickness of the wall shall be 0.066" (nominal) for 2" through 4" size conduits and 0.095" (nominal) for 4-1/2" through 6" conduit. The inside dimension shall be full, actual trade size.
- 4. For conduit trade sizes 2" and below, conduit elbows shall have a minimum 30" radius,

all others shall have a minimum radius of 36". Conduits carrying 2000kcmil negative return cables shall have a minimum radius of 48".

5. The conduit shall have a resin surface that shall be impregnated with carbon black for protection against ultraviolet degradation. The conduit shall be marked at least once every 10' with the manufacture's name, size and type of conduit.
6. Use only approved fittings, adhesives and sealants recommended by the conduit manufacturer.
7. FRE Conduit shall contain no halogens above trace amounts and shall be fire resistant to UL94. In addition, conduit for subway (interior) use shall conform to the requirements of MBTA specification no. P-138E while conduit for outdoor use shall conform to MBTA specification no. P-175.

C. Flexible Metallic Conduit

1. Flexible metallic conduit shall be Hydotite type "Saf-T-Flex" as manufactured by Eastern Wire and Conduit, or MBTA accepted equal.
2. All flexible metallic conduit shall have a "Zero Halogen" outer jacket.
3. Outer jacket material shall exceed ASTM 162 surface flammability tests, be ultra violet radiation resistant, water resistant, and resistant to petroleum products.
4. Flexible metallic conduit shall be CSA Certified and UL Approved.

D. Cordura Hose and Fittings

1. Cordura hose shall be provided at locations as required by the DB Entity's design.
2. Orange colored Cordura hose shall be used at locations where carrying 600V DC circuits, such as switch heater cables.
3. Black colored Cordura hose shall be used at all other locations, such as AVI Prefabricated Loop bond locations, etc.
4. Suitable liquid-tight hose fittings and adapters shall be provided to properly install hoses as required.

2.4 STAINLESS STEEL PULL BOXES

- A. NEMA 4X, 12 gauge, 304-type stainless steel pull boxes shall be provided required by the DB Entity's design.
- B. The required dimensions for these pull boxes shall be as required by the DB Entity's design.
- C. At certain pull box locations, hot-dipped galvanized steel supports may be provided. They shall be fabricated in accordance with American Welding Society standards/practices and hot-dipped galvanized in accordance with ASTM-123.

2.5 AERIAL CABLE SUPPORT SYSTEM

- A. Messenger and Guy Wire

1. Messenger and guy wire shall meet ASTM A363-55T. Messenger and guy wire shall be 3/8" Extra High Strength (EHS), 7-strand construction, Type C galvanized. Guys shall be made of the same material as the messenger wire.
 2. Strandwise type dead ends, suitable for 7-strand type wire, shall be installed to dead-end messenger/guy wire. A preformed-type wire fitting may be used at one end of a messenger run in order to terminate messenger or guy wires. Preformed-type wire fittings may be used to splice messenger wire. Acceptable fittings shall be specifically for the size and type application intended and shall not degrade the overall strength or longevity of the wire.
 3. Messenger/cable diameter shall not exceed 4 1/2". Additional messenger runs shall be installed if the overall messenger/cable diameter will exceed 4 1/2".
- B. Aerial cables shall be attached to their respective supporting messengers by cable straps.
1. Cable straps shall be as manufactured by Thomas & Betts # TYD5270M, or approved equal. The overall equivalent diameter of cabling supported on a common messenger shall not exceed 4 1/2". Spacers shall be Thomas & Betts # TCP5255, or approved equal.
 2. Wherever cables depart from or join a messenger system at a junction box, signal case, or other wayside housing drop points, the cables shall be securely fastened and anchored to the messenger with extra cable straps and extra cable straps and spacers to prevent cable from slipping and sagging.
- C. Multi-messenger support brackets and steel support stanchions shall be fabricated in accordance with American Welding Society standards/practices and hot-dipped galvanized in accordance with ASTM-123.
- D. Dimensions for Multi-messenger support brackets shall be determined by the DB Entity's design.
- E. Cable guards shall be provided to prevent cable bundles from rubbing and/or chafing against supports, columns, and/or other similar potential problem areas.
- F. Wooden Poles shall comply with ANSI 05.1, Specification and Dimensions for wood Poles, latest revision for kiln dried Southern Pine, ANSI code SP. Machine or hand trimmed poles are acceptable. All poles shall be Class 2, 35' in length.
- G. All poles shall be treated with a preservative agent meeting cited reference specifications. All treatment methods shall be submitted and are subject to the MBTA's acceptance.
- H. Poles shall be roofed prior to preservative treatment, field cut poles shall be treated by an MBTA accepted process. All unused holes shall be plugged.

2.6 MISCELLANEOUS MATERIALS

- A. All concrete anchoring hardware for securing equipment, conduits, pullboxes and supports shall be 304 type stainless steel and suitable to safely support the intended equipment.
- B. Hilti adhesive anchors, type and size shown on the Contract Documents for particular installation, shall be utilized at locations shown on the Contract Documents.
- C. Drop-in type or quickbolt-type anchors may also be used in areas where concrete is not exposed

to wet/freezing conditions.

PART 3 – EXECUTION

3.1 GENERAL

- A. This Section covers installation of prefabricated cable troughs, conduit and aerial cable support systems.

Each type of cable support system shall be installed as recommended by the manufacturer and as shown on the Contract Documents and the installation drawings as accepted by the MBTA.

- B. All backfill material shall be power tamped and compacted in accordance with the Section 16806, Excavation of these Specifications. Fill material shall be in accordance with these Specifications and with manufacturer's recommendations and shall not be placed on frozen ground.
- C. Trenches shall be kept free of construction debris, rock, or earth. Foreign material shall be removed out of trough, conduit, and raceways prior to placing cables and covers.
- D. The track bed and ballast shall be protected from contamination during excavation, and shall be restored to the existing condition after excavations have been completed. Plastic tarps and plywood shall be used to prevent ballast contamination.
- E. Troughs shall be protected against damage in areas of working cranes, backhoes, front end loaders, or any other heavy equipment, by coverings of wood, steel or other material in a manner as accepted by the MBTA.
- F. Care shall be used to select correct accessories when transitioning from one cable support system to another, such as aerial to conduit risers. The cables shall be properly protected at these transitions and recommended bending radius shall not be compromised.
- G. Manufacturer's recommending installation procedures shall be followed for all materials.

3.2 CABLE TROUGH, PULL BOXES AND CABLE VAULTS

- A. Cable trough, pull boxes and cable vaults shall be installed in accordance with the manufacturers' recommended procedures.
- B. Trenches for cable troughs shall be excavated to provide 12" of free access to both sides of trough. Trench excavations shall be accepted by the MBTA prior to backfilling operations.
- C. Prior to placing the cable troughs in the trench, the trench shall receive a crushed stone base, compacted to a depth of not less than six inches as specified in Section 16806, Excavation, of these Specifications and as per manufacturer's recommended installation procedure.
- D. A transit or other suitable approved instrument or method, shall be used to establish line grade of the trough system. Line grade shall follow the contour of the site.
- E. Assemble multiple trough sections and lower them to the prepared bedding material. Complete

assembly by installing lids. Lids shall be securely in place prior to backfilling of crushed rock.

- F. When forming a 90 degree bend or a “tee” intersection, a handhole shall be installed at the point of bend or “T” intersection if the approved trough manufacture does not have a preformed 90 degree or preformed “T” fitting. The DB Entity is to take care that the minimum bending radius of future cable, as well as the trough’s capacity, will not be compromised as a result of field installed “tee” intersections or other trough layout scenarios.
- G. All exposed trough ends shall be equipped with end plugs of the same material as the trough and sealed as per the manufacturer’s recommendation.
- H. Upon completion of each section of trough, the trench shall be backfilled with 1 1/2 to 2” crushed rock in layers of 4” and compacted between layers. Backfilling shall be done simultaneously on both sides of the duct in successive layers of 4”.
- I. Covers shall be installed and sealed after the MBTA has accepted the cable installation.
- J. Polymer Concrete pull boxes shall be installed no closer than 4’ from the edge of railroad tie, and the top of pull box and/or vault shall not be placed at an elevation below the bottom of railroad tie, without MBTA’s acceptance. The DB Entity shall inform the MBTA immediately of the locations where this 4’ clearance requirement cannot be obtained.

3.3 CONDUIT AND ASSOCIATED MATERIALS

- A. All exposed conduit work shall be run true, plumb, and in straight lines parallel with, or at right angles to buildings, walls, floors, ceilings or structure members and present an orderly, neat and workmanlike appearance. Where a number of conduits are run together, they shall be grouped in a neat and logical manner. Supports for conduit shall be in accordance with NEC, Article 346.
- B. All exposed steel conduit and fittings that have field cut edges, tool marks or other breaks in the finish shall be given a protective coating. Use an electrically conductive anti-seize compound on GRS joints. All GRS conduit terminations shall have metallic insulated bushings.
- C. Conduit bends shall not be flattened by more than five (5) percent of the outside diameter of the conduits. Where required, conduit offsets shall be made. The offsets and bends, where they are installed in parallel, shall be made symmetrical.
- D. Conduit shall be supported immediately on each side of a bend and not more than 18” away from an enclosure.
- E. All cable to be installed in the same conduit shall be pulled and installed simultaneously. Extreme care shall be used during the installation of the cables so as to avoid twisting, kinking, or in any way injuring cable or its sheath.
- F. Conduit shall be cleaned before and after installation. All ends shall be reamed free of burrs and inside surfaces shall be free from imperfections.
- G. Glycerized liquid lubricant or other approved lubricant shall be applied to the cable when installing cables in conduits or ducts.
- H. Where cable enters or leaves conduit, the ends of the conduit shall be fitted with approved

bushings to prevent damage to the cable.

- I. Cables shall not be pulled into conduits until the conduits have been cleaned and swabbed, and free from obstruction.
- J. All underground conduit shall be installed 36” below the top of tie, at a minimum.
- K. Multiple conduits shall be rigidly supported by stainless steel unistrut, with stainless steel conduit clamps. For single conduit installation, hot dipped galvanized conduit straps with back spacers shall be used. All nuts, bolts, concrete anchors, washers, hardware, etc., shall be stainless steel.
- L. After cable installation, conduits shall be sealed with expanding foam or other approved weather sealer.
- M. Spare conduits shall be capped/sealed in an approved manner.
- N. In no case shall deformed, split or defective conduit be installed. All joints shall be made with standard threaded or approved coupling.
- O. Field cuts in conduit shall be square and made with a hand or power band saw. All threads on GRS conduits shall be cut accurately and all burrs shall be removed.
- P. Conduit pull boxes, sized in accordance with the NEC, shall be installed wherever necessary to avoid excessively long pulls or an excessive number of bends.

3.4 AERIAL CABLE SUPPORT SYSTEM

- A. The work shall consist of installing messenger for the support of new cables as shown on the Contract Documents, and not exceed sag or tension values for the specified loading.
- B. The DB Entity shall perform field measurements to ensure that the mounting of the new messenger support hardware and proposed cable bundles does not impact the train’s clearance envelope.
- C. Cables shall be installed within a reasonable time after the strand is installed and tensioned. The DB Entity shall submit tension values for approval, prior to messenger installation. The DB Entity shall record applied messenger tension, temperature and weather at time of installation, for submission to the MBTA.
- D. When tensioning messenger the cable suspension clamps shall be loose enough to allow free movement of the strand.
- E. The DB Entity shall use extreme care to prevent the messenger wire from coming into contact with the third rail or running rails.
- F. All guys shall be installed and tightened before the messengers are tensioned.
- G. Aerial cable shall be supported on a messenger wire by cable straps as necessary.
- H. Recommended hardware shall be used when cable transitions from a messenger wire to a conduit or other cable support system.

- I. Generally, messenger/cable system shall be supported by messenger brackets attached to the subway tunnel wall, or steel support stanchions placed approximately 20' apart.
- J. Cables shall be strapped snug against the messenger with a suitable lay along the span length but shall have sufficient slack to prevent the cable from chafing on the messenger clamps and to permit future access to the cable by others.
- K. Where the cable is pulled around an outside corner, or where it may come into contact with an object not designed for cable installation, it shall be protected by means of a protective mat or pad to eliminate any abrasion to the outer jacket.
- L. Holes for wooden poles shall be of sufficient diameter to permit the pole to settle freely to the bottom of the hole without trimming the butt and still have sufficient space between the pole and the sides of the hole to permit proper tamping of the backfill at every point around the pole, and throughout the entire depth of the hole.
- M. Setting depths for the 35', Class 2 poles shall be 8' minimum. Measurement for the depth of hole shall be from existing ground level, on sloping ground measure from the low side of the pole. Where a steep slope (i.e. >30% grade) is encountered or where soil erosion is a consideration or at the discretion of the MBTA, set the pole one foot deeper to 9'.
- N. The bottom of the hole shall be thoroughly tamped to compact any loose earth prior to setting the pole.
- O. Backfill holes with soil or small rock. Backfill shall be thoroughly tamped to the full depth of the pole hole, in 6" lifts. Ears shall be banked around the pole to a minimum height of 6" above the grade level.
- P. Ground shall be installed at each pole location to ground the messengers. Pole butt grounds or ¾" x 10' copper clad ground rods shall be installed.

3.5 OUTDOOR CABLE TRAYS

- A. The cable tray system and supports shall be installed as shown on the Contract Documents in accordance with NEC Article 392, and so as to be rigid, level, and straight.
- B. Tray supports hardware shall be stainless steel.
- C. Cable tray runs shall be made up of straight sections, bends, dropouts etc. as required. Each run shall be structurally supported to counter the loads due to weight of cables and trays. Cable loads shall be calculated prior to determining the location of tray supports.
- D. Recommended accessories shall be used for horizontal tees, crosses, bends, drop etc. Splice plates shall be used to extend the length of the tray. All tray sections, fittings, connectors, fasteners, and bolts shall be installed so that there will be no sharp burrs to damage cables.
- E. The cable tray shall be supported at intervals not exceeding 5', except where shown otherwise on the Contract Documents. Each end of the tray run shall be supported.
- F. Raceway grounding shall be assured by installing copper ground conductor sized in accordance with NEC table 250-122, properly attached to the cable tray in the manner recommended by the tray manufacturer and as required by NEC Article 250.

END OF SECTION

SECTION 16829

INSULATED JOINTS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The work to be done under this Section consists of the manufacture, inspection, factory testing, delivery and installation of bonded insulated joint plug rails in welded rail. The work also includes thermite field welds.
- B. The work to install and field weld all insulated joint plug rails required in this Contract shall be performed by a qualified and approved track installation subcontractor.
- C. Insulated joints shall be installed at all locations as required by the DB Entity's design.
- D. Additional insulated joints may be required for track circuit polarity management in order to keep polarities staggered at each insulated joint, it shall be the DB Entity's responsibility for the design, furnishing, and installation of any additional insulated joints and transposition wires required.

1.2 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements", the DB Entity shall submit the following to the MBTA for acceptance:

- A. Calibration certificates for all testing equipment used to perform the tests specified herein;
- B. The proposed method of packaging, handling and loading all track appurtenances and other track material for approval;
- C. Working drawings showing the proposed method and equipment for handling and installing bonded insulated joint plug rails, and conventional plug rails showing locations of field cuts in existing track, and locations of field welds in CWR, and length of rails, for review and acceptance prior to the commencement of work;
- D. Prior to the initiation of thermite welding, submit detailed specifications showing the proposed quick preheat thermite kit, method and procedure for thermite welding. The specifications shall comply with these Specifications and that of the weld kit manufacturer, and shall include the name of the weld kit manufacturer and details of the following operations:
 - 1. Rail preparation;
 - 2. Rail end spacing, tolerances, and procedure to maintain rail gap during the welding operation including the type of hydraulic rail puller and profile rail grinder;
 - 3. Rail alignment, including the type of alignment beam system;
 - 4. Placing and securing of prepared molds;

5. Preheating of rail, including method, temperature, and time;
 6. Crucible tapping procedures, including duration of weld and cooling time;
 7. Trimming and grinding of weld.
- E. Submit a complete and current record of all field welds showing the following for each weld:
1. Location by station, track designation and rail;
 2. Date and time;
 3. Rail weight and section, mill brand, year rolled, heat number;
 4. Name of manufacturer of field weld kit used;
 5. Air temperature, rail temperature and approximate weather conditions;
 6. Rail gap to nearest 1/16 “;
 7. Track alignment and construction (curve, tangent, grade, etc.);
 8. Name of Engineer or authorized representative present;
 9. Name of DB Entity's foreman present.
- F. Submit for approval procedures for adjustment of CWR and rail anchoring prior to commencing work.
1. Also, provide a site specific record of work on a daily basis which shall include the following:
 2. Location by engineering station, track designation, and rail;
 3. Date and time;
 4. Air temperature, rail temperature and weather conditions;
 5. Rail gap at time of anchoring to nearest 1/16”;
 6. Adjustment applied (type and movement).
- G. Submit the following for review and approval by the MBTA:
1. Ample thermite field welds and their certified qualification test and inspection results;
 2. Supervisor and field welder's qualification certifications for each welder who will perform work on this Contract. Weld supervision and all welders shall be required, upon request of the MBTA, to submit their qualifications during the duration of the project;
 3. Certification that persons who shall perform ultrasonic testing of field welds have previously tested a minimum of 250 welds;
 4. Certified ultrasonic inspection results for all field welds;
 5. Design of bonded insulated joint plug rails.

1.3 QUALITY CONTROL

H. General

1. Perform all field weld hand testing and inspection at no additional cost to the Contract.
2. All field weld hand testing and inspection shall be performed by an approved certified independent testing laboratory. The MBTA may audit the operations to ensure that the inspection and test are being performed in accordance with approved procedures and in compliance with these Specifications.
3. To be accepted, all rail, welds, and track must fulfill all the requirements of these Specifications.

I. Field Weld Qualification Inspection and Testing

1. Prior to field welding, the welds, and each welding crew shall be qualified as specified below. Welding crews shall prepare, in accordance with the methods and procedures for thermite field welding submitted and approved under Article 1.2 of this Section, at least three samples of each type of thermite weld; heat treated rail welded to heat treated rail, heat treated rail welded to control cooled rail, and control cooled rail welded to control cooled rail. Each welding crew shall perform at least one of each type of the sample welds. The sample welds shall join two pieces of rail a minimum of 30" in length each.
2. Test three sample welds from each type of rail, if required by the MBTA, as follows:
 - a. Perform the Rolling Load Test as specified in Article 1.3.2 of this Section on one sample weld from each type of rail.
 - b. Perform the Slow Bend Test specified in Article 1.3.2 of this Section on a second sample weld from each type of rail.
 - c. Perform the Hardness Test specified in Article 1.3.2 of this Section on a third sample weld from each type of rail.
3. Rolling Load Test
4. Test one sample weld from each type of rail on a 12" stroke rolling load machine.
5. Welds tested under this Article shall sustain without failure not less than 2 million cycles of repeated loadings of a 44,000 pound wheel load.
6. Slow Bend Test
 - a. Subject a second sample weld from each type of rail to the Slow Bend Test described in the Proceedings of the AREA, Volume 68.
 - b. The acceptance criteria for this test shall be a minimum deflection of 1" and 100,000 pounds per square inch modulus of rupture.
7. Hardness Test
 - a. Longitudinally cross-section a third sample weld of each type of rail for a distance of one foot each side of the weld, micro-etch and test by the Brinell Hardness Testing method using a 150 kgf diamond sphero-conical penetrator.
 - b. Test the rail for hardness on the sectioned face at points on a grid pattern of 1/8" increments for one inch on each side of the centerline of the weld, and on a grid pattern of 1/2" increments beyond until the hardness readings coincide with the hardness of the

parent rail metal.

- c. Inspect the micro-etched section for compliance with field weld requirements of full penetration, complete fusion and internal defects specified herein.
 - d. The weld materials and the rail one foot away from the weld shall have Brinell hardness numbers between 248 and 280.
8. Approval of the weld kit, welding process, and welding crews will depend upon all sample welds satisfying the specified requirements. Should any sample weld fail to satisfy the specified requirements, the welding process, the welding crew, or both, will not be qualified for the work.
 9. Employ a supervisor and welders for each welding crew, trained and certified for the performance of thermite field welds by the manufacturer supplying the weld kits. Should any supervisor of the welding crew be replaced during the work the welding crew shall be re-qualified under the new supervisor. Welding supervision or the welders shall be required to show proof of certification as requested by the MBTA.
 10. Prior to performing welds in specified work, satisfactorily qualify the welds and welding crew as specified herein.

J. Field Weld "In-Track" Testing

1. During field welding, the DB Entity shall hand test and inspect all field welds as specified herein to ensure compliance of all field welds daily to the requirements of these Specifications.
2. Each field weld shall have full penetration and complete fusion with no evidence of surface or internal fissures, cracks, porosity or slag type defects.
3. Ultrasonic Testing
4. Inspect all field welds ultrasonically and daily in accordance with the recommendations of the Nov. 29-30 1983 Proceedings of Association of American Railroads (now AREMA) entitled "Railroad Rail Welding" pages 191-205. Weld quality shall meet the requirements of Article 3.4 of this Section.
5. Identify each ultrasonic test including the engineering station and track and rail identity. Submit a letter of identification with each test to the Engineer, giving comments on any irregularities found in the weld, whether the weld passes or fails the above recommendations and the requirements of Article 3.4 of this Section.
6. Physical Inspection - Visually and dimensionally, inspect each field weld daily to determine conformance with the alignment and finishing tolerances specified herein.
7. Defective Welds - Any defective welds detected by the above testing and inspection shall be removed by saw cutting in a new rail not less than 19'-6" in length and installing two thermite welds. All corrective procedures, as above, for the removal of defective welds shall be at the DB Entity's expense.

K. Tolerances - After insertion of bonded insulated joint plug rails, the final established gauge, cross level, super-elevation and vertical and horizontal alignment for the affected track shall be within the following tolerances:

1. The deviation from zero cross level at any point on tangent or from designated elevation on

- curves between spirals may not be more than 1/8",
2. The variation in cross level on spirals in any 31' shall not be more than 1/8",
 3. The difference in cross level between any two points less than 62' apart on tangents and curves between spirals may not be more than 1/8",
 4. The deviation from designated elevation on spirals may not be more than 1/8",
 5. The deviation from uniform profile on either rail at the mid-ordinate of a 62' chord may not be more than 1/4",
 6. The variation of track gauge shall not exceed plus or minus 1/16" unless otherwise directed by the MBTA.

L. Factory Qualification Tests - Bonded Insulated Joints - Plug Rails

1. Electrical Resistance Test - A rail joint shall be assembled in accordance with manufacturer's recommendations and supported on non-conducting material. With 500V DC applied to the rail across the bonded insulated joint for a duration of three minutes, the current flow through the joint should be measured to the nearest 0.01 micro ampere. The minimum acceptance resistance for the test shall be 10 megohms. With 50V AC applied to the rail across the bonded insulated joint for a duration of three minutes, the impedance shall be measured with an accuracy of plus or minus 2%. This test shall be repeated three times, once with a frequency in the range from 20Hz to 100Hz, again with a frequency in the range from 200Hz to 1000Hz and again in the range from 2000Hz to 10KHz. The minimum acceptable impedance for any of these tests shall be 10,000 ohms.
2. Rolling Load Test - The rail joint used in the Electrical Resistance Test shall be mounted on a 33" stroke rolling load test machine supported on 36" centers with the joint centered between the supports. Apply a 44,400 pound wheel load on the rail for 2,000,000 cycles and measure and record to the nearest 0.001 in. the deflection of the rail at the centerline of the joint. The deflection at the ends of the joint shall also be measured at every 500,000 cycles. The wheel path shall travel from a point 6 in. from the center of the joint to a point 9 in. outside the opposite end of the joint. Total range of deflection of the joint shall not exceed 0.065" during the test and the joint shall show no evidence of failure by bending. The electrical resistance test shall then be repeated and the test results shall be within the acceptance criteria specified.
3. Longitudinal Compression Test - The assembled joint shall be sawn in half where the rails are joined together in a manner which will prevent overheating and damage to the epoxy bond. The cut shall be perpendicular to the centerline of the top of rail.
4. A fixture or device shall be used so that the reaction at the sawn ends occurs only on the face of the joint bars when a load is applied to the centroid of the rail at the opposite end. The load shall be applied in increments of 25,000 pounds, maintaining each load increment until the deflection of the rail stops before increasing the load. The load shall be increased to 650,000 pounds and a record of loading and differential movement of the rail measure to 0.00" shall be measured for each increment. The joint shall show no indication of slippage prior to reaching a compressive load of 650,000 pounds and the movement shall be less than 1/8" in any direction. The relative position of the rail and joint bar shall be within 1/32" of its original value when the load is removed.
5. The DB Entity shall submit certification and test results that an insulated joint has passed the qualification testing specified herein.

1.4 RAIL

- A. Shipping. - Load rail and bonded insulated joint plug rails only into rail cars or specially equipped vehicles which are in good order.
- B. Handling - Handle rail, bonded insulated joint plug rails and other track material in a manner that will not damage the material in any way.

PART 2 - PRODUCTS

2.1 MATERIAL

- A. New control cooled carbon steel rail in 78' or longer lengths, shall be furnished in sufficient quantity for the completion of work as indicated.
- B. The materials shall be loaded, transported, unloaded and distributed by the DB Entity.
- C. Furnish quick preheat thermite weld kits.
- D. Furnish bonded insulated joint-plug rails, as follows:
 - 1. Provide bonded insulated joints shop fabricated into plug rails for installation into CWR. Plug rails shall be 39'-0" in length.
 - 2. All rail furnished for plug rails shall be fully heat treated.
 - 3. The joint bars shall be 36", full face contact design.
 - 4. Material. Fabricate joint bars from quenched carbon steel conforming to AREMA Manual for Railway Engineering, Chapter 4, Specification for Quenched Carbon-Steel Joint Bars.
- E. Configuration. Provide full-face contact joint bars conforming to the configuration of the rail, as required. Joint bars shall be smooth and straight. The inside face of the joint bars shall have insulating material pre-bonded, and be smooth with no branding or stamping.
- F. Fabrication Tolerances
 - 1. Finishing Height. Within plus or minus 1/64" of the dimension shown on the approved shop drawings.
 - 2. Straightness. All portions of the joint bars adjacent to the rail shall be straight within a tolerance of plus or minus 1/32", measured with a 36-inch straight edge.
 - 3. Length. Within plus or minus 1/8" of the dimension shown on the approved shop drawings.
- G. Insulating Material
 - 1. All insulating materials shall be of high pressure, laminated design, impervious to oil, grease and water, and shall have electrical resistance characteristics equal to or greater than fiber

insulation meeting the requirements of the AREMA Manual for Railway Engineering Chapter 4 Section 3.8, Specifications for Bonded Insulation Rail Joints. End posts shall project 1/4", plus or minus 1/16" below base of rail and shall be 3/16" thick.

2. Bonded insulated joint to be cemented together with adhesive and bolted together with six high strength, 1" diameter bolts. Provide bolts, nuts and flat washers conforming to the chemical and mechanical requirements of ASTM Designation A490, Quenched and Tempered Alloy Steel Bolts for Structural Steel Joints, and having Class 2A and 2B thread fit. Provide a positive means for maintaining the tension in the bolts through in-service vibrations by a prevailing lock nut complying with Industrial Fastener Institute Standard IFI-100 and IFI-101, or approved equivalent. Locate and size the bolt holes in conformance to the drilling as specified in AREMA Specifications. Flat washers, if required, shall be hardened A-325 or A-490 and tempered carbon steel.

- H. Provide new Pandrol Modified "e" clips for all insulated joints.

PART 3 – EXECUTION

3.1 INSTALLATION OF BONDED INSULATED JOINT PLUG RAILS

- A. The DB Entity shall install bonded insulated joint plug rails at the required locations within CWR territory.
- B. Bonded insulated joints shall be installed as suspended joints and existing crossties shall be re-spaced as necessary to achieve this requirement.
- C. Joints created by installation of the insulated joint plug rails shall be field welded by an approved thermite process.
- D. Bonded insulated joints at resilient fasteners shall be secured with the modified "e" clips.
- E. Rail removed for the installation of the insulated joint plug rails shall be salvaged as specified in this Section.

3.2 REMOVAL OF BONDED EXISTING INSULATED JOINT PLUG RAILS

- A. The DB Entity shall remove existing insulated joint plug rails and install standard rail at required locations within CWR.
- B. Removal of an existing insulated joint plug rail shall be accomplished by cutting the plug rail with a rail saw or an abrasive cutting disk only, 1'- 6" inside both existing thermite welds, which shall result in the proper salvage of a 36' long bonded insulated joint plug rail.
- C. The installation of standard running rail shall be accomplished by cutting out the existing thermite welds with a rail saw or an abrasive cutting disk only, 1'- 6" outside both existing thermite welds and installing a 42' minimum length of rail which shall be field welded in track by an approved thermite process.
- D. Bonded insulated joint plug rails removed from track shall be salvaged as specified.

3.3 ADJUSTMENT OF CONTINUOUS WELDED RAIL

A. Rail Temperature

1. Determine rail temperature by an AREMA standard rail thermometer as specified in the current AREMA Manual for Railway Engineering, Chapter 5, Plan Number 34-71.
 - a. Determine the temperature of the rail by placing the rail thermometer on the shaded side of the rail base next to the web and leaving it there for not less than five minutes and until no change in its reading is detected.
 - b. Record rail temperature readings of CWR at the time of rail laying.

B. Adjustment of CWR

1. The DB Entity shall obtain records from the MBTA of the installation temperature of CWR at locations where CWR is to be cut.
2. When the rail is cut and the rail temperature is less than the rail temperature when originally installed or if the records are not available, the CWR must be adjusted for thermal expansion.
3. Adjustment of CWR shall include removal of rail anchors for 1/4 mile in both directions of cut and expanding rail by either natural or applied heat to obtain zero thermal stress. The MBTA shall approve any methods for obtaining zero thermal stress.
4. Before allowing rail to expand, an appropriate length of rail shall be removed to allow for expansion. This rail end gap (G) shall be determined by the formula:

$$G = (t-T) LK$$

where:

G = Rail end gap in inches

t = Zero Thermal Stress temperature (95°Fahrenheit)

T = Rail temperature in degrees Fahrenheit

L = Length in feet of rail to be expanded

K = Coefficient of thermal expansion for steel rail = 0.000078

5. Any alternate method for allowing rail to expand shall be submitted to the MBTA for review and approval.
6. After rail is thermally expanded, weld rail ends, re-apply anchors immediately, recording new adjusted temperature on form to be forwarded to the Authority. Such form shall identify:
 - a. Location of cut by mile post to the nearest tenth.
 - b. Location of cut by rail as N.S.E. or W.
 - c. Temperature of rail before cutting.
 - d. Temperature of adjusted rail.
 - e. Air temperature.
 - f. Length of rail expanded in either direction.
7. Once thermally expanded, joints in CWR shall be field welded immediately.

C. Rail Anchoring Temperature

1. The DB Entity shall anchor rail when the temperature is within the zero thermal stress temperature range. When zero thermal stress temperature is obtained, begin anchoring immediately. Rail temperature shall remain within the specified zero thermal stress range until the rail is fully anchored. If the rail temperature deviates from the specified zero thermal stress range, cease anchoring until the rail temperature returns to within the specified range.
2. When rail temperature is below the zero thermal stress temperature range, an approved rail heating device may be used for expanding the CWR to make proper adjustment.
3. During anchoring, it is important to ensure uniform expansion. To control this, mark the quarterpoint of strings on a rail and tie plate so the amount of expansion can be accurately determined then make sure the rail expands as follows:
 - 1/4 Point - 1/4 of Required Expansion
 - 1/2 Point - 1/2 of Required Expansion
 - 3/4 Point - 3/4 of Required Expansion
 - a. In the event the first half of the heated CWR string does not have the required expansion at each quarter point, when heating artificially back the heater over the heated portion, without applying heat and then reheat the rail until the necessary expansion is obtained.
 - b. The rail shall be fully clipped immediately behind the heater and must be clipped while the rail is within the zero thermal stress temperature range.
4. The temperature of a rail, when being clipped opposite an anchored rail, shall be within plus or minus five degrees Fahrenheit of the temperature of the anchored rail when the anchored rail was anchored.
5. Record the rail temperature and related information during the rail anchoring process. Record the rail temperature every 30 minutes during the anchoring process at the anchoring location.

D. Zero Thermal Stress

1. The DB Entity shall install, anchor, join, and field weld CWR to produce zero thermal stress in the rail at 90 degrees Fahrenheit, to 110 degrees Fahrenheit.
2. Zero thermal stress may be achieved by heating. Rail pulling shall not be allowed. All methods for artificially obtaining zero thermal stress must be acceptable to the MBTA. Take care to prevent any damage to trackwork components during any heating process. If any damage occurs, make repairs at no additional costs to the Authority.
3. Vibrate rail during thermal adjustment to relieve internal rail stresses. Continue vibration during the full period of rail length correction. Mechanical vibrators used for relieving internal rail stress shall be of a type acceptable to the MBTA and shall not damage the CWR. Continuous welded rail shall be vibrated whether installed at ambient temperature or distressed artificially.

3.4 THERMITE FIELD WELDING

A. General

1. The DB Entity shall join strings of CWR laid in tracks together by the thermite welding process except where insulated joints, are located.
2. Field welds shall not be located within the following area unless approved, or directed, by the MBTA:
 - a. Within ten feet of a field weld in the opposite rail;
 - b. Within 18' of a field weld in the same rail;
 - c. Within 18' from the center of any bolted joint;
 - d. Within 3' of a shop weld;
 - e. Within 10' of a bridge deck;
 - f. Within 20' of a highway crossing;
 - g. On a tie plate.

B. Weld Quality - Each field weld shall have full penetration and complete fusion with no evidence of surface or internal fissures, cracks, porosity or slag type defects.

C. Welding Requirements

1. The DB Entity shall use approved weld kits that are self-tapping, and require minimum preheating.
2. Rail ends shall be saw cut at right angles to the rail. The DB Entity shall clean the surface of the rail for a length of approximately six inches from each end, free of all grease, dirt, loose oxide, scale and moisture. All burrs and lipped metal that would interfere with the proper fit of the molds shall be removed. Torch cutting of rails is prohibited.
3. Prior to field welding strings of CWR, the DB Entity shall adjust the length of the CWR strings for zero thermal stress temperature, vibrate the rail to relieve internal rail stresses, and fully anchor the rail.
4. At the time of field welding, the rails shall be aligned to produce a weld which, with respect to alignment, shall be in accordance with current ARMEA Specifications for Fabrication of Continuous Welded Rail modified to require a slight crown in the running surface to assure a flat surface after the weld has cooled. The maximum vertical offset permissible is 0.015" using a 36" straightedge. The maximum horizontal offset in the rail head using a 36" straightedge is 0.060". The maximum combined vertical offset and crown camber determined using a 36" straightedge shall not exceed 0.060".
 - a. Negative camber or dip shall not be permitted.
 - b. The proper rail end alignment shall be achieved by the use of an approved alignment device designed and manufactured for this purpose. In no case will the use of track jacks or track spikes be allowed for rail end alignment.

D. At the time of field welding the rail gap shall be as specified by the manufacturer of the weld kit.

If the rail gap is not within the recommended tolerances for field welding, the DB Entity shall un-anchor the CWR strings for 300' each side of the rail gap and readjust each CWR string for 300' within the specified zero thermal stress range. The DB Entity shall re-anchor the CWR before performing a field weld. Should the rail gap on anchored CWR be larger than the manufacturer's recommended gap after the CWR strings have been readjusted for zero thermal stress, the DB Entity shall saw a length of rail from one end of one of the anchored CWR's and insert a rail not less than 19' long to provide the manufacturer's recommended gap for field welding. At locations where the rail gap is smaller than the manufacturer's recommended gap, the recommended gap shall be obtained by sawing a piece from the rail.

1. Thermite field welding is prohibited when the rail temperature is below 32 F., measured on the shady side of the rail.
 2. When the rail temperature is between 32 F. and 50 F., a hydraulic rail puller, designed and manufactured for this purpose, must be used to maintain proper rail end gap. The puller shall be left in place until the rail has cooled to below 700 F. Any movement of the rail before the weld has cooled to at least 700 F. will result in the weld failing. It is important that the weld is not subjected to a sudden strain by releasing the hydraulic pressure too quickly.
 3. The hydraulic rail puller shall not be used to establish the proper rail end gap.
- E. The DB Entity shall trim and grind weld to meet the following requirements and as otherwise specified by the manufacturer:
1. Finish the top and sides of the weld at the rail head to within plus 0.005" or minus inch of the parent section.
 2. If the field weld is located within three inches of the edge of a rail support finish the weld at the rail base to within plus 0.01" or minus 0.00" of the parent section.
 3. Finish the web zone and the remainder of the rail weld to within plus 0.375" or minus inch of the parent section. Finish grind the weld to eliminate visible cracks.
 4. Eliminate notches created by offset conditions by grinding to blend the variations. Remove all protrusions or gouges in the welded area and blend the weld area into the rail contour by grinding in a manner which will eliminate fatigue crack origins. The DB Entity shall remove, by grinding, all defects visible to the unaided eye, except if removal by grinding cannot be accomplished without damaging the rail, the DB Entity shall remove the weld. The DB Entity shall take precautions to avoid excessive pressure during grinding of the weld in order to prevent overheating of the rail surface.
 5. The DB Entity shall complete all heavy grinding after the weld has reached the ambient rail temperature, or as recommended by the manufacturer. Removal of the weld upset by the use of a saw or other such device is prohibited.
 6. Finish rail grinding shall be completed prior to the operation of trains over the weld. Finish grinding of the weld shall be accomplished with an approved rail profile grinder. The use of hand held grinders is prohibited.
 7. Thermite field welds shall be made in accordance with, and shall not deviate from, the manufacturer's recommendations and AREMA Chapter 4. Short cuts in the recommended preheating process are prohibited.
 - a. Welding during inclement weather such as rain, mist, snow, etc. is prohibited.

3.5 TRACK ALIGNMENT AND GAUGE

- A. The installation of plug rails shall not disturb existing vertical, horizontal track alignment, or track gauge. Should the DB Entity alter or disturb track alignment or gauge while conducting the work the track shall be repaired to the required Authority tolerances at no additional cost to the Authority.

3.6 SALVAGE

- A. The DB Entity shall recover all bonded insulated joint plug rails and conventional lengths of rail removed from track. This material shall be properly loaded, transported, unloaded and neatly stockpiled at a location to be determined by the MBTA.

3.7 TRACK USAGE

- A. No work under this Section shall be performed without proper authorization from the MBTA.

END OF SECTION

SECTION 16830

RUNNING RAIL BONDING FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the provision of all necessary material and labor to bond the running rails for optimum performance of the negative return system and (signal) track circuits.
- B. Typical running rail bonding details for rail connections, track cross bonding and signal bonding connections shall be as stated herein and as shown on the Contract Documents.

1.2 QUALITY ASSURANCE

- A. Material, equipment and systems procured for this Contract shall be produced under control of a formal Quality Assurance Program to ensure an acceptable level of quality of the equipment provided. Comply with the provisions of Volume 1 DB Contract Terms and Conditions Section 4 "Quality Control and Quality Assurance" and Volume 2 Technical Provisions Subsection 2.5 "Quality Management". Furnish certificates of compliance for Quality Assurance Programs as requested by the MBTA.
- B. The DB Entity shall install and test each welded bond and mechanical connector in accordance with the requirements of this Section and other sections of these Specifications.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements", submit catalog cuts and descriptive literature for the following:

- A. Material composition, electrical and mechanical characteristics for power bonds, signal bonds, and track circuit split bolt connectors,
- B. Field installation procedures for welded signal and power bonds,
- C. Field test procedures for welded signal and power bonds,
- D. All devices for securing and protecting running rail bonding,
- E. Plan showing detailed final design for bonding to assure that all impedance bonds, crossbonding and signal bonds are properly connected electrically.

PART 2 – PRODUCTS

2.1 MATERIALS

- A. Provide bonding materials and track circuit connectors, as manufactured by Stanley Brazing

Systems, Dwight and Wilson Co., United States Steel, or approved equal. Provide bonds and materials manufactured for welding by the exothermic process. The MBTA shall approve all bonds, bonding, materials and types of molds. The type of bonding required shall be selected for the correct application as follows:

1. Power Bonds

- a. Installing impedance bond and crossbond connections to the running rail shall be made with two-500 kcmil extra flexible cables as shown on the Contract Documents.
- b. Provide power bonds for frog and switch fouling connections and expansion joints of 2-500 kcmil extra flexible cables.
- c. Provide 500 kcmil extra flexible cable for frog and switch jumpers, and end of storage track crossbonds where required for welding to the base of the rail as accepted by the MBTA.
- d. Where bond-to-bond or bond-to-return cable (splice) application is required, use of 1000 kcmil cables and mechanical connectors is acceptable, as accepted by the MBTA.

2. Guardrail Bonds and Signal Rail Bonds

Provide guardrail bonds and signal bonds for signal rail sections using rail-head type manufactured for welding application. The bonds shall be 7/32" x 6 1/2" and of required length.

- B. Furnish welding material consisting of copper exothermic mixture employing tin-metal in an amount to effectively constitute 4-1/2 percent to 5-1/2 percent of resulting weld metal. Resulting weld metal shall be of high electrical conductivity with minimum tensile strength of 39,000 pounds per square inch. Determine tensile strength by performing tensile tests on 1/2" nominal diameter tensile specimens (without flaws) cast in graphite molds.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Crossbonding shall be installed at locations as required by the DB Entity's design. All components of the trackwork shall be bonded in accordance with the approved plans in order to establish electrical continuity and conductive capacity for proper operation of traction power return system and signal system track circuits.
- B. For all rail-joint bonds, impedance bond connections to the running rails, the surfaces of the rails where the bond is to be applied, shall be ground clean with a reinforced grinding wheel, of a type as recommended by the bonding material manufacturer. The use of vitrified grinding wheels will not be allowed. After grinding, the surface shall be cleaned with an approved non-toxic solvent to remove all traces of grease and dirt.
- C. After the surface has been ground and cleaned, the surface shall be heated to drive out any moisture. The cable bond shall then be welded by the approved exothermic process in such a manner as to ensure a thorough mechanical and electrical connection.
- D. The casting of the test specimens shall be by the direct reduction of the exothermic mixture and the flowing of the weld metal into a graphite mold to form the one-half (1/2)" diameter specimens.
- E. At the DB Entity's expense and before beginning work on these bonds, the DB Entity shall

require each welder to weld in the field under conditions similar to those of the regular installation, not less than three complete rail connections, and as many more as the MBTA considers necessary to determine that the welds are being made satisfactorily. Such welds shall be subject to inspection and test by the MBTA, and his approval as to method and quality of workmanship will depend on the results of these inspections and tests.

- F. It is of great importance that each rail connection be thoroughly welded to the rail. To reduce the possibility of any of these welds breaking in service, the MBTA reserves the right to require a test of each weld by hammer and striker, or in any other manner which in the opinion of the MBTA is reasonable.
- G. No cable larger than 500 kcmil shall be weld connected to the rail without acceptance of the MBTA.

3.2 TESTS

- A. The DB Entity shall demonstrate that the bonding is in accordance with the requirements of this Section, those as shown on the Contract Documents, and as specified in AREMA C&S Manual, Section 8, Track Circuits.
- B. Bonds, welds, or connections installed by the DB Entity which are found to be defective prior to acceptance, shall be removed and a new bond shall be installed as part of the work.

END OF SECTION

SECTION 16835

SIGNAL AND UTILITY POWER SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies providing equipment, installation, wiring and testing for signal and house utility power for the new Green Line central instrument houses (CIHs) on the GLX. CIH signal power is required for supplying 120V AC isolated (ungrounded) power to signal equipment. House power is required for CIH air conditioning (AC), lighting, receptacles and other CIH auxiliary equipment.
- B. Work to be performed under this Section consists of supplying, installing and testing at both the factory and in the field the following major electrical components in each CIH:
 - 1. Non-fused disconnect switches;
 - 2. Automatic transfer switches (ATS);
 - 3. Panelboards;
 - 4. Isolation transformers;
 - 5. General purpose transformers;
 - 6. Fused disconnect switches;
 - 7. Contactors;
 - 8. Air conditioning system disconnect switches
 - 9. Conduit, wire and miscellaneous devices required for installation and connection of CIH power equipment.
- C. Utility power at each CIH shall consist of a 480V, three phase four wire grounded feed from the station transformer to a 480V to 240/120V single phase transformer located in the CIH. One fused disconnect switch shall terminate the 240/120V single phase, four wire incoming CIH feeder cables.
- D. Signal power at each CIH shall consist of dual 480V single phase two wire ungrounded feed from two separate signal power substation transformers. Each 480V source shall have a separate 480V to 240/120V transformer located in the CIH. The signal power shall come into the CIH as a 240/120V three wire ungrounded system.

1.2 QUALITY ASSURANCE

- A. The DB Entity shall comply with the requirements of all national, state and local codes, laws and ordinances, and all rules and regulations of public administrative authorities having jurisdiction over the work.
- B. Workmanship shall conform to the best modern practices for a rugged, long-lived, safe installation required for a public transportation system. Materials to be installed shall be new and

of the highest industrial grade as specified, designed and configured to operate in an atmosphere containing conductive metallic particulates (rail dust).

- C. All equipment specified in this Section shall be capable of operating at 125% of equipment rating.

1.3 COORDINATION STUDY

The DB Entity shall perform a coordination study for all electrical equipment provided under this Specification Section to ensure proper protection and coordination of upstream and downstream devices; the coordination study shall be included in Article 1.4.1 below. Electrical ratings and settings of the proposed equipment shall be selected to ensure coordinated operation under both normal and worst case conditions.

1.4 SUBMITTALS

- A. Within 180 days from the Notice-to-Proceed, the DB Entity shall submit load calculations based on the total peak and continuous demand signal system loads (VA) that will exist at each CIH 120V bus, and total auxiliary CIR loads (KVA). The calculations shall also include the normal and worst case conditions assumed in the load determination.
- B. Prior to the procurement or manufacture of distribution equipment, the DB Entity shall submit the following for review and approval.
 - 1. Schematic diagram of the proposed system, showing equipment and protective device ratings and wire and cable types and sizes.
 - 2. Catalog cuts, shop drawings, or other descriptive information for the wire and cable, disconnect switches, power transformers, circuit breakers, switchboards, panelboards, conduit, fuses, and miscellaneous hardware. Information shall include electrical ratings, protective device coordination curves and recommended settings, physical dimensions, and manufacturer's recommended installation instructions.
 - 3. Equipment layout plans showing the proposed location of the electrical equipment and cable routings between equipment locations.
 - 4. Switchboard panel layout diagrams showing the proposed arrangement and labeling of circuit breakers and disconnect switches for CIH 240/120V utility power and 240/120V signal power equipment.
- C. The DB Entity shall submit, 60 days prior to factory testing, a Factory Test Procedure for testing of the factory installed CIH/CIR power equipment specified in this Section (field installed power equipment will require field testing based on an accepted procedure and schedule). This shall include:
 - 1. Procedure of testing.
 - 2. Equipment tested.
 - 3. Description of test.
 - 4. Test results and conclusions. (To be added to test report at conclusion of testing)
- D. Provide complete "As-Built" drawings, prior to MBTA acceptance, including full-line and schematic

diagrams and point-to-point wiring drawings for all electrical equipment, which reflect the status of the equipment up to and including final factory acceptance testing.

PART 2 - PRODUCTS

2.1 CIH EQUIPMENT FINISH

- A. All electrical CIH equipment specified herein shall be finished as follows:
1. All metalwork shall be carefully finished to remove sharp edges and burrs.
 2. All surfaces shall be cleaned and treated with rust inhibiting phosphatized coating prior to painting, then finished with two coats of semi-gloss ANSI-61 light gray paint, unless otherwise specified.

2.2 AUTOMATIC TRANSFER SWITCHES

- A. Automatic transfer switches are required in each CIH and shall be two pole, double throw, with fully rated overlapping neutral transfer contacts, having the following ratings:
1. Rated voltage: 240V
 2. Rated continuous current: 100A
 3. Number of phases: 1 phase – 3wire
 4. Rated frequency: 60 Hz
 5. Transfer time, maximum: 0.2 Sec.
- B. The available fault supply at the automatic transfer switch terminals shall be taken as 10,000A with system X/R ratio of four.
- C. The specified current ratings of the transfer switch shall be for continuous duty when enclosed in an unventilated sheet metal enclosure and applied for all classes of loads, including UL-1008 classifications. The ratings shall not be affected by cumulative operations (6000 cycles minimum) over the entire life of the transfer switch.
- D. Operation Requirements
1. Automatic transfer switch shall be mechanically held, electrically operated by a single solenoid or motor-driven stored energy type, with quick make, quick break mechanism. Mechanical interlocks shall be provided to insure that the load cannot remain simultaneously disconnected from or connected to both the normal and standby supplies when either or both supplies are available. The mechanism and interlocking system shall be designed to prevent transfer in either direction in the event of welding of one or more contacts in the power circuits. The interlock circuit wiring shall be factory connected and located entirely within the transfer switch enclosure. All parts of the mechanical interlock shall be electrically dead. Molded plastic parts shall not be used as part of the operating linkage between the electrical operator and the main operating shaft of the switch.

2. A manual operator shall be provided to transfer the switch to either position with the same contact-to-contact operating speed as the electrical operator. The manual operator shall be so located with respect to other components that it is accessible without subjecting the operator to a shock or an accident hazard. Means shall be provided to prevent automatic operation during the manual transfer.

E. Following mode of operation shall be provided:

1. The voltage of the "normal" supply shall be monitored continuously so that when it drops to 85 percent of rated, or lower, for a preset period of time between 1 to 10 seconds, the switch shall automatically transfer the load to the "stand-by" source, provided that the voltage of the "stand-by" source is 90 percent of rated or higher.
2. Upon restoration of "normal" source voltage to 95 percent of rated, the switch shall automatically re-transfer the load to the normal supply after a preset time delay of 3 to 30 minutes. If the "stand-by" source should fail while carrying the load, retransfer to the "normal" source shall be made instantaneously upon restoration of the "normal" source.
3. A selector switch shall be provided for selecting either of the two supply circuits as the "normal" source. The circuits of the green and red indicating lights and the two auxiliary contacts for remote indication shall be interlocked with the source selector switch so that their functions will correspond with the source selection. The selector switch shall be provided with two nameplates to indicate the supply source that has been selected as the "normal" source.

F. Enclosure

1. The transfer switch and all control components shall be assembled in a sheet steel NEMA Type 1 enclosure, suitable for wall mounting.
2. A full height, full access door, shall be provided in front of the enclosure. Door shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be of heavy duty, of a type accepted by the MBTA. Door shall be securely fastened in the closed position with a minimum of two latches easily opened without the use of tools. Door shall be provided with stop to hold it securely in the open position.

G. All surfaces of the enclosure shall be finished in accordance with Section 09900 - PAINTING.

H. Transfer Switch Assembly

1. All current carrying components of transfer switch shall be fabricated of high conductivity copper or copper alloy designed to carry the specified rated current continuously without exceeding the hottest-spot temperature rise of 65 degrees C above a building ambient of 40 degrees C.
2. Switch contacts shall be silver alloy or silver plated. Contacts shall be individually adjustable and located for convenient examination and maintenance. Arc barriers shall be provided to protect the operator in the event of an inadvertent operation of the switch under load.

I. Sensing and control relays shall be industrial type, rated for continuous duty, having accurate response, positive contact pressure and wiping action. Contact shall be rated 10A, minimum.

- J. All switch and relay contacts, coils, springs and control elements shall be replaceable parts as individual units, accessible from the front without removing the switch panel from the enclosure or disconnecting operating linkage or power conductors.
- K. Control and terminal blocks shall be provided. No. 16 AWG wiring will be acceptable for low-voltage, low-energy circuits.
- L. Wiring associated with the interlock circuit shall be protected from possible damage during any servicing of the switch.
- M. Circuits requiring external connections shall be factory-wired to terminal blocks for connection to field wiring entering from the top. Sufficient number of terminals to satisfy all external connection requirements and 20 percent additional unassigned terminals shall be provided.
- N. Control circuit shall be designed to operate on 120V, 60Hz.
- O. Accessories furnished shall include, but not be limited to, the following:
 - 1. One test switch mounted on the door of enclosure to simulate normal source failure.
 - 2. One pushbutton to bypass time delay on re-transfer to normal source,
 - 3. One selector switch on the door of enclosure for selection of "normal" source,
 - 4. One selector switch on the door of enclosure to permit or block automatic re-transfer,
 - 5. One green pilot light to indicate switch in "normal" position,
 - 6. One red pilot light to indicate switch in "stand-by" position,
 - 7. Two pilot lights to indicate the source which has been selected as "normal",
 - 8. Time delay relay with an adjustable time delay adjustable between 1.5 and 15 seconds, connected to the output circuit, for sensing loss of voltage, with two contacts (one N.C. and one N.O.) wired to external terminal block for remote alarm. Contacts shall be rated for 125V DC,
 - 9. Two auxiliary relays that monitor the presence of CIH feeder voltage shall be supplied. They shall have auxiliary contact(s), rated 125V DC, to close when the load is transferred from "normal" to "stand-by" position, wired to external wiring terminal block for remote indication,
 - 10. Time delay relay, adjustable between 1 and 10 seconds, for the transfer circuit,
 - 11. Time delay relay, adjustable between 3 and 30 minutes, for the retransfer circuit,
 - 12. Transfer control voltage relays, set for 95 and 90 percent pickup and 85 percent dropout,
 - 13. Handle to facilitate manual transfer to either position,
 - 14. Wiring diagram. Diagram shall be laminated in plastic and fastened to the inside of the door,
 - 15. Nameplates, identifying each control device, switch and indicating light,
 - 16. Power circuit and ground terminations.
 - 17. Source terminals and load terminals of Device 83A, automatic selective/ control transfer relay, shall each be furnished with heavy duty bolted type terminal lugs, one copper cable per phase and neutral. Terminal lugs shall be sized to fit the appropriate size cable as indicated on the Contract Documents.

2.3 TRANSFORMERS

A. CIH 480V to 120/240V Isolation Transformers

1. Insulation: resin-encapsulated dry-type, UL 220 Degree C. class.
2. Electrical Ratings
 - a. Primary Voltage: 240V line-to-line
 - b. Secondary Voltage: 120V line-to-line, ungrounded
 - c. No. of Phases: 1
 - d. No. of Wires: 2
 - e. Continuous Load: as determined by the load calculations
 - f. Frequency: 60Hz
 - g. Temperature Rise: 80 Deg. Cover 40 Deg. C ambient
 - h. Insulation Rating: 220 Deg. C operating temperature
 - i. Impedance: Manufacturer's standard impedance
3. Windings all copper.
4. Core Steel: Grain-oriented high grade electrical steel.
5. Load Taps: 4 taps, $\pm 2\frac{1}{2}\%$, and $\pm 5\%$.
6. Provide wall-mount, indoor, non-ventilated NEMA Type 4 enclosure.
7. Provide electrostatic shield between primary and secondary windings.
8. Design, manufacture, and test in accordance with the following standards:
 - a. NEMA ST 20, Requirements for Dry-Type Transformers for General Applications.
 - b. UL 506 and 1561.
9. Warrantee: free from defects in material and workmanship for a period of five (5) years from the in-service date.
10. Acceptable Manufacturers
 - a. ACME Electric Corp.
 - b. Square D.
 - c. Siemens Energy & Automation.
 - d. or Approved Equal.
11. The 480V to 120/240V isolation transformers shall be indoor rated and mounted on the wall inside the CIH.

B. General Purpose Transformers

1. Furnish, install, and connect single phase power transformers as required by the DB Entity's design. Transformers shall conform to NEMA, IEEE and ANSI Standards and shall be UL

listed. Transformers shall be suitable for continuous operation and rated kVA, 24 hours a day, 365 days a year with normal life expectancy as defined in IEEE Standards.

2. Transformers shall be non-ventilated dry type for outdoor installation. Transformers shall be pad mounted type with rigid drip-proof and rodent-proof enclosure. Provision for lifting shall be provided so as to facilitate handling and installation without removal of enclosure components.
3. Winding insulation shall be class H rated for minimum end temperature of 220 degrees C. Average winding temperature rise by resistance from continuous operation at full load shall not exceed 150 degrees C at maximum ambient temperature of 40 degrees C.
4. High voltage windings shall be of copper, single phase, 60Hz, 480V nominal. High voltage winding insulation class shall be 1.2kV, minimum.
5. Low voltage winding shall be of cooper, single phase, 60Hz, 240/120V nominal, for 3-phase, 4-wire service. Low voltage insulation class shall be 1.2kV, minimum.
6. Six 2-1/2% no load capacity taps shall be provided in the high voltage winding, two above and four below the rated primary voltage.
7. Terminal boards shall be made of strong fiberglass with terminals clearly marked for identification. Terminals and wiring compartment shall be completely front accessible.
8. Terminations and wiring compartment shall be arranged to facilitate entry and connection of primary and secondary cables.

2.4 LOAD DISTRIBUTION PANELBOARDS

- A. Furnish, install and connect panelboards for distributing 240/120V single phase, four wire CIH service supplies as required by the DB Entity's design.
- B. Panelboards shall be factory assembled, distributed type, to supply CIH loads as shown on the accepted drawings. Panelboards shall be dead front type with bolt-on molded case circuit breakers, sized, as a minimum, for the quantity and rating of main and branch circuit breakers shown on the accepted drawings.
- C. Panelboard interiors shall consist of a steel backplate structure holding the bus, terminal, and neutral assemblies. The backplate shall be removable and shall be adjusted in depth unless the assembly of the panelboard is specifically designed to ensure proper depth positioning of the panel interior without adjustment. All spaces shall be fully bussed and equipped requiring no modification for the addition of future breakers. Unused spaces shall be covered to preclude accidental access to the bus. All bus bars and bus connections to breakers shall be sequence phased, such that all poles of multi-pole breakers shall be connected to different phase legs regardless of location in the panelboard.
- D. Bus shall be copper, silver plated, braced to withstand a short circuit equal to the largest short circuit capacity of any breaker installed in the panel. Bus bar cross-section shall be uniform and contact surface area shall be based on tests similar structures. Panel shall be equipped with insulated neutral and uninsulated ground bar.
- E. Panelboards shall have main and branch circuit breakers of molded case bolt-on type, having trip ratings shown on the accepted drawings, and subject to the MBTA's acceptance. Multi-pole circuit breakers shall have common trip arrangement. Trip elements shall be thermal-magnetic

type. Single pole circuit breakers shall be rated 240V. The minimum interrupting rating of the circuit breakers 10,000A, rms symmetrical, on 240V for panelboards. Circuit breakers shall be quick make, quick break, manually operated, ambient compensated provided with trip free mechanism and trip indication.

- F. Circuit breakers shall be UL listed and shall conform to NEMA Standard Publication No. AB1.
- G. Panelboard shall be furnished with NEMA type 1 general purpose surface mounting cabinet. Cabinet shall be of a gauge not less than that specified by applicable UL Standards. Wiring gutters shall conform to the requirements of the National Electrical Code and the applicable UL Standards, but in no case shall be less than six inches. Box shall be furnished with single size knockouts of sizes required or may be field drilled. Spare knockouts or combination knockouts will be acceptable.
- H. Panelboard front trim and door shall be of gauge not less than specified by the applicable UL standard and shall be cold rolled or other suitable steel with concealed hinges, concealed trim clamps, flush catch and lock with two keys. A typewritten directory with plastic covering shall be installed on the interior of the door.
- I. Terminal lugs shall be suitable for terminating the quantity and size of cable shown on the accepted drawings.
- J. Detachable threaded hubs shall be provided for terminating the incoming and outgoing conduits at the panel.

2.5 600V CLASS DISCONNECT SWITCHES

- A. Furnished disconnect switches shall be 600V class, three-pole, single throw, quick-make, quick-break, suitable for heavy-duty application. Ampere ratings shall be as required by the DB Entity's design.
- B. Switches mounted inside substations or CIHs shall be housed in grounded steel NEMA Type 12 enclosures. Switches utilized for the ungrounded signal power distribution system and mounted outside substations or CIHs shall be housed in fiberglass NEMA Type 4X enclosures.
- C. Provide provision for padlocking in the "off" position.
- D. Provide two normally open and two normally closed Form C contacts per switch, operated from the switch mechanism.

2.6 NAMEPLATES

Furnish and install nameplates for all devices, including those integrally-mounted. Nameplates shall be of black laminated plastic composition bearing permanent; white-engraved lettering, with beveled edges and fastened to panels by means of round-head screws.

2.7 INSTRUMENT AND CONTROL SWITCHES

All instrument and selector switches shall be of the rotary type, heavy-duty, rear-connected for semi-flush mounting, rated for not less than 20A at 600V.

2.8 INDICATING LAMPS

All indicating light lamps assemblies shall be of the low drain switchboard type with integrally mounted resistor that is compatible with the circuit voltage involved.

2.9 SWITCHBOARD METERS

Furnished meters shall be analog voltmeters and ammeters, 250-degree scale, rear-connected, 4.5 in. long switchboard type.

PART 3 - EXECUTION

A. General

1. This DB Entity shall formulate overall factory test program for all new CIH equipment identified in this Section. The factory test program shall include tests that ensure equipment compliance with relevant standards, this Specification and reliable performance of the intended operation. This factory test program shall be submitted to the MBTA 60 days prior to testing.
2. Factory tests shall include but not be limited to:
 - a. Tests as listed in this Specification.
 - b. Tests per relevant NEMA, IEEE, NETA and ANSI Standards.
 - c. Any other tests to ensure satisfactory performance of equipment.

B. Each item of electrical equipment shall be subjected to the manufacturer's routine factory tests and other tests as specified below. The factory test equipment, test methods and procedures shall conform to all applicable standards.

C. The signal and auxiliary power distribution systems installed in CIHs shall be factory tested for continuity, isolation, grounding, and proper operation and conform to all applicable standards.

D. Conditions for Tests

1. The DB Entity prepared test procedure has been accepted by the MBTA.
2. The DB Entity shall assume full responsibility during the field testing of all supplied equipment and installation provided. Should there be any loss or damage to such equipment as result of these tests, the DB Entity shall be fully responsible for replacing the damaged equipment.
3. When a piece of equipment or a component failed to withstand tests or meet specified test values, that equipment or the component shall be replaced at no cost to the MBTA.
4. New equipment or component that has replaced the damaged or failed equipment shall be subjected to same requirements of tests as those of the similar existing equipment or the failed equipment.
5. Test reports shall be submitted as described in the Submittal section of this Specification.

END OF SECTION

SECTION 16838

CENTRAL INSTRUMENT HOUSES FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the requirements for procurement and fabrication of factory-wired Central Instrument Houses (CIH).
- B. CIHs shall be provided with all vital and non-vital circuitry, equipment and components required to comprise a safe and reliable signal system and shall also include a local control panel and maintainer's panel.
- C. The CIHs shall be provided with an approved means of event recording to record status changes for both vital and non-vital functions at each location.
- D. The size of the CIH shall be determined by the DB Entity as being adequate to house all equipment and provide spare space as described within these Specifications. Each CIH shall be a minimum ten (10)' in width.
- E. Within the CIH, a separate room shall be provided at one end, for access to the local control panel. A locked door shall be provided between this local control room separating it from the signal equipment area of the CIH.
- F. Work to be done under this Section shall also include the preparation of "as-built" detail drawings for the CIH, the rack arrangements, panel arrangements, and equipment arrangement.
- G. The DB Entity shall be responsible for arranging transport of the CIHs from the manufacturer's factory to their final field sites along the right-of-way. Prior to transport, the DB Entity shall prepare each site for CIH installation by providing foundations including cable vaults, cable routing systems and electrical power service, etc.
- H. Upon delivery the DB Entity shall commence with CIH field installation. Field installation shall include, but not be limited to, termination of the wayside cables on the entrance rack(s), connection of local electrical power, final hook-up for HVAC, communications and fire alarm systems, and interconnection with other locations.
- I. The CIH's shall be mounted on foundation piers as shown on the Contract Documents. The DB Entity shall submit, for approval, a method for installing a skirt around the base of the CIHs.
- J. HVAC units are to be provided with an automatic thermostat feature to maintain an ambient room temperature between 60°F and 70°F.
- K. The DB Entity shall make a site survey and confirm the adequacy of the proposed CIH locations and submit a report to the MBTA noting concurrence or any discrepancy. The DB Entity shall also assess and report on the means and methods for transporting the CIH to its final location. Based on the results of the site survey, including the transportation assessment, the MBTA may require that the DB Entity perform a "clearance survey" to determine that placement of the CIH structure along the right-of-way shall not infringe on the dynamic clearance envelope of Green Line car equipment.

1.2 QUALITY ASSURANCE

- A. All equipment and materials provided shall conform to the requirements of Volume 1 DB Contract Terms and Conditions Section 4 “Quality Control and Quality Assurance” and Volume 2 Technical Provisions Subsection 2.5 “Quality Management” and other applicable references as stated within this Specification.
- B. Factory test of the CIH for the functioning of the equipment contained within the house shall be conducted in accordance with the DB Entity's Factory Test Procedure as accepted by the MBTA. The DB Entity shall inspect the CIH as part of the test procedure and correct any deficiencies.
- C. All electrical components, unless otherwise specified herein, shall be rated to operate at power, voltage, current and temperature levels 25% above that level which the components will be subject to in normal service.
- D. The DB Entity shall inspect the CIH after it has been installed and correct any deficiencies. This inspection shall be conducted in conformance with the requirements of the DB Entity's Installation Inspection Procedure as accepted by the MBTA.
- E. FM-200 chemical agent suppression system shall be included within each CIH and comply with the guidelines contained in the National Fire Protection Agency (NFPA) Standard 2001.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”, the DB Entity shall submit the following for approval prior to the manufacture and assembly of the CIH:
 - 1. Catalog cuts and descriptive literature for all CIH equipment and material as specified herein and as shown on the Contract Documents;
 - 2. Drawings showing the construction details, proposed size, layout, grounding arrangement and detailed bills of material for the CIH;
 - 3. Drawings of the relay, instrument and entrance racks showing the arrangement and description of the mounted equipment and the proposed method of inter- and intra-rack wiring. These shall also include the numbering system used for identifying the rack and components by coordinates;
 - 4. Drawings showing the location, size and mounting arrangement of each maintainer and/or local control panel, plan file/rack and plan table;
 - 5. Drawings showing the local control panel and maintainer's panel screen configurations, including types of icons, plug couplers, terminals and workstation components that the DB Entity proposes to furnish. These drawings shall show how the panel aligns with respect to the actual track configuration;
 - 6. Drawings and descriptive information, including manuals, of the HVAC, fire detection, fire extinguishing and the intrusion detection systems proposed;
 - 7. Calculations for the sizing of the HVAC equipment for each location;
 - 8. Drawings of the cable entrance provisions, final arrangement of apparatus and details of wire/cable raceways and entry to and through the CIH;

9. Drawings showing the size, battery & tray arrangement, wiring details;
 10. Drawings showing the desktop cabinet housing the control panel.
- B. Factory Test and Inspection Procedure(s) for the CIHs shall be submitted in a timely manner, sufficient to accommodate the approved CPM (schedule) and all other time requirements referenced herein.
 - C. A Field Test and Inspection Procedure for each CIH shall be submitted not later than six weeks prior to scheduled cut-over.
 - D. Within 180 days of Notice-to-Proceed the DB Entity shall provide a plan for the installation of the CIH(s) along the right-of-way. The plan shall include the means of delivering and transporting the CIHs. The DB Entity shall utilize a template the size of which is determined by the actual size of the CIH to determine if the housing can be installed without fouling the track or other equipment.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Conform to the requirements of Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM for delivery, storage & handling. All equipment shipped within the CIHs shall be properly fastened and braced to prevent damage during transit.
- B. It shall be the DB Entity's responsibility to replace any material or equipment damaged, lost or stolen at no additional cost to the Contract.
- C. Relays and printed circuit boards shall be removed from their receptacles following acceptance of factory testing and prior to CIH shipping. Relays and other equipment, as designated by the MBTA, shall be re- packaged in an approved manner for separate shipment to the designated storage site at a designated time.
- D. The DB Entity shall be responsible for coordination of delivery routes and provision of an acceptable storage site to accept delivery. The DB Entity shall obtain all necessary permits required for transport and delivery.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All equipment and materials provided shall conform to the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM and other applicable references as stated within this Specification.
- B. All equipment described in this Section shall be painted in accordance with the requirements of Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM and other applicable sections of these Specifications.
 1. Terminal, apparatus boards and shelves shall be painted with fire retardant gray, ANSI 61 or approved equal.
 2. The manufacturer is to apply approved corrosion resistant under coatings to metal parts of the CIHs.

3. The battery trays shall be painted with two coats of an approved acid resistant black paint.
- C. All equipment, materials and components shall be new and free of manufacturing defects.
- D. The CIHs shall be dust-tight and insulated to provide maximum heating and cooling system efficiency.
- E. The testing plan for all systems and equipment contained within the CIH shall be in accordance with the requirements of Section 16898 –SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

2.2 MATERIALS

- A. Central Instrument House Design and Fabrication
 1. CIHs shall be of modular construction of 12 gauge sheet steel, unless otherwise accepted by the MBTA.
 - a. The house shall comply with the applicable Standards of ASTM E-84 for exterior walls. The interior paneling shall comply with a flame spread of 0-25 in accordance with ASTM E-84.
 - b. Top, floors and sides shall be lined with fire resistant insulating material with a minimum insulation value of R-19 complying with a flame spread of 0-25 and a fire rating of 7 in accordance with ASTM E-84.
 - c. The interior walls shall be paneled. Roof and side ventilation openings shall be provided, if required, for the size of the CIHs.
 - d. CIHs shall be constructed to provide access for underground and aerial cable knock-out entrances to the main terminal rack.
 - e. The free floor space shall be covered with vinyl tile, 12" by 12" squares or as accepted by the MBTA.
 - f. Hoist bars shall be provided to facilitate the movement of the CIH.
 - g. Removable covers shall be provided inside the CIH to provide access to the foundation bolts.
 - h. CIH design drawings shall be stamped by a registered professional engineer.
 2. As shown on the Contract Documents, there shall be two rooms in the CIH. The larger area shall accommodate the signal equipment, and a smaller area shall house the local control panel. An inner door shall separate the signal equipment area from the vestibule and an outside lockable access door shall be provided for each area.
 - a. The interior common wall(s) and door shall be constructed to allow total room ventilation with a single, common HVAC system. Provide the interior door with a lock arranged for access from the signal equipment side only.
 - b. CIHs shall be equipped with two doors as shown on the Contract Documents. The doors of the CIHs shall be hinged and gasketed to provide a dust-proof and airtight seal. Doors shall be provided with cast iron handles, welded to a three-point locking device that shall ensure the door cannot be locked until it is in the fully closed position. Doors shall be provided with a two-position retaining device to secure the door when open. Door mechanism shall allow the door to be opened from the inside even if the padlock is

applied to the outside of the door mechanism.

- c. Hinges shall be separate castings welded to the housing and door. The hinges shall be equipped with bronze hinge pins and shall be lubricated by the manufacturer before the house is shipped.
3. The local control panel area shall be equipped with a desk/console for the operator's use while operating the panel and with an adjustable swivel chair on rollers of correct height to operate panel. The area shall also have 3 wall mounted coat hooks.
4. Overhead cable trays as shall be provided and factory installed for all intra-rack and inter-room wiring.
5. The size of the CIHs shall be sufficient in capacity to house all the equipment required by this Contract. Spacing between instrument racks shall be as indicated in the guidelines, as shown on the Contract Documents, and according to the accepted layout drawings.

B. Cable Entrance Facilities and Utilities

1. Cable entrance knockouts in the floor and the upper walls shall be provided for full flexibility in arrangement of entrance racks such that cables entering shall not require undue bending for proper termination.
2. A dedicated cable entrance knockout or sleeve access shall be provided for the signal power line cable.

C. Fire Alarms and Suppression System

1. Fire alarms and suppression system shall be furnished and installed in the CIH and shall be composed of the following principal components:
 - a. The system shall be a total flooding FM-200 chemical agent extinguishing system designed to provide early warning detection and automatic release of FM-200 providing a uniform concentration of 8% in 10 seconds in the area. The design shall take into consideration such factors as enclosure openings (if any) "run-down" time of fans, time required for dampers to close and requirements for any additional dampers and any other feature of the facility that could affect concentration.
 - b. The system shall be activated by cross-zoned or dual-loop system of ionization, photo-electric or a combination of ionization and photo-electric products of combustion smoke detectors. Automatic operation in each separate protected area shall be as follows:
 - 1) Activation of one detector in either zone or loop shall:
 - a) Illuminate the respective zone circuit lamp in the control panel;
 - b) Energize the pre-alarm audible device associated with the area;
 - c) Transmit a signal to the control center as shown on the Contract Documents;
 - d) Light an individual lamp on the alarm annunciators;
 - e) Activate external horn and light unit.
 - 2) Activation of a second detector in the same area, but on the second zone or loop shall:
 - a) Illuminate the respective zone circuit lamp in the control panel;

- b) Activate and release the FM-200;
 - c) Energize the FM-200 discharge visual indicating light;
 - d) Shut-down the air conditioning system, fans, and close all dampers;
 - e) Shut-down ac power equipment within the protected areas.
- c. The system shall transmit a health indication to the control center to indicate system trouble status.
- d. The system shall be capable of being activated manually, discharging the FM-200 which shall cause alarm and shutdown devices to operate the same as if the system had operated automatically. Manual discharge devices shall be provided at each protected area.
- e. The system shall include emergency power backup. Upon loss of power supplying the control unit, the system shall automatically transfer to stand-by battery power supplied by the control unit for a minimum of 24 hours.

D. Control Panel

1. Control panel shall consist of a zone non-coded system, manual and automatic, fully supervised, U.L. listed, local and auxiliary type as described herein. It shall contain an automatic type battery charger capable of recharging the batteries within 14 hours. All switches and controls shall be provided inside a locked cabinet with windows on the hinged door to view visual displays. Cabinet shall be of 14 gauge steel, painted red, with pin and tumbler type lock, provided with 6 sets of keys. Locks shall be keyed the same on all panels. Control shall include the proper number of initiating circuits, indicating circuits, relay control circuits, supervisory circuits and power supplied as required. All end of line devices shall be located in control panel, Class A preferred.

To prevent the panel from inadvertently being left in silence condition, the trouble signal and indicating signal silence switch shall be of the self-restoring type that cannot be left in an abnormal position. The Control panel shall have adequate 4-wire Class A wiring detecting circuits and zones including two spare zones. Systems that cannot receive an alarm from all detectors even though there is a single-fault condition in the detection loop, shall not be acceptable. Power for all ionization detectors shall be provided by the detection 4-wire Class A wiring. Systems that power detectors from power source separate from the detector circuit with Class A wiring shall monitor the power source and independent wiring to each zone so "true" trouble and alarm by zone is achieved for reliability and ease of maintenance.

The control panel shall have a trouble and an alarm lamp for each detection circuit. Systems that have a common trouble lamp only, or rely on a combination of indicators that require operator interpretation to determine if there is an alarm or trouble, or which zone has given an alarm condition, shall not be acceptable.

120V AC primary power shall be monitored and a power-on lamp shall be provided. Upon power outage the system shall light a power trouble condition lamp and automatically change to standby batteries. The control panel shall also monitor the batteries and upon a low battery condition, light the low battery trouble lamp and indicate a trouble condition. Fire system ground detection shall be provided for the alarm system. Upon ground detection, the

ground detection lamp shall light and a trouble signal indicated. The DB Entity shall provide a lamp test switch to test all alarm lamps on the control panel.

All alarms shall lock-in until both the initiating device has been restored to normal and the system control unit is reset. Alarm may be silenced, but subsequent alarms from another zone shall cause the signals to re-sound. When system is restored and horn silenced, a system trouble signal shall be indicated. Any fault on the system that would prevent the transmission of an alarm signal shall cause the trouble signal to operate. The audible trouble signal may be silenced by operating a momentary silencing switch, but the visual trouble signal shall remain lighted. After the fault has been corrected, the trouble circuit shall automatically restore to normal. All remote trouble indicating devices shall operate identically, including the self-restoring feature. Faults on any zone shall cause an individual zone trouble indicator to light. Control unit shall include a momentary lamp test switch which shall light all visible indicators in the control unit when operated. The system shall indicate trouble when horns are silenced and alarm circuits are in non-alarm condition.

2. The control unit shall be a solid-state modular assembly mounted on channels facilitating easy removal for repair and ease of expansion.

Zone Module shall have four zones of supervised initiating circuits with a trouble alarm lamp for each zone. Detection circuit wiring shall be 4-wire Class A and shall power all ionization detectors. A common trouble and common alarm relay output and voltage output shall be provided.

Control Module shall supply the necessary power for the control panel and all detectors and shall contain a battery charger to charge the batteries. An AC power-on lamp shall be provided to indicate the normal condition of the panel. Individual supervisory lamps shall be provided for AC power failure and indication, ground fault detection, municipal-trip disconnect and low battery. All controls shall be behind a key-locked door to prevent unauthorized operation. The enclosure shall be surface mounted with module termination drawings mounted on the inside of the panel cover.

Accessory Relay Module shall provide the necessary relays or devices for functions such as releasing door holders, remote annunciation, closing hampers, shut down fans, etc. All relays shall be of high quality fitted with dust tight plastic covers and plug-in basis, UL listed and rated for a minimum of 5A at 115V AC.

3. Detectors and Initiating Devices

Fire Detectors - The photoelectric fire detector shall operate on the photoelectric principle. It shall have a response sensitivity of 1.2% per foot or will alarm when the smoke in the chamber reaches the fixed sensitivity setting of 1.5%. The detector sensitivity shall be expressed in percent per foot of light obscuration caused by smoke. Each detector shall also have a visual indicator to indicate its initiation of an alarm. The detector shall be calibrated and adjusted for sensitivity at the manufacturer's factory to known standards. The detector shall have a LED (Light Emitting Diode) light source and operate on the multiple cell concept. LED intensity shall be controlled by a regulating photocell circuit matched to the smoke detection circuit, or use a light source and photocell arranged such that smoke particles which have entered the chamber shall be illuminated and the scattered light from

such particles reach the photocell and generate a voltage which is amplified, causing the ignition of the cold cathode tube to initiate the alarm. The detector shall be UL listed as an automatic smoke and fire detector for open area protection.

Ionization Detectors - The ionization detectors shall be activated by products of combustion. They shall have a sensitivity of not less than the minimum required by Underwriters' Laboratories, Inc. and shall be listed and approved by Underwriters' Laboratories. Further, the ionization detectors shall not be subject to alarm as the result of rapid changes of humidity nor shall they contain material which will require licensing by the Nuclear Regulatory Commission for this application.

4. Alarm Indicating Devices

a. FM-200 Release Indicating Light

Above the entrance door to the room or bungalow, the DB Entity shall furnish and install on the outside wall, an indicator light. Upon release of any FM-200, the indicator light shall flash to warn that FM-200 has been released. This warning light shall remain activated until turned off manually.

b. Alarm Horn

The alarm horn shall indicate the detection of smoke or heat. This same alarm horn shall be sounded in the event of an intrusion detection.

The horn shall operate from a timer capable of being adjusted from 1/2 minute to 20 minutes.

Alarm horns shall be suitable for indoor or outdoor application with the appropriate 4x4 in. electrical box. All horns shall be 24V DC polarized. The minimum sound level shall be 95dB at 10'. Horns shall be semi-flush or flush mounted. Single and dual projectors are to be supplied.

c. Combination Horn and Light

Audio-visual alarm devices may be combination horn/lamp units with built-in alarm flasher. Lamp bulbs shall be replaceable only from the rear, shall be vibration proof mounted, and shall be protected by a red lens. Units shall be red with legend "FM-200 Discharge" in white letters on both sides of the lens. Audio-visual devices can have trumpet horn projectors and shall be compatible with existing system. Outside flashing light shall be weatherproof, and shall have a cast aluminum housing with a red polycarbonate lens.

Contact closures shall be provided for: indication of alarms to the control and indication panel, future remote control, and indication to the DB Entity supplied alarm panel for MBTA's Operations Control Center.

5. Electromagnetic Door Holders and Damper Closers

Door and damper holders when required, shall be of the electromagnetic type to hold the door or damper open, and automatically release the door or damper upon alarm condition by the interruption of the holding current from the fire alarm control unit or approved pressure operated released by the FM-200 discharge. The holder shall consist of a wall or floor mounted unit with electromagnetic assembly and cover plate and a swivel door mounted armature or

other approved assembly.

6. FM-200 Supply

- a. Each protected area shall have its own separate supply of FM-200, and shall be a total-flooding, high pressure system which shall conform to all applicable sections of NFPA Standard 2001.
- b. Each supply shall be located within the hazard area or as near to it as possible so that a minimum of distribution piping is used.
- c. Each system shall be single-hazard, one-bank, or multi-bank system capable of being electrically triggered by the fire detection and alarm system or manually triggered as defined below.
- d. The FM-200 shall be stored in cylinders of high strength alloy steel construction that complies with the Department of Transportation regulation type 4BW500 or 4BA500. Each cylinder shall also have a pressure gauge and pressure switch to facilitate visual and electrical supervision of the container pressure.
- e. Cylinders shall be shipped fully charged with FM-200, superpressurized with nitrogen to 360 pounds per square inch. The filling weight of the internal material shall be consistent with the required discharge rate and the volume of the protected location. All cylinders shall be permanently marked to identify the pressurization, the internal chemical composition by weight, and the serial number. When a multiplicity of cylinders is required to provide the proper protection, all cylinders shall be identical. The capacity of the cylinder bank shall be so chosen that, upon release, the area to be protected shall be flooded to achieve a concentration of six percent in ten seconds or less.
- f. The cylinders shall be installed on a level hard surface in a dry location. The DB Entity shall install rugged supports designed to maintain the cylinder securely upright with approved clamps or straps. An electrical interlock shall be provided which shall indicate the cylinder is properly seated in place and is capable of discharging its contents. When there is any impediment which will prevent the cylinder from discharging its contents, the condition shall indicate at the Control Center as being a trouble in the fire detection and alarm system.
- g. Cylinders shall be located such, that they may be easily removed for recharging or replacing without special tools or handling devices, also they shall not interfere with existing or any future equipment, general maintenance, or operations of the signal or communication equipment.
- h. Each system shall be discharged when triggered from either the electrical command from the Smoke/Fire Detection System or the manually operated actuator assembly. A solenoid valve shall be employed to initiate discharge of the system electrically and shall contain interlocking contacts to indicate when the actuator has operated.
- i. A pressure operated vertical flood valve shall be attached to the cylinder neck. A quick release discharge head shall be mounted on the vertical flood valve. The FM-200 shall be discharged through nozzles. The nozzles shall be sized and located to provide the rates of discharge and the coverage required to assure a minimum concentration by volume of 8% in 10 seconds or less. Nozzles shall be fabricated of corrosion resistance materials.
- j. An abort switch shall be provided in the protected area. By operating this switch, the discharge mechanism shall be disabled and the audible trouble alarm shall sound. This trouble alarm shall continue until the abort, or disconnect switch is returned to normal.

This trouble indication shall appear on the system control unit.

- k. To detect the flow of FM-200, a three pole, double throw toggle type pressure-operated switch shall be used to indicate that FM-200 has been discharged. This switch shall be manually reset.
7. Piping - The manifold and discharge piping shall be fabricated of galvanized steel pipe and fitting or shall be welded and then plated with corrosion-resistant metal.
 - a. Discharge piping 4" and smaller shall be Schedule 40; if piping larger than 4" is used, it shall be Schedule 80. Galvanized steel pipe shall meet the requirements of ASTM A-53 and A-120. Pipe fittings shall be galvanized and shall meet the requirements of ASTM A-197, A-445, or A-234 and shall have a minimum bursting pressure of 6000 psi.
 - b. Any piping through building walls, partitions, floor slabs, roof slabs, etc. shall be run through sleeves of Schedule 40 pipe at least two sizes larger than the pipe being run and not smaller than one inch. Sleeves shall be packed with oakum and asphaltum, or equal, so as to be dust tight. Sleeves through floor slabs shall extend at least two inches above the floor. Sleeves through roof slabs shall extend above the roof 6 to 10" and shall be flashed in accordance with local building requirements.
 - c. Pipe supports and parts shall be of steel. Conduit, beam and "C" clamps shall not be used. Piping shall be anchored to rigid members, such as walls, ceilings and columns, to prevent longitudinal or lateral sway. Nozzle piping shall be well braced. Hangers and supports shall be of rugged design and shall be installed so that they will not be loosened by movement of the supported pipe. "U"-bolts with double nuts shall be used where appropriate. Pipe supports shall be installed to avoid interference with other piping, conduit structure, and equipment. Pipe lines shall not be supported from other piping lines.
 - d. Control tubing under continuous pressure shall be 3/8" soft copper with 0.065" wall. Forged steel compression fittings shall be used in sections under continuous pressure. SAE flare fittings shall be used on sections not under continuous pressure. Tubing shall be formed with a copper tubing bender. Tubing ends shall be cut square and reamed. Tubing shall be assembled with true alignment to the center line of fittings without distortion or tension. Tubing shall be supported with straps or brackets to prevent sagging.
 8. Instructions - The system shall include permanent type name-plates and condensed instruction plates to identify the system and instruct in its use under emergency conditions. Six copies of operating and maintenance instructions shall be provided.
- E. Vandal Protection and Security - An intrusion alarm shall be installed at each entrance to protect against unauthorized entrance to the CIH. A pushbutton reset or switch mounted within an instrument rack, location to be accepted by MBTA, shall be provided for re-setting of the alarm. The intrusion alarm shall be provided with contact closures which shall indicate at the local control panels and the MBTA's Operations Control Center.
 - F. Equipment Racks
 1. Channel racks as specified in Section 16853 – Instrument Racks shall be the

manufacturer's standard for the type equipment furnished and accommodate standard 19" mounting for equipment. Equipment racks shall include all necessary supports for wire and equipment.

2. The CIHs shall contain spare equipment racks or space on racks to accommodate 20% expansion.
3. Racks shall be oriented as shown on the Contract Documents.

G. Relays, Modules and Component Mounting

1. Relays and mounting shall be as specified in Section 16858 - Relays. The top and bottom relay rack rows shall not be utilized for this Contract and shall not be considered as available "spare" space. Relay mounting bars shall be provided for these rows.
2. In laying out the racks, panels and other equipment within the Central Instrument House, the DB Entity shall utilize the layout as shown on the Contract Documents, grouping the rows of racks and the instruments thereon so that similar types of equipment or functions of a similar nature are together.
3. Relay Plugboards shall be designed for insertion of removable type contacts. The method of attaching the wires to the removable contacts shall be a solderless connection. Unless otherwise accepted by the MBTA, or proven by type acceptance testing, the plugboard shall be designed so that the removable contact will have a direct connection with the relay coil and the contact prongs. Plugboards provided shall be in accordance with the requirements of the applicable sections of AREMA C&S Manual, Part 6.2.2, Recommended Design Criteria for Vital Plug-in Relay Plugboards.
4. At the end of each row of racks, or as specified by the MBTA, a 120V AC, 15A ground fault interrupter (GFI) duplex outlet wired to the CIH breaker panel shall be provided.

H. Identification

1. A white identification rack number shall be stenciled at the top of the front and rear of the frames of each rack or panel. The numbering and system used to identify rack and equipment coordinates shall be submitted for approval prior to implementing. Each row shall also be identified with an approved stencil designation.
2. There shall be an identifying nameplate for each relay and/or other instrument mounted on the racks or panel.
3. Wire and cable conductor identification tags for terminal board mounting shall be as specified in Section 16897 –MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

I. Cable Entrance Racks (Terminal Boards) shall be as specified in Section 16854 –ENTRANCE RACKS FOR THE LIGHT RAIL SIGNAL SYSTEM.

J. Apparatus Boards. A full complement of apparatus boards shall be furnished on the side(s) of each CIH and shall be three-quarter inch, Type AB exterior plywood securely fastened to the walls in such a manner to permit mounting of battery charging equipment, transformers, terminals, fuses, etc.

K. Batteries. - The DB Entity shall furnish and install batteries and associated equipment as required. Batteries shall be installed on wood battery trays mounted on steel racks of a design and

size suitable for the batteries supplied. Unless otherwise approved, the design shall provide for batteries to be mounted on battery racks having a single tier.

- L. Grounding Material. Grounding material shall be as specified in Section 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
- M. Wiring shall be in accordance with the requirements of Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM.
- N. Plan Rack and Plan Table. The DB Entity shall provide plan files and/or rack for the storage of plans and a plan table to be used when reading plans in the Central Instrument House. The location of the plan rack and table shall be situated in a convenient location within the CIHs.
- O. Painting. The exterior of the CIH shall be painted aluminum in accordance with the applicable standards of AREMA C&S Manual and applicable sections of these Specifications.
- P. Telephones shall be provided in accordance with Section 16710 – TELEPHONE SYSTEMS AND INSTRUMENTS.
- Q. Indicating fuse systems shall use FNA type fuses as manufactured by Bussman or approved equal. All associated holders and associated material and equipment for an indicating fuse system shall be supplied by the same manufacturer.
- R. Power frequency track circuits shall be as shown in the Contract Documents and as specified in Section 16819 – TRAIN DETECTION FOR THE LIGHT RAIL SIGNAL SYSTEM.
- S. Vital microprocessor interlocking systems shall be as specified in Section 16859 – VITAL MICROPROCESSOR INTERLOCKING SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- T. Rectifiers shall be as specified in Section 16860 – RECTIFIERS, BATTERIES, AND BATTERY CHARGING EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
- U. Direct current power supplies shall be as specified in Section 16861 – DC POWER SUPPLIES FOR THE LIGHT RAIL SIGNAL SYSTEM.
- V. Transformers shall be as specified in Section 16863 – SIGNAL TRANSFORMERS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- W. 100Hz static frequency converters shall be provided as specified in Section 16862 – 100 HZ FREQUENCY CONVERTERS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- X. Local control and maintainer’s panels shall be as specified in Section 16866 – NON-VITAL SUPPORT SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- Y. Provide fiber optic cable and terminations as specified in Section 16749 – FIBER OPTIC CABLE SYSTEM.
- Z. Provide miscellaneous components and products as required and as specified in Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

2.3 CIH UTILITY POWER

- A. Each CIH shall be provided with a lighting and appliance branch circuit panelboard for utility power supply conforming to the requirements of Section 16835 – SIGNAL AND UTILITY POWER SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Lighting - The CIH shall be provided with fluorescent lights as required to provide complete illumination of 30 footcandles (at minimum) in all areas at floor level between rows of racks and at the end of rows. The lighting shall be operated from switches conveniently placed near each door.
- C. Convenience Outlets (Receptacles) – GFI Convenience outlets shall be furnished and installed at the end of each rack and along the perimeter walls of the CIH, four feet above the floor and spaced not more than six feet apart.
- D. Environmental Requirements
 - 1. The environment in the CIH shall be regulated by thermostatically controlled heating/air conditioning/ ventilating combination units. Heating units shall be sized based on 4 watts per cubic foot of area of the CIH. Cooling units shall be based on 60 BTU per hour per square foot minimum. The thermostat shall be provided with functions for "auto heat or cool" and "fan auto-on". The thermostat shall automatically regulate heating and cooling equipment that shall maintain a room temperature not to exceed 70°F nor go below 60°F.
 - 2. Air conditioning units shall utilize single-phase power.
 - 3. Openings in the walls or roof for the combination units shall be sealed against penetration of moisture and outside air and arranged to be secure from vandalism.
 - 4. Heating and air conditioning units shall be disabled when the fire suppression system is enabled.
- E. Branch Circuit Wiring
 - 1. Branch circuit wiring for the CIH utilities shall conform to the requirements of The Massachusetts Electric Code (MEC) and shall be installed within Electrical Mechanical Tubing (EMT). Wire sizes, EMT conduit and liquid tight flexible conduit shall be sized in accordance with the MEC.
 - 2. EMT shall not be connected directly to the Heating Ventilating & Air Conditioning Units. Liquid-tight flexible conduit shall be furnished between the unit and the EMT, for a distance of no less than two feet.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. CIHs shall be constructed for mounting on a foundation as described herein. Access shall be provided to the foundation bolts from inside the CIH. CIHs shall be mounted on a foundation as shown in the Contract Documents. CIHs shall not be installed less than 8' - 6" from the centerline of tracks at any point.
 - 1. The CIH shall be mounted level and plumb on piers as shown on the contract documents.

2. The CIH shall be grounded as specified in Section 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
 3. Cables shall enter the CIH through entrance knockouts and fittings and entrance pipes as required. Cables shall be dressed, tagged, sealed airtight and terminated as specified in Section 16808 – EXTERNAL SIGNAL CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Relays shall be provided as specified in Section 16858 –RELAYS FOR THE LIGHT RAIL SIGNAL SYSTEM.
1. Relays shall be installed on the relay plugboards corresponding to the relay nomenclature and securely fastened in place with the hardware and identification tagging provided.
 2. After acceptance of factory testing and prior to shipment of the CIHs, all relays, printed circuit boards and other equipment as designated by the MBTA shall be removed and re-packed in approved containers for separate shipment to the approved storage site.
- C. Batteries and chargers shall be provided as specified in Section 16860 – RECTIFIERS, BATTERIES, AND BATTERY CHARGING EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
1. Batteries shall be installed on trays and located as shown on the Contract Documents. Battery posts shall be coated with an approved grease and battery connectors shall be securely fastened to the battery posts.
 2. After acceptance of factory testing and prior to shipment of the CIHs, all batteries shall be removed and re-packed in approved containers for separate shipment to the approved storage site.
- D. Indicating fuses shall be mounted at eye level in a standard instrument rack for ease of troubleshooting.
- E. Internal wiring shall be provided as specified in Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM.
- F. Printed circuit boards and other electronic components shall be installed in accordance with manufacturer’s recommended practices as outlined in the approved installation procedure.
- G. Track Circuits shall be installed as specified in Section 16819 – TRAIN DETECTION FOR THE LIGHT RAIL SIGNAL SYSTEM.

3.2 CIH UTILITY POWER

- A. CIH utility power shall be installed in accordance with the requirements of the Massachusetts Electric Code and the requirements included in these project Specifications.
- B. Refer to Section 16835 – SIGNAL AND UTILITY POWER SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM.

3.3 TESTS

- A. All of the systems and equipment contained within the CIHs shall be factory tested in accordance with the requirements of Section 16898 – SIGNAL SYSTEMS TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM and the DB Entity’s Factory Test Procedures as accepted by the MBTA.

- B. All of the systems and equipment contained within the CIH shall be tested in accordance with the accepted Installation & Test Procedures, other applicable references of this Specification and on schedule according to the approved CPM.
- C. All of the systems and equipment contained within the CIHs shall be factory tested and field tested in accordance with the approved CPM (schedule) and other applicable references of this Specification.

3.4 PAINTING

- A. All equipment described in this Section shall be painted in accordance with the recommendations of AREMA C&S Manual, Part 1.5.10, Recommended Instructions for Painting and Protective Coatings, and the applicable references of these Specifications.
- B. Terminal, apparatus boards and shelves shall be painted with fire retardant gray, ANSI 61 or approved equal.
- C. The DB Entity shall apply approved corrosion resistant under coatings to metal parts of the CIHs.
- D. Battery trays shall be painted with two coats of an approved acid resistant black paint.

END OF SECTION

SECTION 16840

JUNCTION BOXES FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies requirements for furnishing and installing junction boxes for signal cable and other related small equipment items as required.
- B. Generally, two types of signal junction boxes are to be installed on the project. Typically, wall mounted type junction boxes are to be installed when in a confined areas and pedestal mounted type junction boxes at all other locations.
- C. These junction boxes shall be used as a termination/break-out point for signal cables from the CIH to service wayside equipment with individual runs of local cabling and individual express cable runs to/from adjacent CIH's. These shall include, but not be limited to, field devices such as signals, bus hold, and TAK light units, AVI loops, 100Hz track circuits, and switch machines.
- D. The DB Entity shall submit junction boxes locations to the MBTA for acceptance.

1.2 QUALITY ASSURANCE

- A. Comply with the requirements of Volume 1 DB Contract Terms and Conditions Section 4 "Quality Control and Quality Assurance" and Volume 2 Technical Provisions Subsection 2.5 "Quality Management".

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements", the DB Entity shall submit the following to the MBTA, for all junction box types, for his acceptance:

- A. Manufacturer's drawings and catalog cuts for junction boxes.
- B. Detailed/scaled internal junction box layout showing all internal accessories, aisle space for dressing/running wire conductors, methods/materials for securing wiring and components to backboard/terminals.
- C. Typical installation drawings and installation procedures for junction boxes.
 - 1. Drawings or lists describing the number and locations of junction boxes shall be submitted for acceptance prior to cable installation.
 - 2. Additional installation drawings/procedures are to be submitted in instances where the typical details do not apply.
- D. For Pedestal Mounted Junction Box - Detailed installation drawings showing cabling between cable raceway and wayside junction box.

- E. For Wall Mounted Junction Box - Detailed installation drawings showing local cabling from junction box, down conduit to track level signal equipment.
- F. All associated junction box hardware and installation materials.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage during delivery, storage and handling. Comply fully with the requirements of Section 16801 – Basic Technical Requirements.
- B. Damage to material, resulting from improper handling by the shipper or the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the Contract.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Junction boxes shall be equipped with ¾” A/B marine plywood backboard, primed and then painted ANSI 61 gray.
- B. Each junction box shall be stenciled with the junction box name from the as-built drawings for field identification purposes.
- C. Terminals for wires and cables:
 - 1. Terminal Blocks shall be in accordance with the recommendations contained in the AREMA C&S Manual, Part 14.1, Recommended Wire Connectors, Terminals.
 - 2. Insulated test links shall be used for all terminations. Insulated test links shall be Siemens Part No. 024620-1X, or approved equal.
 - 3. All stranded copper wire shall be fitted with an approved type of crimp terminal at all points where the wires are to be terminated on terminal binding posts.
 - 4. Terminals shall be of the solderless crimp-on type. Spade lug, forked lug or Faston type terminals shall not be used. Only eye-type terminals with nylon insulation shall be used. Eye-type terminal shall be sized properly for wire insulation diameter and stud size of terminal post.
 - 5. Terminals shall be attached to the wire with approved tools and methods. See Section 16808 – External Signal Cable for requirements of termination equipment and procedures.
 - 6. Sleeve tags shall be installed on individual cable conductors. Plastic tags shall be installed to identify individual cable entering each junction box. See Section 16808 – External Signal Cable and Section 16897 – Miscellaneous Components and Products for additional tagging information/requirements.

2.2 WALL MOUNTED JUNCTION BOXES

- A. The typical wall mounted junction box shall be NEMA 4X with padlock hasp sized for standard MBTA's hex keyed lock, and manufactured of type 304 stainless steel.
- B. Wall mounted junction boxes are to be installed to wall with stainless steel hardware.
- C. All Wall mounted junction boxes shall be equipped with a vent to help prevent condensation.

2.3 PEDESTAL MOUNTED JUNCTION BOXES

- A. Pedestal mounted junction boxes shall be provided in accordance with the recommendations of the applicable sections of the AREMA C&S Manual.
- B. All Pedestal mounted junction boxes shall be equipped with a vent to help prevent condensation.

PART 3 - EXECUTION

3.1 GENERAL

- A. Signal cable junction boxes shall be furnished and installed at the locations as required by the DB Entity's design.
- B. A minimum of 8" of slack shall remain secured within the junction box for each individual conductor.
- C. For pedestal mounted junction boxes, a minimum of 6' of cable shall be left coiled around the base of the pedestal. This underground cable coil shall be encased in 4" of sand on all sides with caution tape laid over the coil.
- D. Wall mounted junction boxes shall be installed plumb and level and shall not interfere with the train envelope.
- E. Conduit/cable entrances into junction boxes shall be sealed with expanding foam filler or other approved method.

END OF SECTION

SECTION 16850

SNOW MELTER HEATING SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The work to be done under this Section consists of furnishing and installing heater elements and snowmelter control cases for the field control and indication of track switch snowmelter heating. Each control case layout shall consist of a fiberglass housing containing all the components specified herein to control and indicate the operation of the heating elements assigned to that case, and the equipment required to mount the case as specified.
- B. The DB Entity shall provide new snowmelter layouts consisting of electric-type heater units functioning in a manner to keep the switch points free and clear of snow or ice to the extent necessary to permit free and unobstructed operation under all weather conditions.
- C. Each switch snowmelter layout as installed shall be complete with heating elements, external cable, conduit, rail connections, and other miscellaneous hardware required to mount and interconnect it to the rail and the associated snowmelter control case.

1.2 QUALITY ASSURANCE

- A. Factory Test
 - 1. Each control case shall be factory tested as prescribed in a test procedure accepted by the MBTA to assure mechanical, electrical, and operational conformance with the requirements of these Mandatory Specifications. The DB Entity shall record the results of these tests on the prescribed Factory Test Report forms for submittal to the MBTA. Only those cases for which Factory Test Reports have been approved shall be shipped to the job site.
 - 2. Each snowmelter heating element shall be factory tested. The factory tests for these items shall be conducted in accordance with procedures previously submitted by the DB Entity and accepted by the MBTA. As part of its factory test, each snowmelter heating element must withstand a potential of 1500 Volts DC, applied between conductor and sheath, for 30 seconds.
- B. Field Inspection
 - 1. Each control case shall be inspected after it has been delivered to the job site. Only those cases which have sustained neither external nor internal damage during shipment and handling shall be installed.
 - 2. Each snowmelter heating element and contact rail fuse box shall be inspected immediately prior to installation of the snowmelter layouts. Only those heating elements and fuse boxes which have suffered no damage due to shipment and handling shall be installed.
- C. Final Operational Test

The final operational test for each control case shall be conducted as part of the field testing of snowmelter layouts as specified in Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.

- D. All equipment provided shall perform satisfactorily under the following environmental requirements:
1. Ambient Operations Temperature: minus 22 degrees F to plus 158 degrees F.
 2. Relative Humidity: 0 to 100 percent.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following to the MBTA for acceptance:

A. Control Cases

1. Drawings and product information of the fiberglass control case proposed to be furnished under this Project;
2. Mechanical and layout plans of the proposed control case housing and all major components contained therein, including the internal arrangement plan, mounting hardware, and wiring diagram;
3. Catalog cuts, and complete performance data for the proposed control contactors and all other electrical/electronic components comprising the control panel and case;
4. Power feed fused disconnect installation details, catalog cuts, and bill of materials;
5. Drawings showing control case wiring;
6. Factory test procedure;
7. Installation inspection and test procedure;

B. Heater (Element) Layouts

1. Assembly drawings and a bill of materials for the type of switch snowmelter layouts to be furnished. The MBTA's acceptance of the snowmelter layouts is required prior to their shipment to the job site;
2. Drawings showing field mounting arrangement for the switch heater elements. The drawings shall illustrate the details of the mounting hardware and the method of installation;
3. A factory test procedure for snowmelter elements;
4. The following reports and manuals upon delivery of the track switch snowmelter layouts:
 - a. One copy of factory test reports of the snowmelter layouts prior to shipment.
 - b. Ten manuals for snowmelter layouts furnished describing the installation, operation, and maintenance procedures.
5. An installation inspection and test procedure;
6. "As-Built" drawings, prior to MBTA acceptance.

- C. Factory test results for all items shall be submitted five days after completion of tests, and prior to shipment of equipment.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Heaters and cases shall be properly braced to prevent damage during shipment. Individual crating/packing as well as protected inside storage shall be provided for any equipment not ready for immediate installation upon delivery to the site.

- B. Fully comply with all requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- C. Any and all heating elements and control cases damaged during the course of shipment, handling, or installation shall be replaced by the DB Entity at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 CASE DESIGN

- A. General Description - The heater control case, including its monitoring panel shall be used for the control and monitoring of resistive heater elements. The panel will support a maximum of (6) fused outputs switched from one main breaker. The control-monitoring panel shall be of a proven design, acceptable to the MBTA, based on proven (submitted) record of satisfactory transit system service for a minimum of one year. System control and indication shall be accessible by local or remote means.
- B. Each of the (6) fused outputs can control two heaters elements per MBTA standards, resulting in 12 heaters total per case.
- C. Enclosure - The housing for all control cases shall be of weatherproof, gasketed design and single-door, molded fiberglass construction. The thickness of the housing sides and door shall be one-quarter (1/4) inch minimum, with the bottom and back being three-eighths (3/8) inch thick. The housing shall comply with the applicable standards of ASTM-E-84 for exterior walls. Interior paneling shall comply with a flame spread of 0-20 and a fire rating of 7 in accordance with ASTM-E-84. The fiberglass shall have ultra-violet ray protection by special additives. The outside color shall be gray. The inside color shall be white.
- D. Size - The housings for snowmelter control cases shall be all the same size. External dimensions shall be as submitted by the DB Entity and accepted by the MBTA.
- E. Door and Hinge - Each door shall be fastened to its housing with a minimum 16-gauge stainless steel hinge continuous over the full height of the door. The hinge fastenings shall be concealed when the door is closed. The door shall swing through an angle of 180 degrees in line with the track structure.
- F. Door Latch and Interlock - The door shall be equipped with a latching mechanism of a three-point lock design. The handle for this mechanism shall be designed for the use of a standard MBTA padlock. The housing shall be equipped with a heavy duty interlock device that shall, whenever the door of the control case is opened, disconnect both sides of the circuit that remotely controls the snowmelter contactors. A bypass switch shall be provided to permit testing when the door is open. When the switch is in "bypass" position, the door shall be prevented from being fully closed by a mechanical means.
- G. Vents - Each housing shall be equipped with at least two vents. Each of the vent openings shall be hooded or protected by a rain guard on the outside and shall be covered with a fine mesh screening of stainless steel, copper, or brass, on the inside. These vents shall be so designed and located that an object cannot be inserted through the vent and make straight line contact with energized components inside the housing.
- H. Backboard - A non-metallic, fire resistant backboard panel shall be mounted on fiberglass channels inside the housing to support the snowmelter control and indication equipment.

- I. The enclosure shall include suitable outdoor lighting fixture for “HEATER ON” indication. Fixture wiring shall penetrate the side of the main enclosure.

2.2 CONTACTORS

- A. Each control case shall be equipped with one main contractor. The main contractor shall be single pole rated not less than 1000V and 150A. Contactor shall operate on 120V AC control voltage with necessary aux. contacts for “HEATER ON” indication. All snowmelter contactors provided shall be identical in size and rating.
- B. Coils - The coil of each contactor shall be designed for operation at 120V AC, 60 Hertz power, but shall be capable of successful continuous operation without resultant damage at voltages from 90 to 130V AC. The coil of each contactor shall be equipped with arc suppression.
- C. Contacts
 - 1. Each contactor shall have a sufficient number of main contacts and a sufficient number of auxiliary contacts to accommodate the circuit requirements of each case.
 - 2. The main contacts shall be able to make, break, and carry a 50,000- Watt heater element load continuously without resultant damage at 550 to 800 Volts DC.
 - 3. The contactor shall be so designed that arcing between the contacts shall be suppressed. Voltage breakdown between coil and contacts must be precluded.

2.3 CASE HEATERS

- A. Each control case shall be equipped with one 50- Watt, 650- Volt rated, 1000V DC maximum, heater resistor, mounted on the lower portion of the backboard panel to control moisture condensation within the housing.
- B. The case heater shall be controlled by a 1,000-Volt manual switch mounted in the case.

2.4 FUSES

- A. All fuses used in rail heater control cases for DC circuit protection shall be of the non-renewable, fiber case, time lag, fusion type, rated for 1,000 Volt DC operation.
- B. One fuse, sized for the load, shall be provided for each snowmelter heating element controlled from the case. The case heater shall be protected by a fuse sized as required by the DB Entity.
- C. Fuses sized for protection of the contactor control circuit shall be as required by the DB Entity’s design.

2.5 WIRE

- A. All control case internal wiring shall be insulated for 1,000 Volts and shall meet the applicable requirements specified in the Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specification.
- B. Low voltage control, indication, and communication wiring shall be run separately from the 650-Volt heater element wiring.

2.6 TERMINALS

Terminals for connection to snowmelter elements must be capable of securing No. 6 field wires or larger as required for operation. Terminals for connection to 650-volt DC supply shall be capable of securing a field wire properly sized for that housing and load.

2.7 WIRING

Wiring for the contactor control and indication circuits shall be trained and run separately from snowmelter element wiring. Low voltage and snowmelter element circuit terminations are to be kept separated. Flashover between adjacent circuits or classes of wiring must be precluded. All heater control wiring shall be sized for maximum load requirements.

2.8 INDICATIONS

- A. Indications are to be provided locally and remotely, interfacing with the non-vital system.

2.9 HEATER CONTROL CASE

Switch heating system control cases shall be designed and fabricated as a complete unit provided by a single manufacturer with a proven record of satisfactory service for this application. Control cases are to be provided fully functional, ready-for-use without the need of additional components or modification within the case itself.

2.10 TRACK SWITCH SNOWMELTER LAYOUTS

- A. The track switch rail heater elements shall be of the tubular type rated for 1000-Volt DC service and normally operable at 650 Volts DC, and 350 Watts/foot of effective heating length.
- B. The snowmelter heater elements shall conform to the length of the switch rail. The effective length of the switch heater elements shall be designed to extend at least one foot beyond the point of switch. The flexible wire leads of the snowmelter elements shall be 10 feet in length.
- C. Cover guard heater elements shall meet the electrical requirements as specified herein for the switch rail heater elements.
- D. Track switch snowmelter layout hardware and fittings shall be furnished by the DB Entity.

2.11 SNOWMELTER POWER FUSE BOX

- A. One snowmelter power fuse box shall be provided for each control case layout.
- B. Snowmelter power fuse boxes shall be constructed of fiberglass and rated for maximum service voltage of 750 Volts DC.
- C. The snowmelter power fuse box shall be so constructed that the lifting of the cover shall open the circuit by disconnection and removal of the fuse. The fuse shall be rated for the size of the load.
- D. Both sides of the snowmelter power fuse box shall be permanently and prominently labeled, "DANGER HIGH VOLTAGE".
- E. The fuse box handle shall be permanently labeled "DO NOT OPERATE UNDER LOAD".

2.12 WIRE AND CABLE

- A. Snowmelter power cable shall conform to MBTA Specification S-112E.
- B. The negative end of the element, where connected to the impedance bond, or negative propulsion rail, shall be permanently and prominently labeled, "DANGER-HIGH VOLTAGE".

2.13 CONDUIT

- A. Fiberglass conduit shall be provided for protection of the external snowmelter wire and cable connections, as shown on the Contract Documents. Conduit shall conform to requirements as stated in section 16826 – CABLE RACEWAYS AND AERIAL CABLE SUPPORT SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.

2.14 MISCELLANEOUS HARDWARE

Electrical connectors, electrical tape, identification tags, and all necessary appurtenances to install the Snowmelter Layout shall be as specified within these Mandatory Specifications, or as accepted by the MBTA.

2.15 SNOWMELTER JUNCTION BOXES (SMJBs)

Junction boxes in ballast shall be fiberglass, hot-molded of high impact, long fiber, prepregated glass fiber reinforced polyester to ensure uniform strength. Fiberglass shall have ultraviolet ray protection by special additives. Seals will be molded with oil resistant neoprene gaskets. They shall be a NEMA Type 4X enclosure and shall have a hinged cover with padlock hasp. Hinge and hasp shall be 316 stainless steel. Box and cover thickness shall be ¼ inch.

PART 3 - EXECUTION

3.1 GENERAL

- A. Each control unit shall be installed at the locations as required by the DB Entity's design to ensure coverage of all track switches installed under this Project.
- B. Control cases shall be located at least 10 feet from other electrical equipment and signals, unless otherwise accepted by the MBTA.
- C. Separate FRE cable entrance risers shall be provided through the bottom of the housing for entrance of the "high" and "low" voltage wire and cable.
- D. The cases shall be installed in such a manner that their doors shall open, close, seal, and lock without binding.
- E. Upon installation, each control case shall be locked with a padlock of the standard MBTA hex key type.

3.2 IDENTIFICATION

- A. The identification number for each control case shall be stenciled on both the inside and outside of the case door.
- B. The case identification number shall correspond to an approved scheme utilizing the numbers of

the switches for which snowmelters are designated.

- C. The door shall be permanently and prominently labeled, "DANGER-HIGH VOLTAGE".

3.3 TRACK SWITCH RAIL HEATER ELEMENTS

- A. Track switch rail heater elements shall be installed on the outside of the bent and straight stock rails of the switch layout. The outside of the heating element shall be in direct contact with the rail to the extent practicable. The heating element shall be installed under dry conditions to eliminate the entrance of moisture into the heater system.
- B. The heating element shall be located on the neutral axis of the rail, as shown in the Contract Documents. The element shall be enclosed with one-inch minimum of thermal insulation encased in an aluminum alloy shield. The shield shall be held in place by rail clips.
- C. The heating element shall be where the rail is supported by track braces.
- D. Power feed, cable leads to the heating element shall be installed in one inch (inner diameter) cordura flexible hose or approved equal with water-tight compression fittings and placed underneath the rails. Interconnections between the elements shall be thermally and electrically insulated from the rail. Connections shall be thoroughly dry during installation to eliminate the entrance of moisture.

3.4 SNOWMELTER JUNCTION BOXES

Snowmelter junction boxes shall be installed at the locations as required by the DB Entity. Each junction box shall be level and plumb. The top of the junction boxes, with the covers on, shall be even with the top of finished grade/ballast.

3.5 CONNECTIONS

- A. Dedicated conduit runs shall be provided for high voltage cables.
- B. Sufficient slack shall be left in all connection wires to allow for running of the rail.
- C. Connection from the heating element lead to the control case feeder shall be tap spliced with an approved type service connector. The connection shall be sprayed with an approved sealant before and after taping with electrical plastic tape.
- D. Connection from the heating element leads to the impedance bond neutral or the negative propulsion rail, shall be as shown in the Contract Documents.

END OF SECTION

SECTION 16853

INSTRUMENT RACKS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing the following:
 - 1. Sectional type signal instrument racks. Signal instrument racks shall be free standing open frame weldments and shall include not only relay racks, but other racks such as signal power racks, rectifier racks, and racks containing track circuit equipment.
 - 2. Control system computer and communication equipment racks. These racks shall be fully equipped with the required numbers and types of processor chassis, network equipment, carrier equipment, status indication panels, keyboards, track balls, slide out (keyboard) trays, busses, terminals, and all miscellaneous electrical and mechanical components required by the DB Entity's design.
- B. The work to be done under this Section shall also include the preparation of detail drawings for each instrument rack, the equipment arrangement thereon and circuits associated with it.

1.2 QUALITY ASSURANCE

Each instrument rack shall be tested and inspected prior to shipment. Tests and inspections shall conform to the DB Entity's Factory Testing and Inspection Procedure(s) as accepted by the MBTA.

1.3 SUBMITTALS

The DB Entity shall submit the following to the MBTA for acceptance:

- A. Approval of equipment layout and detail arrangement on instrument racks is required prior to the assembly of the equipment and the central instrument houses (CIH) and cases. The DB Entity shall take the arrangements as shown in the Contract Documents and make his own determination of the number of racks that can be assembled as a row with due allowance for the means of access based on the particular equipment being provided. The MBTA's acceptance of instrument rack layouts is required prior to the manufacture of the equipment.
- B. Drawings shall show the proposed arrangement of the instrument racks, including a drawing to show methods of grounding, and the relation to other equipment in the room.
- C. Factory Test and Inspection Procedure(s) for instrument racks shall be submitted not later than six weeks prior to final assembly.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Instrument racks shall be properly braced to prevent damage to other racks and equipment installed in the CIH during shipment. Individual crating/packing and protected inside storage shall be provided for racks not already mounted within the CIH for delivery to the site
- B. Vital relays shall be shipped separately and identified for the racks and the particular slot in which they are to be used. Relays shall be stored in a protected area until installed in the racks.

- C. Printed circuit cards shall be shipped separately and identified for the racks in which they are to be used. Card locations shall be recorded to facilitate re-insertion into their proper location (same slots as during factory testing) upon delivery to the field site. Cards shall be stored in a protected area until final installation in the racks.
- D. Fully comply with all requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

PART 2 - PRODUCTS

2.1 INSTRUMENT RACKS

- A. Signal instrument racks shall be open frame weldments designed to accommodate mounting of standard 19-inch panels. The frame shall be constructed of 14-gauge minimum cold rolled steel. The width shall not exceed 24 inches. The panel mounting angles shall be constructed with the standard EIA hole spacing.
- B. The racks shall be shock mounted and secured to 12-gauge minimum cold rolled steel bases. The base shall be the same width as the racks, with a height of three and one-half inches.
- C. Chassis supports or guides shall be provided for auxiliary support of heavy equipment such as power supplies, CPUs and carrier chassis. The chassis supports shall be made of 11-gauge minimum cold rolled steel, capable of being mounted directly to the panel-mounting angles, and shall permit side-to-side guide adjustment. Support bars shall be provided for each row of apparatus. Slide trays shall be utilized for keyboard shelf and trackball shelf.
- D. Relay plugboard support bars shall be provided for each row of relays and be of sufficient strength to support the manufacturer's equipment to be mounted thereon without flexing due to the pressure exerted during wiring termination.
- E. The terminal, plug connector, and power panel shall be located on the upper portion of the rack for connecting wires and cables. The panel material shall be fire retardant. A minimum of 10% spare terminals shall be provided on each instrument rack.
- F. Rows of racks shall be oriented to have adjacent rows either front-to-front or back-to-back. Row to row and row to wall spacing shall be a minimum of three feet, measured at the base of the racks, unless otherwise accepted by the MBTA.
- G. Each instrument rack shall be fully equipped with the required numbers and types of power supplies, transformers, relay plugboards, buses, terminals, and all miscellaneous electrical and mechanical components specified. Terminals and resistors for energy busses where required, shall be located on the upper portion of the rack. Vital inter-rack wiring shall be direct from relay to relay. Insulated terminals shall be as specified in the AREMA C&S Manual Part 14.1.5, Recommended Design Criteria for Molded Terminal Blocks.
- H. Wire supports which form interior wire raceway on instrument racks shall be fabricated from steel or other approved material of non-flammable composition.
- I. In designing the detail layout of the racks and other equipment, the DB Entity shall group the rows of racks and the instruments thereon so that similar types of equipment or functions of a similar

nature shall be together.

- J. Relays or components shall not be mounted at a height of more than six feet - six inches from the floor of the room, or closer than 10" to the floor. The overall height of the rack shall not exceed 7'-6".
- K. A minimum of 20 percent spare space on each group of instrument racks for additional relays for each rack required to be equipped with plug couplers shall be provided.
- L. Plug-in relays, transformers, rectifiers, ground detectors, and other rack-mounted components shall conform to the requirements as described elsewhere within these Mandatory Specifications.
- M. Approved types of resistors, capacitors, arresters, electronic components, and fuses shall be connected into track, line, and power circuits as required by the DB Entity. These components shall be of such design and capacity to protect the equipment and provide positive and safe operation.
- N. All fuses shall be locally and remotely alarmed or indicated except for main power fuses and power frequency track circuit fuses.
- O. Plugboards for plug-in relays shall be designed and furnished for insertion of removable type contacts. The method of attaching the wires to the removable contacts shall be a solderless connection and shall be subject to approval by the MBTA. Unless otherwise accepted by the MBTA, or proven by type acceptance testing, the plugboard shall be designed so that the removable contact will have a direct connection with the relay coil and the contact prongs. In general, the plugboards shall be in accordance with the requirements of applicable sections of AREMA C&S Manual Part 6.2.2, Recommended Design Criteria for Vital Plug-in Relay Plugboards. The wiring to each removable contact shall carry an approved tag indicating the relay name and contact number, wire name, and termination of the other end of the wire. All wires shall be of sufficient length to permit them to be moved to any contact on the same relay. Plugboards for vital relays shall be equipped with a (type) registration plate to prevent relays of the wrong style, contact arrangement, or operating characteristics from being inserted.
- P. Components shall be protected from damage in the event a plug connector or plug-in unit is removed while equipment is energized.
- Q. Convenience type outlets shall be mounted at the end of each row of racks. Convenience outlets shall be supplied from the utility panel and those inside the signal equipment room area shall be GFI protected.

2.2 PLUG CONNECTING CABLES

- A. Plug Connectors shall be as specified in Section 16857 – PLUG CONNECTORS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.
- B. Cable and wire for plug connecting cables shall be in accordance with Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.
- C. Plug couplers shall not be used between instrument racks within a CIH.
- D. Equipment mounted in the instrument racks shall not utilize “plug-in” power. All equipment such as monitors, power supplies, etc. shall be hard-wired to terminals and shall include an individual fuse for that particular device in the circuit.

2.3 GROUNDING POSTS

Grounding posts and ground jumpers shall be furnished with each rack. These posts shall be of the bolted type to permit isolation of the rack from all ground sources for testing by removal of the ground wire connections.

2.4 IDENTIFICATION

- A. A white identification (rack) number shall be stenciled at the top of the front and rear of the frame of each rack. Also, approved vertical coordinate lettering shall be stenciled from top to bottom.
- B. There shall be an identifying nameplate for each relay, rectifier, transformer, or unit of equipment to be mounted on instrument racks. Nameplates shall be used front and back where the device or its connections are on both sides.
- C. The back of the plugboard shall be equipped with a tag, or other approved means of identification, to indicate the nomenclature of the relay for which it is wired.
- D. The contact numbering system shall be uniform for each type of relay used.
- E. The wiring to each removable contact shall carry an approved tag indicating the relay name and contact number, wire name, and termination of the other end of the wire.
- F. Signal power racks shall have special high voltage labels affixed in the color, format and size accepted by the MBTA.

2.5 PAINTING

Entrance racks shall be painted in accordance with Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM. Racks shall be painted gray, ANSI-61, or approved equal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Instrument racks shall be factory-installed within the central instrument houses. The racks, equipment, and all necessary mounting and fastening materials to mount the racks shall be installed as required. All interconnecting cables, wiring, and connections to power sources and entrance racks shall be installed as shown on the Design Documents, including interconnections to self-contained, rack mounted equipment units. Interconnecting cables shall be the same cables used in the factory test of the instrument racks.
- B. Signal instrument racks shall be electrically insulated from each other and from the supporting framework. Grounding of the racks shall be as specified in Section 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.
- C. Wiring of instrument racks shall be as specified in Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications. Wires and cables shall be installed in a neat, workmanlike manner. Wires and cables in ducts shall be laid therein and not pulled in. Wires and cables shall be installed with a minimum amount of crossover in the duct and shall not be pulled tightly around bends. All exposed wires and cables entering or

leaving equipment racks shall be protected from abrasion and sharp edges. Slack shall be provided for each interconnecting cable or wire.

- D. Energy buses shall be located at the top of the rack and shall not be wired with positive and negative energy on the same vertical terminal section.
- E. A reference voltage test point shall be provided on each rack for all energy busses used on that instrument rack.
- F. Insulated nuts shall be provided when terminating voltages in excess of 55 volts.
- G. Where wire and cable transfers from ducts to open wiring, the ends of the duct shall be fitted with bell ends to prevent damage to the wire or cable.
- H. Wire and cable shall be permanently tagged by a white sleeve tag with permanent black 1/8" minimum lettering.

3.2 TESTS

Instrument racks and the equipment mounted thereon shall be tested and inspected in accordance with the requirements of the Factory Test and Inspection Procedure as accepted by the MBTA.

END OF SECTION

SECTION 16854

ENTRANCE RACKS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing sectional type racks in central instrument houses (CIHs) for terminating incoming wire and cable and making interconnections to the internal wiring on instrument racks, except for second range, or higher, voltage signal power wires.
- B. The work to be done under this Section shall also include the preparation of detail drawings for each entrance rack in each housing showing terminal block arrangement and both working connections and spare terminals.

1.2 QUALITY ASSURANCE

- A. The DB Entity shall inspect each entrance rack prior to installation in its permanent location. This inspection shall conform to the DB Entity's Factory Inspection Procedure as accepted by the MBTA.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following to the MBTA for acceptance:

- A. Drawings for each CIH showing the proposed arrangement of entrance racks and their relation to other equipment in the room or housing. DB Entity shall make his own determination of the number of racks that can be assembled as a row with due allowance for the means of access. These drawings shall be coordinated with the drawing submittal required in Section 16853 – INSTRUMENT RACKS FOR THE LIGHT RAIL SIGNAL SYSTEM and the drawing submittal required in Section 16838 – CENTRAL INSTRUMENT HOUSES FOR THE LIGHT RAIL SIGNAL SYSTEM where instrument racks are located within the same housing.
- B. MBTA's acceptance of entrance rack arrangement plans is required prior to the manufacture and assembly of the equipment.

1.4 DELIVERY, STORAGE AND HANDLING

Entrance racks, shall be properly braced and protected to prevent damage to the racks and other equipment during shipment. Comply fully with the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

PART 2 - PRODUCTS

1.5 MATERIALS

- A. Entrance racks shall be open frame weldments with a maximum width of 24 inches. The frame shall be constructed of 14-gauge (minimum), cold rolled steel. The panel mounting angles shall be constructed with the standard EIA hole spacing.

- B. The racks shall be shock-mounted on and secured to 12-gauge minimum cold rolled steel bases. The rack base shall be the same width as the racks, with a height of three and one-half inches.
- C. Entrance Rack Accessories
1. All incoming wires, including spare wires, shall be terminated on binding posts and molded terminal blocks conforming to the recommendations as set forth in the AREMA C&S Manual, Part 14.1. Insulated test links shall be used for all terminations. The entrance racks shall be fully equipped with the required number of terminal blocks, tags, rack and row identification, and accessories. Lighting arrestors shall be provided on the entrance racks. Refer to Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM for additional information/requirements on tagging, terminals and lightning arresters.
 2. Terminal Mounting
 - a. The terminal blocks and spacing of terminals shall be so arranged as to permit each internal wire and its field wire interconnection to be separated on an individual basis without removing either wire from its terminal. This shall be accomplished by use of insulated test links in accordance with Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
 - b. Ten percent of the total number of terminals spare binding posts shall be provided.
 - c. All materials needed to assemble the racks one to another to form complete sections shall be furnished.
 - d. Communication type terminals shall be provided for terminating communication cables. Ten percent spare communications terminals shall be provided.
 3. Wiring - Cable and single wire terminations shall be as specified in Section 16808 – EXTERNAL SIGNAL CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM and Section 16855 – INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.
 4. Grounding Post - A grounding post shall be furnished with each rack. This post shall be of the bolted type to permit removal of the ground wire connection for testing.
 5. Identification
 - a. A white identification number shall be stenciled at the top of each entrance rack on both the front and rear of the frame. The minimum size of the identification figures shall be one and one-half inches. Also, vertical coordination letters shall be stenciled on both sides from top to bottom of each rack.
 - b. Each terminal and terminating wire shall be identified or tagged in accordance with the circuit nomenclature and in a manner as specified in Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
 6. Painting - Entrance racks shall be painted in accordance with Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM. Racks shall be painted gray, ANSI-61, or approved equal.

PART 3 - EXECUTION

1.6 INSTALLATION

- A. Entrance racks shall be installed with all the necessary fittings mounting and fastening material as required.
- B. Entrance racks shall be installed in such a manner as to be insulated from ground and from each other and from any supporting framework or wire troughs.
- C. Entrance racks shall only be electrically connected to each other by the ground connection as specified in Section 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
- D. DB Entity shall install all interconnecting cables, wiring and connections and terminate all cables.
- E. DB Entity shall provide insulated nuts when terminating wiring with voltages in excess of 55 volts.
- F. Energy busses shall be located at the top of the rack(s) and shall not be wired with positive and negative energy on the same vertical terminal section.
- G. DB Entity shall provide a reference voltage for all energy busses used on the entrance rack.

1.7 TESTS

Entrance racks and the equipment mounted thereon shall be tested and inspected in accordance with the requirements of the Factory Test and Inspection Procedure as accepted by the MBTA.

END OF SECTION

SECTION 16855

INTERNAL WIRE AND CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing wire and cable in the Central Instrument Houses (CIH's), wayside cases, equipment, devices and in enclosures where it will not be exposed to the elements. All intra-rack and rack-to-rack wire and cable shall conform to the requirements of this Section. All required wiring materials shall be accepted by the MBTA. Internal wiring for vital circuits shall be in accordance with applicable sections of the AREMA C&S Manual unless otherwise specified herein.
- B. Stranded wire, including individual conductors of multi-conductor cables covered by this Section, shall be TEFZEL® (ETFE) or E-CTFE per Military Specification, MIL-W-22759 and these Mandatory Specifications.

1.2 QUALITY ASSURANCE

- A. Quality Assurance provisions of the applicable Military Specifications shall be followed in the manufacture of wire covered by this Section. The DB Entity shall be responsible for witnessing and reporting the results of any and all required qualification tests. One-half of each qualification sample shall be retained for the DB Entity's evaluation and the remaining one-half shall be forwarded to the MBTA for final acceptance. The DB Entity shall be responsible for monitoring the manufacturer's conformance to the quality assurance requirements and the MBTA reserves the right to audit conformance in accordance with the MBTA Standard Specifications.
- B. All other work covered by this Section shall be accomplished in compliance with a Quality Assurance Program that meets the intent of ANSI/ASQC C1-1996 (ANSI Z1.8-1971): Specifications of General Requirements for a Quality Program.
- C. Multi-conductor cables shall be tested to verify conformance with the requirements of this Section as follows:
 - 1. Individual conductors shall be tested per the requirements specified herein for Stranded Wire for General Use, prior to cable assembly.
 - 2. All finished cables shall be placed in water at room temperature. After 48 hours immersion and while still immersed, all conductors shall be tested for breakdown at a voltage of 2,500 Volts (rms) for five minutes.
 - 3. Samples of finished cable fabricated from each batch of cable outer sheath material shall be flame-tested per IEEE Standard 383-1974.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following for the MBTA's acceptance:

- A. Complete technical data verifying that the internal wire and cable which the DB Entity proposes to furnish is in compliance with the requirements of this Section;

- B. Qualification samples;
- C. Reports of all qualification tests witnessed by the DB Entity;
- D. Certified test reports of all breakdown tests conducted on finished cable;
- E. Certified test reports of all flame tests conducted on finished cable;
- F. Submit a Certificate of Compliance to the requirements these Mandatory Specifications. The certificate shall list all requirements and shall show a confirmation for each item. The certificate is to be signed by the DB Entity's quality control officer.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage throughout delivery, storage and handling. Comply fully with the requirements of Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Damage to material resulting from improper handling by the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Stranded Wire for General Use
 - 1. General Requirements
 - a. Internal wire shall conform to this Section and the issue in effect of Military Specification MIL- W-22759 in effect at award of this Project. Where there is a discrepancy between this Section and the requirements of the applicable Military Specification, the requirements of this Section shall govern. The requirements of this Section shall also be used where the Military Specification refers to ".the requirements of the applicable military specification sheet."
 - b. Wire and cable provided under this Section shall be from a wire and cable manufacturer with proven experience in the Railroad/Rail Transit industry.
 - c. All internal stranded wire furnished and installed under this Project shall be subject to the following requirements:
 - 1) Conductor: Concentric-Lay-Stranded, Annealed Copper per ASTM B8
 - 2) Coating: Tin or Lead per ASTM B33 or B189
 - 3) Insulation: ETFE – Ethylene-Tetrafluoroethylene or E-CTFE - Ethylene-Chlorotrifluoroethylene per MIL-W-22759
 - 4) Chlorotrifluoroethylene per MIL-W-22759
 - 5) Construction: per Table 1.
 - 6) Performance: per Tables 2. and 3.

TABLE 1.
Construction Details

Wire Size (AWG)	Conductor Stranding (Strands x Size)	Maximum Diameter Stranded Conductor (Inches)	Conductor Resistance Maximum @ 20 C (Ohms/1000 Ft.)
22	19 x 34	.033	16.2
20	19 x 32	.041	9.88
18	19 x 30	.051	6.23
16	19 x 29	.058	4.81
14	19 x 27	.073	3.06
12	37 x 28	.090	2.02
10	37 x 26	.114	1.26
8	133 x 29	.173	.701

TABLE 2.
Performance Details

Wire Size (AWG)	Minimum Resistance (Inches of Tape)	Weight Support Bracket	Weight (Pounds)	Tension Load (Pounds)
22	26	A	1.0	1.0
20	26	A	1.0	1.0
18	27	A	1.0	1.0
16	28	A	1.0	2.0
14	19	B	3.0	2.0
12	29	B	3.0	2.0
10	36	B	3.0	3.0
8	35	B	3.0	3.0

TABLE 3.
Performance Details

Wire Size (AWG)	Mandrel Diameter Life Cycle	Cold Bend (Inches Max.)	Test Load Life Cycle	Cold Bend (Pounds)
22	3/4	1	1.5	3.0
20	3/4	1	2.0	4.0
18	1	1 - 1/4	2.0	4.0
16	1	1 - 1/4	2.0	5.0
14	1 - 1/4	2	2.0	5.0
12	2	2	2.0	5.0
10	3	3	2.0	5.0
8	3	4	3.0	6.0

TABLE 4.
Additional Requirements for Stranded Wire

Type of Insulation	ETFE or E-	Polyarylene	Polymide Film Tape
Military Specification	MIL-W-	MIL-W-81044	MIL-W-81381
Nominal Wall Thickness Size 22-14	15 mils	10 mils	10 mils *
Nominal Wall Thickness Size 12-8 AWG	20 mils	12.5 mils]12.4 mils *
Temperature Rating	150 C	150 C	150 C
Blocking (Qualifications only)	200 C	200 C	200 C
Color	Contractors		
Flammability **	pass	pass	pass
Identification **	30 inch intervals (max.)		
Identification Stripping or Printing Durability	125 cycles (250 strokes) (min.) witT 500 grams weight		
Life Cycle	Oven temp. 200 C for 168 hours		
Dielectric Test	2200 volts (rms), 60 Hz		
Accelerated Aging	7 hrs. at 210 C (Quality Conformance Test, Group II; Procedure as in Life Cycle Test)		

TABLE 4A
(Continued) Additional Requirements for Stranded Wire

Physical Properties of Insulation			
Physical Properties of Insulation			
Tensile Strength PSI (min.)	5,000	12,000	24,000
Elongation percent (min.)	125	50	40
Chemical Resistance	Test not required		
Shrinkage at 200 +/- 2 degrees C (inches max.)	0.125	0.125	0.303
Smoke	200 ^o C	200 ^o C	200 ^o C ***
Thermal Shock			
Cold Bend	-65 ^o C	-65 ^o C	-65 ^o C
Dynamic Cut Through pounds (min.) at 23 degree C with size 20 AWG	90	90	90
Wicking	Test not required		
Abrasion Resistance after Immersion	Same as initial		
Nominal wall thickness for Polyimide film shall be achieved by the following combinations of 50 percent overlapped tape wraps plus an outer 1 mil coating of modified aromatic polyimide resin: First wrap, 1/2/.5; Second wrap, .5/1/.5; Third wrap,			
** As required by this Section *** Test per MIL-W-22759			

Table 4B.
(Continued) Additional Requirements for Stranded Wire

Type of Insulation	ETFE or E-CTF	Polyarylene	Polyimide Film Tape
Military Specification	MIL-W-22759	MIL-W-81044	MIL-W-81381
Lamination Sealing	NA	NA	230°C 48 hrs
Polyimide Cure Test	NA	NA	required
Resin Coating Durability	NA	NA	****
Humidity Resistance	IR after exposure shall meet initial requirements		
Voltage Rating	600 V RMS	600 V RMS	600 V RMS
Impulse Dielectric Test (100%)	8 KV Peak	8 KV Peak	8 KV Peak
Insulation Resistance	5000 megohms per 1000 ft. (min.)		
Spark Test	Test not required		
Surface Resistance Megohms per inch (min.) Initial and Final	500	500	500
Wet Dielectric Test Volts (rms)	2500	2500	2500
**** 250 cycles (500 strokes) (minimum) with one pound load.			

2.2 Special Requirements for Stranded Wire

A. Vertical Flame Test

1. Single Wire. The test specimen shall be 18" in length, and shall be placed vertically within a chamber approximately 2' by 1' by 1', open at the top and one vertical side (front), which allows a sufficient flow of air for complete combustion, but which is free from drafts. The upper end of the specimen shall be fastened in the chamber by means of a clamp and a weight shall be attached to the lower end of the specimen to hold the specimen taut during the flammability test. The weights shall be the same as those used for the life cycle tests. The specimen shall be marked at approximately 7" above the floor of the chamber to indicate where the flame is to be applied.
2. A flame from a Bunsen burner shall be applied for 15 seconds to the specimen. The Bunsen burner shall be positioned below the test mark on the specimen and at an angle of 20 degrees to the vertical plane of the specimen. The Bunsen burner shall have a 1/4" inlet, a nominal bore of 3/8", and a length of approximately 4" from the top to primary inlets. The burner shall be adjusted to produce a 3" high flame with an inner cone approximately one-third of the flame height. The temperature of the hottest portion of the flame, as measured by a thermocouple pyrometer, shall be not less than 955 degrees C ±30 degrees C. The burner shall be positioned so that the hottest portion of the flame is applied to the approximate position of the test mark on the wire. The time of burning and the flame travel after removal of the flame shall be recorded. Breaking of the wire specimens in sizes 24 and smaller shall not be considered as a failure.
3. Bundles. The test specimens shall be prepared by assembling seven single wire specimens, each

14" long, into a bundle tied in two places with glass cord or equivalent non-metallic, noncombustible material, 3" from each end. The bundles shall be suspended vertically in the test chamber described above. A flame from a Bunsen burner shall be applied vertically to the base of the bundle for 15 seconds. The burner flame shall be adjusted as described for the single wire flame test. The time of burning and flame travel after removal of the flame shall be recorded.

B. Dynamic Cut-Through

1. The dynamic cut-through test shall be performed at room temperature using a tensile testing machine equipped with a recorder which shall be suitable for recording the force in pounds necessary to force a tungsten carbide cutting tool through the insulation of a finished wire specimen. This cutting tool shall have a cutting edge of 0.005" radius of curvature on a 90 degree wedge. The testing machine shall also be equipped with a 12-Volt detection circuit designed to stop the testing machine when the cutting edge cuts through the wire insulation and contacts the conductor.
2. One inch of insulation shall be removed from one end of an 18" finished wire specimen. The specimen shall be placed on a hard, flat surface and the cutting edge oriented perpendicularly to the axis of the wire specimen. The cutting edge shall be forced through the insulation at a constant rate of 0.2" per-minute until contact with the conductor occurs. The force measured at the time of contact with the conductor shall be recorded. Four tests shall be performed on each specimen with the specimen being moved forward one-inch (minimum), and rotated clockwise 90 degrees between each test. The cut-through resistance shall be the average of the four test result values.

C. Identification

1. Each stranded wire shall be marked with the following information:
 - a. Manufacturer's name
 - b. Year in which wire is manufactured
 - c. Size of conductor
 - d. Type of insulation.

D. The identifying markings shall be permanent and shall be easily readable and understandable.

E. Stranded wires used in multi-conductor cable shall be numbered or color-coded in addition to the basic four-part identification.

1. Internal Multi-Conductor Cable
2. The outer jacket shall be fabricated of TPR - thermoplastic rubber and shall comply with the requirements of IEEE Standard No. 383 latest revision. The jacket shall be stabilized for outdoor exposure. The outer sheath shall have a nominal thickness in accordance with ICEA S-95-658 / NEMA WC70. The barrier tape shall be 0.005 inches thick, with a minimum 25 percent overlap. The individual conductors shall be sized to meet 150 percent of the load requirements, but shall be no smaller than size 19 AWG, stranded.
3. Cables shall be made by assembling the individual or twisted pairs of insulated wires into a tight, cylindrical form. Individual or twisted pairs shall be assembled helically and with adjacent layers wound in opposite directions.

4. The makeup of multi-conductor cables specified by this Section shall not exceed thirty or fifty conductors for use with vital or non-vital plug connectors respectively.
5. Multi-conductor cables shall have 10% spare conductors. Reduction in the number of spares is not allowed unless otherwise directed by the MBTA in writing. All spare conductors are to be terminated unless otherwise directed by the MBTA.
6. The cable outer sheath shall be marked with the following information repeated at intervals no greater than 36 inches:
 - a. Manufacturer's name
 - b. Year of cable manufacture
 - c. Number and size of conductors
 - d. Type of insulation on wires
 - e. Type of outer sheath insulation
 - f. Voltage rating.
7. The identifying markings shall be permanent and shall be easily readable and understandable.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General

Internal wire and cable shall be installed in accordance with the applicable requirements of AREMA C&S Manual Part 10.4.1, Recommended Instructions for Wire and Cable Installation and Maintenance, and as specified herein.

1. Wires and cables shall be installed in a neat, workmanlike manner. Cables in trays or in troughs shall be laid therein and not pulled in. Cables shall be installed with a minimum amount of crossover in the trays and troughs and shall not be pulled tightly around bends. All exposed wires and cables entering or leaving equipment racks or housings shall be protected from abrasion by sharp metallic edges.
2. Nylon straps shall be provided and installed for bundling and cabling of conductors where two or more single conductors are exposed in internal rack bundles, cable trays or cable troughs, or whenever wires are to be bundled. Tape shall not be used for this purpose. Straps shall be installed at intervals not greater than five feet along the cable run. Wires of multi-conductor cables exposed by stripping the cable jacket for termination shall be trained in a neat, workmanlike manner and tied approximately every three inches with nylon straps.
3. There shall be no point-to-point redundancy of wires for increased current capacity.
4. Single conductor No. 14 stranded wire shall be used for interconnecting signal junction boxes and lamp compartments and other miscellaneous equipment, unless other size is shown on the Contract Documents.
5. Internal Ground wires are to be run separately and shall be colored green.
6. Low-voltage wiring, less than 50 Volts shall be separated, from wiring carrying more than 50 Volts, by a minimum of six inches. Where wiring of less than 50 Volts crosses wiring of more than 50 Volts it shall do so at right angles. Individual ground wires shall be separated from all wiring by a minimum of 6".

B. Rack Wiring

1. Vital Racks

Unless otherwise accepted by the MBTA in writing, all vital rack wiring shall be accomplished with approved solderless connections. Wire for vital rack wiring shall be stranded wire as specified herein, minimum size No. 16 AWG or multi-conductor cables as specified herein.

2. Non-Vital Racks

Unless otherwise accepted by the MBTA in writing, all non-vital rack wiring shall be accomplished with approved solder less connections. Wire for non-vital rack wiring shall be stranded wire as specified herein, minimum wire size No. 19 AWG or multi-conductor cables as specified herein.

3. Rack wiring shall be neatly tied into compact bundles. The main bundles and branches shall be secured to the racks in a manner which shall preclude physical damage due to pressure of abrasion and prevent the wire weight from being supported by the wire terminations, connections, or plug connection. The arrangement of the wire bundles and cables shall be such that they do not interfere with visual inspecting, troubleshooting, or repair of the rack-mounted equipment.

C. Rack-to-Rack Wiring

All rack-to-rack wiring shall be routed via the overhead cable trays with one foot of slack between the cable tray and each rack to which the cable or wire is connected.

1. Vital Racks

Unless otherwise accepted by the MBTA in writing, all rack-to-rack wiring for factory wired housings shall be accomplished using single conductors tied into bundles to form unjacketed multi-conductor cables. Unjacketed multi-conductor cables shall consist of individual conductors of size 16 AWG or larger wire and shall have a maximum tie spacing of six inches. Internal wiring for vital circuits shall be in accordance with applicable Sections of the AREMA C&S Manual unless otherwise specified herein. No. 16 AWG 19-strand single conductor flexible wire minimum shall be used for all circuits.

2. Non-Vital Racks

Unless otherwise accepted in writing by the MBTA, all rack-to-rack wiring for non-vital racks shall be accomplished using single wire and multi-conductor cables as specified herein. Non-vital plug connectors use shall be minimized and only as required and as specified within these Specifications.

3. Non-Vital Racks to Vital Racks

Unless otherwise accepted in writing by the MBTA, all wiring between non-vital racks and vital racks shall consist of single conductors, tied into bundles, between the non-vital rack and the vital rack connection points. These individual conductors shall consist of size 16 AWG or larger wire and shall have a maximum tie spacing of six inches. Unless otherwise accepted by the MBTA in writing, all wiring for non-vital circuit energy distribution shall be accomplished using single conductor 19 strand No. 16 AWG. Non-vital intra-rack wiring shall be minimum size No. 20 AWG 19 strand single conductor. Non-vital rack-to-rack wiring shall be single conductor minimum size No. 16 AWG 19 strand wire.

D. Entrance-to-Instrument Rack Wiring

Wiring from entrance racks to instrument racks shall be accomplished using stranded wire, as specified herein, minimum size No. 16 AWG 19 strand wire, and as accepted by the MBTA. Larger flexible stranded wire (No. 14 AWG 19-strand minimum) and (No. 10 AWG 27 strand single conductor flex minimum) shall be used for wiring to switch machines as specified herein and as shown on Contract Documents.

E. High-Voltage Wiring

Internal wire used in circuits directly connected to the rails and internal wire used in circuits which operate at voltages in excess of 600 Volts shall meet the requirements of Section 16808 – EXTERNAL SIGNAL CABLE FOR THE LIGHT RAIL SIGNAL SYSTEM, as specified herein.

F. Energy Distribution

1. Vital Racks

Unless otherwise accepted by the MBTA in writing, all wiring for energy distribution shall be accomplished using single conductor stranded wire as specified herein. Rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 14 AWG. Rack-to-rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 14 AWG.

2. Non-Vital Racks

Unless otherwise accepted by the MBTA in writing, all wiring for energy distribution shall be accomplished using single conductor stranded wire as specified herein. Rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 16 AWG. Rack-to-rack wiring shall be accomplished using solderless connections using stranded wire, minimum size No. 14 AWG.

G. Conductor Sizing

All conductors must be sized per the National Electrical Code and to satisfy the load requirements of the equipment and systems provided, but shall not be smaller than the minimum conductor sizes specified herein.

3.2 TESTS

Internal wire and cable shall be tested as specified herein and in accordance with the requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.

END OF SECTION

SECTION 16856

CABLE TRAYS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section consists of furnishing and installing approved fireproof cable trays adjacent to racks, complete with associated material, in each Central Instrument House.

1.2 QUALITY ASSURANCE

The completed cable tray layout shall be inspected after it has been installed. This inspection shall be conducted in conformance with the requirements of the DB Entity's Installation Inspection Procedure as accepted by the MBTA.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following for the MBTA's acceptance:

- A. Drawings showing design and details of the entire cable tray layout for each Central Instrument House shall be submitted for acceptance by the MBTA. These drawings shall also show the proposed method of installing the overhead cable tray assembly;
- B. Detailed drawings of any required fiberglass support arms for cable trays shall be submitted. The strength, electrical and flame retardant properties of the fiberglass shall be included as a part of the submittal;
- C. An Installation Inspection Procedure for cable trays shall be submitted.

1.4 DELIVERY, STORAGE AND HANDLING

The trays shall be properly braced and protected with padding prior to shipment to prevent damage.

PART 2 - PRODUCTS

2.1 CABLE TRAYS

- A. Cable trays shall be of open ladder type, aluminum or other suitable material commercially available and provide spacing support and strength of material characteristics equal to or greater than the aluminum.
- B. The aluminum ladder type cable tray shall be as manufactured by Husky Products, Inc., "Ventray," Type A6, or MBTA accepted equal, with the following minimum requirements:
 - 1. Ladder rung spacing shall be approximately 6".
 - 2. Side stringer section shall be 0.094".
 - 3. Top and bottom flange section shall each be 0.094".

4. Flange width shall be 0.75”.
 5. Height of rail shall be 3.375”.
 6. Rung thickness shall be 0.062”.
 7. Rung bottom width shall be 2.20”.
 8. Rung top width shall be 0.75”.
 9. Loading, with four foot mounting support:
Six-inch width: 450 lbs., with maximum deflection of 0.20”. Eighteen-inch width: 305 lbs., with maximum deflection of 0.14”.
- C. If the cable tray material is conductive in nature and the layout includes any support mounting to the instrument and entrance racks, such mounting shall be by means of MBTA accepted fiberglass arms or stand-offs in order to insulate the cable tray assembly from the instrument and entrance racks.
- D. Each cable tray shall be designed and fabricated with sufficient capacity to provide 50 percent of the cross-sectional area as free air space after the full number of cables and wires are installed. Corners shall be a minimum radius of six inches, for either horizontal or vertical turns. Sufficient overhead space shall be available after installation to permit wires and cables to be inspected.
- E. Where practicable, the tray shall be constructed in straight sections joined with approved couplers.
- F. Using the manufacturer's standard, the tray shall be laid out using a minimum number of sections, but providing maximum continuous runs without gaps.
- G. All fittings, supports, and accessories shall be furnished in accordance with the manufacturer's recommendations.
- H. Insofar as practicable, cable trays shall be supported by cantilever type brackets in order that the cables can be laid into the tray without pulling.
- I. Where the width of the tray, or the loading of cables is such that cantilever supports are impracticable, other approved suspension methods may be used, but such application shall be kept to a minimum.
- J. At least three supports shall be provided for each length of tray. Supports shall be evenly spaced insofar as possible; in no case shall the spacing between adjacent supports exceed five feet.
- K. To prevent damage to cables, no metal edges of any description shall protrude and no sharp corners shall exist in the completed layout.

2.2 FIBERGLASS SUPPORT ARMS

Fiberglass support arms, where required to insulate the cable tray from the equipment racks, shall be flame retardant, reinforced polyester laminate Class "B", 130°C electrical sheet, meeting NEMA GPO-2, and ASTM D709 requirements and as accepted by the MBTA.

2.3 PRODUCT, PACKAGING AND SHIPMENT

The trays shall be braced properly prior to shipment and covered with padding, as required, to prevent damage.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. The installation work shall include any preparatory work required in connection with the placement of the wire chases and cable trays. Aluminum shall be installed so that it does not come into contact with concrete.
- B. The overhead cable tray assembly for the Central Instrument Houses shall be suspended from the ceiling.
- C. Sufficient support shall be provided to limit the loaded cable tray deflection to a maximum of one-quarter inch at mid-span. Tray supports and trays shall be mounted plumb and level.
- D. Where cable tray splice joints occur in a run, trays shall be supported immediately adjacent to and on both sides of the splice fitting. Trays shall be bolted to support members. Precautions shall be taken to prevent anchoring bolts from damaging cables placed in the trays. All cable trays shall be bonded and grounded. The method of installation shall be in such a manner as to minimize ground loops. All cable trays shall be insulated from all walls, ceilings, instrument racks and terminal racks, prior to grounding as described in Section 16876 – GROUNDING OF SIGNAL SYSTEM EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM.
- E. The DB Entity shall round all edges of the cable tray and cover all edges and angles with rubber protection for the cables or wires run in any cable tray.

END OF SECTION

SECTION 16857

PLUG CONNECTORS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing plug connector assemblies required for connecting multiconductor cables or individual wires to the internal wiring of panels, specified plug-connected racks, or equipment modules. Use of plug couplers shall be strictly limited to those applications where equipment interface requirements provide no other option. It is the intent of this Project to minimize the use of plug couplers.
- B. These assemblies shall hold and insulate individually mated extractable pin-and-socket contacts that shall be mechanically crimped to individual wires or wire wrap pins. The connector assemblies shall be easily connected and disconnected by hand and shall be provided with mechanical locking and keying devices.
- C. Two basic types of connectors shall be furnished; a vital circuit type and non-vital circuit type. The number of contacts in a vital circuit plug connector shall not exceed 30 contacts. Non-vital circuit plug connectors shall not exceed 50 contacts.
- D. The connector assemblies shall be easily connected and disconnected by hand and shall be provided with mechanical locking and keying devices.

1.2 QUALITY ASSURANCE

- A. Each plug connector assembly shall meet the applicable requirements for the documents as listed below, where these documents do not conflict with the requirements of this Specification:
 - 1. MIL-M-14 Molding Plastics and Molded Plastic Parts; Thermosetting
 - 2. MIL-C-8384B Connectors; Plug and Receptacle - Electrical Rectangular Type, Molded Body
 - 3. MIL-W-1687D Wire, Electrical Insulated, Copper
 - 4. MIL-STD-202 Test Methods for Electronic and Electrical Component Parts
 - 5. MIL-STD-454 General Requirements for Electronic Equipment and for solderless pin and socket contacts:
 - 6. MIL-G-45204 Gold Plating, Electrodeposited
 - 7. MIL-C-50 Copper Alloy Number 260 (Cartridge Brass)
 - 8. FS QQ-S-766 Steel, Corrosion Resistant
 - 9. FS QQ-N-290 Nickel Plating; Electrodeposited

- | | | |
|-----|-------------|---|
| 10. | MIL-STD-10 | Surface Roughness, Waviness, and Lay |
| 11. | MIL-STD-105 | Sampling Procedures and Tables for Inspection by Attributes |
| 12. | MIL-STD-202 | Test Methods for Electronic & Electrical Component Parts |
| 13. | ASTM-A-167 | Stainless Steel |
| 14. | ASTM-B-36 | Cartridge Brass |
| 15. | ASTM-B-140 | Commercial Bronze |

B. The following tests shall be made on six or more randomly selected plug connector assemblies at the start of the production run for this Project. The same tests shall be repeated on additional samples selected at intervals of no more than 500 plug connector assemblies as the production run continues.

1. Each half of the plug connector assembly shall withstand for one minute a dielectric strength test of 900 Volts AC (RMS) applied between adjacent contacts and between the contacts and the other metallic parts of the connector assembly.
2. A minimum of six randomly selected contacts shall be tested to have not less than ten pounds of retention after each contact has been inserted and extracted ten times using the applicable extraction tool. The force to dislodge the aged contacts from their cavities shall be measured and recorded after the eleventh insertion.
3. The durability of the connector assemblies shall be measured by subjecting fully wired assemblies having a full complement of contacts to 500 cycles of mating and unmating, with the connectors being fully locked and unlocked during each cycle. After cycling, the connector assemblies shall show no evidence of mechanical damage or missing parts.
4. The mated connectors shall be vibrated in accordance with Method 204, Condition A of MIL-STD-202 with arrangements to monitor a test circuit with 100 ma flowing through the contacts. When tested, the connector assemblies shall show no evidence of cracking or breaking and there shall be no loss of continuity of any circuit greater than one microsecond.
5. The mated connectors shall show no evidence of mechanical damage after being subjected to a shock test in accordance with Method 205, Condition C of MIL-STD-202, repeated three times, for a total of 18 drops.
6. The mated connectors shall show no evidence of mechanical damage after being subjected to temperature cycling in accordance with Method 107, Test Condition B of MIL-STD-202 with a minimum operating temperature of minus 55 degrees C and a maximum operating temperature of plus 150 degrees C.
7. The unmated connectors shall show no evidence of corrosion and shall be capable of being mated and unmated after being subjected to a moisture environment in accordance with Method 106 of MIL-STD-202, except that 7b is not required.
8. The DB Entity shall provide a complete certified test report for each of the plug connector tests prescribed. These reports shall include the date, location, number and origin of specimens, type of test, test conditions, and results of the test.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection

2.8, the DB Entity shall submit the following for the MBTA's acceptance:

- A. Submit an application description evaluating alternate termination methods that shall be subject to the MBTA's final acceptance. No plug couplers shall be utilized prior to acceptance by the MBTA for both product and application.
- B. Complete drawings for each type of plug connector. These drawings shall include complete parts lists and information required for ordering replacement parts. Drawings shall be required for the following components:
 - 1. Molded plug connector blocks,
 - 2. Protective shells for blocks,
 - 3. All locking and keying devices,
 - 4. Strain-relief clamping devices,
 - 5. Extractable pin-and-socket contacts.
- C. Submit three certified copies of all plug connector test reports within seven days of test.
- D. Submit complete reference information for each type of plug connector tool to be used. This includes insertion, extraction, wire crimping and all other tools used in performing installation of a finished wiring system. This information shall include parts lists complete with ordering reference numbers for all replacement tools and parts provided.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Each plug connector assembly shall consist of the following:
 - 1. A two-part molded plastic connector block equipped to hold an appropriate number of solderless, pin-and-socket contacts,
 - 2. Devices for the mechanical locking and keying of the connector block halves,
 - 3. Protective shells for both block halves of the connector,
 - 4. A strain relief device for the external wiring portion of the connector assembly,
 - 5. Solderless, extractable pin-and-socket contacts,
 - 6. Where required, embedded wire-wrap terminals for the internal wiring portion of the connector block.
- B. Connector Blocks
 - 1. The connector blocks shall consist of molded dielectric plastic, shaped to accept the required number and types of contact pins, contact sockets and locking, keying and mounting devices. The dielectric material shall exhibit a minimum insulation resistance of 100 mega-ohms as measured between adjacent pairs of contacts and between the accessory hardware and the closest contacts in each connector assembly half.
 - 2. The contact cavities shall be arranged in a rectangular grid configuration. The opening for each contact shall be uniquely identified by a coordinate molded into both the mating and wiring faces of each part of the connector block.

3. The vital plug connector blocks shall provide a surface leakage distance of not less than 1/4 inch between contacts and between the contacts and any other metallic part of the connector assembly.

C. Locking and Keying

1. Each plug connector assembly shall include a device for mechanically locking the two mated parts together.
2. Mechanical devices and facilities shall also be provided to allow the mating parts of connector assemblies to be keyed in such a manner that they cannot be coupled except when in the correct position relative to each other and cannot be coupled to the mating parts of other coupler assemblies keyed in a different pattern.

D. Protection and Strain Relief

1. Each half of the plug connector block shall be protected by a metal shield that shall extend beyond the mating surface. These two shields shall overlap when the connector halves are coupled.
2. The external wiring portion of each plug connector assembly shall be equipped with a device to grip the external wiring firmly in order to prevent strain on the plug connector contacts.

E. Pin-and-Socket Contacts

1. The pin-and-socket contacts shall be fabricated from commercial bronze or brass and plated with gold over nickel underplate. The retention springs of the pin-and-socket contacts shall be fabricated from stainless steel.
2. The contacts shall be fabricated and classified in the required selection of sizes to accept wire sizes 16 through 22, AWG.
3. Contact current rating and termination resistance shall meet the requirements of the following table with properly sized contacts applied to the wire sizes specified.

	Wire Size (AWG)			
	16	18	20	22
Minimum Current Rating (Amperes)	13.0	10.0	7.5	5.0
Maximum Termination Resistance (Milliohms)	1.7	2.0	2.7	4.0

4. Contact termination resistance shall be measured in accordance with Method 307 of MIL-STD-202 at the rated current specified for each wire size.

2.2 TOOLS

Tools used to apply plug connector contacts to wire and tools used to extract contacts from the plug connector blocks shall be the size and type recommended by the manufacturer of the plug connector assemblies. Two complete sets of plug connector tools shall be provided within a lockable wall mounted cabinet in each CIH furnished.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. The vital plug connector assembly shall be required where any vital circuits are to be interconnected and the non-vital plug connector assembly shall be used where non-vital circuits are to be interconnected, as accepted by the MBTA.
- B. For plug connectors dedicated to single multiconductor cables, 20 percent of the wires and connector contacts shall be reserved for future working circuits. Plug connectors used for made up, unjacketed, cables, 20 percent of the connector contacts shall be reserved for future working circuits.
- C. For plug connectors assembled to a multiconductor cable, the strain relief device shall grip the cable outer sheath.
- D. For vital or non-vital plug connectors dedicated to a cable, each wire of the cable shall be terminated properly on a connector contact.
- E. In each case, a uniform scheme shall be followed in assigning specific cable wires to specific connector contacts.
- F. Where a full hand grasp is required to connect or disconnect a plug connector, a minimum of two inches of clear space shall be provided around the connector. A minimum of three-quarters of an inch of clear space shall be provided around connectors that can be connected or disconnected with thumb and fingertips only.
- G. Plug connectors shall be located and installed in such a manner that no part of the plug connector or its cable will extend beyond the wire routing as defined by the wire supports and in no circumstances shall the connector or its cable be permitted to protrude into an aisle-way.
- H. Each plug connector assembly, as finally installed, shall be marked in such a manner that its mating halves shall be distinctly identified as being related to each other, but to no other plug connector assembly within the immediate area. These identification markings shall be applied in such a manner that they will not be obscured or worn off in normal use.

END OF SECTION

SECTION 16858

RELAYS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the provision of all required relays. Relays shall be plug-in type. Relays of each type shall be uniform in design and contact assembly.
- B. A sufficient number of contacts for the number of circuits to be controlled plus spare contacts shall be provided. Each relay or relay repeater combination shall have at least two spare dependent front-back contacts, or one spare independent front and one spare independent back contact.
- C. All relays and equipment specified shall be capable of rated performance through an operating temperature range of minus 40 degrees F to plus 160 degrees F.
- D. All relays shall be in dustproof enclosures, except, where required, a provision shall be made for ventilation for heat dissipation.
- E. Vital relays shall be equipped with a registration plate to prevent relays of the wrong style, contact arrangement, or operating characteristics, from being inserted into the plugboard.

1.2 QUALITY ASSURANCE

- A. Vital relays shall meet the requirements of AREMA C&S Manual, Part 6.2, Recommended Plug-In Vital Relays, except as specified herein.
- B. Non-vital relays shall meet the requirements of AREMA C&S Manual Part 6.3, Recommended Non-Vital Relays, except as specified herein.
- C. The factory testing of each relay shall be the manufacturer's standard and as accepted by the MBTA.
- D. Relays must be tested in the field after delivery and prior to in service activation.
- E. Prior to use of any relay, the DB Entity shall obtain the MBTA's written approval. Approval will be based on such evidence and tests as the MBTA may require to be carried out, without additional costs to the MBTA.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following for the MBTA's acceptance:

- A. Catalog cuts and descriptive literature for all material as specified herein, as shown on the Contract Documents and proposed for use;
- B. All relay and plugboard specifications, identification tags, and any special mounting or supporting arrangements, and contact stacking arrangements, for all relay types which he proposes to furnish. The submittal shall include any arc suppression where arc suppression is required;

- C. Applicable test form for each vital relay furnished for this Project. The use of typewritten characters shall be used to fill in all information requested on the form and then verified in the field in its final configuration, for accuracy of relay serial number, location and relay identification. Indexing of form cards shall be by serial number, and turned over to the MBTA upon equipment delivery by DB Entity.
- D. Ten relay manuals and ten copies of relay specifications and calibration sheets for each type of relay furnished;
- E. In the event of excessive long relay nomenclature on relay identification tags, the method of identifying such relays;
- F. MTBF data for all types of relays proposed.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Vital relays shall be shipped separately from the wired racks in which they are to be used. They shall be packaged individually, each in a sturdy corrugated cardboard carton with the drawing number of the relay printed on the outside of the carton.
- B. Relays shall be protected against damage during shipment and shall be secured against loss and damage during storage.

PART 2 - PRODUCTS

2.1 VITAL DC RELAYS

- A. General
 - 1. Vital DC relays shall be of the plug-in type and rack-mounted. They shall have a transparent dust cover made of a non-flammable composition that will not support combustion.
 - 2. Vital relays, with a nominal operating voltage of 10-16 Volts, shall be capable of operating continuously without resultant damage with a minimum voltage range of 7 to 21 Volts inclusive applied to their operating circuits.
 - 3. Biased neutral vital relays shall be designed so that gravity alone will prevent the armature from picking up if the permanent magnet is de-energized or if no current is applied to the coil due to interruption of the normal magnetic circuit. Biased neutral vital relays shall be designed so that up to at least 50 times working energization applied for two seconds at both normal and reverse polarity will not affect their operating characteristics by more than 2%, and will not pick up their armature on reverse polarity.
 - 4. Vital DC relays, unless otherwise indicated on the Contract Documents, shall have coil resistance values of 500 ohms or less.
 - 5. Each vital relay shall have a minimum of four dependent front-back contacts, two independent front contacts and one independent back contact. All front contacts shall be silver-to-metalized carbon, except for heavy duty, extra heavy duty, or special application relays.
 - 6. When three DC vital relays suppressed as specified herein are connected in parallel and operated, as a test load from normal working voltage, a vital relay front or back contact that breaks this load shall be capable of at least five million operations at this load without the contact resistance, measured with a 10 ma current, exceeding five ohms.
 - 7. Arc suppression for vital relays shall be built into the relay or into its plugboard.

8. Contact arrangements shall be identical for similar types of relays, exceptions made for special function relays only.
9. All vital plug-in relays, except vital time-element relays and special application relays shall be equipped with front current testing facilities. Where required by the MBTA facilities shall be provided to enable the testing of voltage from the front of the relay.
10. Plugboards shall be manufacturer's standard for the relays provided and as accepted by the MBTA.

B. Track Circuit Relays

1. Track Circuit Relays shall be biased neutral type with high drop away/pick up ratio compatible with the steady energy train detection equipment provided for this Project.

2.2 NON-VITAL RELAYS

- A. Each non-vital relay shall be equipped with a minimum of six front-back contacts. Stationary contacts shall be bifurcated silver, palladium, or approved equal. Movable contacts shall be bifurcated silver, palladium with gold overlay, or approved equal.

- B. Non-vital relays shall meet or exceed the following requirements:

1. Maximum Temperature Rise: 175 degrees F at 30V DC
2. Insulation Resistance: 1.5×10^{10} ohms
3. Ambient Operating Temp.: minus 60 to 160 (degrees F)
4. Dielectric Strength: 500 Volts RMS, 60 Hz between all mutually insulated parts
5. Mechanical Life: 100 million cycle operations
6. Electric Life: 10 million operations (0.5 ampere resistive load at 77 degrees F)
7. Contact Resistance:
 - a. Before Life 100 milliohms max. at 6V DC, 100 ma
 - b. After Life: 200 milliohms max, at 6V DC, 100 ma.

- C. Non-vital relays shall be mounted in dust-proof cabinets having transparent front plates which shall not support combustion. These cabinets shall be mounted in racks as specified. As an alternate these relays may be furnished with individual transparent covers that will not support combustion and shall be rack mounted.

- D. The design of the individual relay covers and of the cabinet in which several relays are mounted shall permit viewing the relays without disassembly or other mechanical manipulation to determine whether each relay is in the picked up or dropped out position.

- E. Non-vital relays shall be plug-in DC neutral, biased, or diode-suppressed relays with a typical, nominal operating voltage of 24 Volts. Where other voltages are required, the relay and application shall be submitted and acceptance will be at the sole discretion of the MBTA. These relays shall pick up with 18 volts or more applied to their operating circuit, and must drop out when

this voltage decreases below two volts. These relays shall be capable of operating continuously up to a maximum of 42 volts applied to their operating circuit. Non-vital relays shall pick up in less than 25 milliseconds when energized with 18 volts, and shall drop out when de-energized from 28 volts in less than 50 milliseconds. These times shall be measured as a front contact closure or opening from the instant the switch applying the voltage closes and from the instant the switch removing the voltage opens.

- F. Contact resistance of non-vital relay front and back contacts shall not exceed five ohms after 10 million operations when breaking a test load equivalent to three non-vital relays connected in parallel and suppressed as required in these Mandatory Specifications. Operating voltage for this test shall be 24 volts. Contact resistance shall be measured with a 10 ma current. All non-vital relays shall be identical by type and class, or function.
- G. Relay coils that are wired to solid state equipment shall have their coils suppressed such that transient voltage spikes are minimized to protect electronic equipment.

2.3 IDENTIFICATION

- A. DB Entity shall mount an approved typed or machine printed relay name tag for each relay on the relay cabinet front plate, if this is not possible, upon acceptance from the MBTA the tag can alternately be applied to the relay cover. The name tag shall be easily replaceable, but shall not come off during normal service. Proposed excessively long relay identification tag nomenclature shall be submitted by the DB Entity for approval.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. The DB Entity shall ensure that all AC and DC power buses are open while installing relays and shall not reconnect these buses until all relays have been installed.
- B. Relays for track circuits shall be mounted in the upper-half of the relay rack.
- C. Relays or components shall be mounted at a height of no more than six feet or less than one foot from the floor of the room. The overall height of the rack shall not exceed seven feet - six inches.
- D. Power feeds through switch mechanism control relays shall be closed only during testing, prior to in- service operation.

3.2 TESTS

- A. The DB Entity shall test all relays in accordance with the recommended practices as established in AREMA C&S Manual Part 6.4.1, Recommended Instructions for Direct-Current Relays, and all requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

END OF SECTION

SECTION 16850

VITAL MICROPROCESSOR INTERLOCKING SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The work to be done under this Section consists of the furnishing, installation and testing of vital microprocessor interlocking systems (VMIS) to control all Vital functions at each interlocking in accordance with all applicable sections of the AREMA C&S Manual, except as specified herein.

1.2 QUALITY ASSURANCE

- A. The DB Entity shall provide for system testing, documentation, training and quality assurance as specified within these Mandatory Specifications.
- B. Processor systems and equipment provided shall be in accordance with latest requirements of the AREMA C&S Manual in effect at the time of award, where the manual does not conflict with these Specifications. The system shall be provided to operate in accordance with all applicable AREMA recommendations/requirements for the control and indication of interlocking Vital functions.
 - 1. The DB Entity shall certify and provide documentation to demonstrate that the system provided has been successfully tested and operated after being exposed to conditions as specified in AREMA C&S Manual, Part 11.5.1 – Recommended Environmental Requirements for Electronic Railroad Signal System Equipment for a Class C environment.
 - 2. The methodology for quality assurance, maintainability, software revision control and reliability assurance shall comply with the recommended practices of the AREMA C&S Manual, Part 17.
- C. DB Entity shall submit to having a representative sample of VMIS Class I printed circuit boards evaluated by an independent third party laboratory to determine quality assurance compliance at the point of manufacture. The laboratory inspection shall require a minimum microscopic examination level of 15X and shall conform to the standards of IPC-A-610. A minimum 10% of the proposed printed circuit boards to be utilized for this Project shall be submitted for evaluation. Further examination of the remaining printed circuit boards will be at the discretion of the MBTA upon review of the independent test results. Independent inspection will be conducted at a laboratory facility within 50 miles of Boston, MA.
- D. The design of the system shall also comply in every respect with the Rules and Regulations Governing Railroad Signal and Train Control Systems as issued by the office of Safety, Federal Railroad Administration, latest publication at the time of award, and of any supplements thereof that become effective before Notice to Proceed.
- E. The DB Entity shall certify that the entire VMIS that he proposes to furnish has been tested to successfully operate in the high EMI noise environment of an operating DC traction power system. The system shall comply with the requirements of MIL STD 461 where applicable to a transit/railroad type environment.
- F. The DB Entity shall have a recommended process for change control, verification and retest of

vital software to be implemented for all vital software changes during and after cut-over and testing.

- G. The DB Entity shall have a recommended minimum retest process for the replacement of various parts of the VMIS including which is not limited to the CPU Board, Power Supplies, Input/Output Boards, serial and network communications boards, etc. This process shall ensure the safety and integrity of the system if all recommended tests are completed after the part of component is replaced.
- H. The modules of the system shall have demonstrated Mean Time Between Failure (MTBF) of no more than one failure in every 35000 hours (or 4 years) of operation when applied at a typical interlocking with two crossovers.
 - 1. The system in the design configuration shall have a Mean Time to Restore (MTTR) of 30 minutes maximum. This does not include travelling time, only the time to return the equipment to normal operation.
- I. Complete calculations of the predicted Reliability and Maintainability (R&M) shall be furnished. Actual performance data for a like system for which reliability records have been maintained for a period of not less than 5 years may be used to support or substantiate the submitted R&M calculations.
- J. The system and equipment shall be designed such that spare parts and software support will be available for a minimum of 20 years. This provision shall require that written certification is furnished to the MBTA prior to delivery.
- K. The DB Entity shall advise the MBTA immediately of any changes or upgrades to the interlocking system software and the reasons for such upgrades. Changes to the system software which affect train safety shall be provided to the MBTA at no additional cost. If, during phased testing (factory and/or field), the DB Entity upgrades the executive software, all locations shall receive an identical upgrade. Also, those systems for which testing has been completed shall be re-tested with the DB Entity at no additional cost to the MBTA.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and 2.8, the following plans and information shall be submitted for approval prior to fabrication and factory wiring of the system. Procurement or fabrication of the VMIS shall be at the DB Entity's risk until acceptance has been received from the MBTA for all relevant submittal documents herein specified.
 - 1. Complete schematic drawings for all systems and subsystems,
 - 2. Complete application circuit plans for all input and output functions performed by each location/system,
 - 3. Complete software application logic (in relay equivalent format) for each location/system fully commented in plain English,
 - 4. Complete power distribution circuit drawings and schematics,
 - 5. Complete power calculations for all power sources energizing the vital controllers or controlled, or switched, by vital controllers. Where specific ripple or regulation specifications exist for the vital controllers or associated equipment, compliance with such ripple or regulation specifications shall be demonstrated to the satisfaction of the MBTA,
 - 6. Complete rack layout and arrangement of equipment,

7. Complete equipment plans and installation drawings showing all components of the system. These drawings shall include complete keyed parts lists for all components of the system, circuit board layouts, keying methods, racks, terminal boards, plug connectors, other interconnecting devices, cable boots, mounting hardware, and all other rack-mounted equipment and hardware,
8. Complete predicted Reliability and Maintainability (R&M) calculations. Actual performance data for a like system for which reliability records have been maintained for a period of not less than five years may be used to support or substantiate the submitted predicted R&M calculations.
9. A complete Factory Test Procedure for testing each location in the factory prior to shipping to the field,
10. Subsequent to qualification testing and factory witness testing, and prior to shipment, certified factory test reports shall be submitted for acceptance,
11. Complete and comprehensive manufacturer's recommended Installation and Inspection Procedures,
12. Field Test Procedures & Test Reports designed to verify that the installed system at each location meets all safety and operational requirements of this Mandatory Specification,
13. One copy of all manuals and documentation required by this specification. Upon approval of the content, organization and format all documentation required by this Section shall be delivered to the MBTA.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Equipment furnished under this Section shall not be shipped until the Factory Test Reports have been accepted, in writing, by the MBTA Comply fully with the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEMS.
- B. Each item of the VMIS shall be inspected by the DB Entity and MBTA (or an MBTA representative) for shipping damage prior to installation.

PART 2 - PRODUCTS

2.1 GENERAL

- A. General Requirements - VMIS systems and equipment shall be provided in accordance with the requirements of this Section and other sections of these Specifications and shall also include, but not be limited to the following:
 1. The product used for this application shall be Ansaldo's Microlok II or MBTA accepted equivalent designed and applied in a hot standby redundant configuration.
 2. In addition to the "Normal" and "Standby" units, a third cold standby unit will be rack installed complete with all (same count) boards specific to the VMIS units installed and running at that location. The cold standby system will include two processor units with application and executive logic preloaded and matching those running in the normal and standby VMIS units. Additionally, the cold standby will include any boards that have site specific IC chips.
 3. Provide a system, which has a proven record of implementation and operation within a 13.8KVAC and 600VDC electrified rail environment for a period of at least five years;
 4. A complete Office Development System that allows programming development and

- simulation to create, edit and generate all application software systems and logic;
5. A complete Field Diagnostic System suited for field environments that allows for real time monitoring of logic execution and analysis of hardware/software operation;
 6. Complete system documentation and user manuals;
 7. Licenses to use all furnished system software;
 8. Other apparatus including, but not limited to, modems, chassis, cables, power supplies, test equipment and all circuit boards;
 9. Engineering including but not limited to, all application, software, hardware and support engineering;
 10. A minimum of 100% spare capacity will be provided for normal and standby systems for future expansion of the application logic. A minimum of 20% spare capacity will be provided for normal and standby systems for future expansion of I/O. This spare capacity requirement applies to the VMIS system in each CIH.
 11. Equipment and software shall be the most recent proven versions.
- B. All microprocessor equipment shall be mounted complete with necessary accessories on standard 19- inch racks to accommodate equipment utilizing standard EIA hole spacing. Racks and/or cabinets shall be furnished with provisions for EMI mitigation and ventilation as required for optimum performance. No forced air ventilation shall be used.
- C. The VMIS and all components associated therewith must have a demonstrable history of safe and reliable use in revenue operation in a similar operating environment to that of the existing MBTA Green Line.
- D. Unless otherwise specified, all systems shall operate without any degradation over the temperature and humidity range specified in the environmental requirements recommended in AREMA C&S Manual, Part 11.5.1, for Class C environment.
- E. Within the system furnished, like functions shall be performed by identical units. In no case shall the hardware or equipment used in one portion of the system be different from that used in another portion to perform the same function under identical operation and environmental conditions.
- F. The application of special custom assemblies shall be confined to those required to comply with the Specification. Every effort shall be made to minimize custom design and minimize the number of unique chassis or modules.
- G. The vital microprocessor interlocking system shall consist of a number of vital processor units and the associated cables, plugs, wire connectors, terminal boards, power conditioning equipment, instrument racks and hardware.
- H. All plug connectors, power supplies, power conditioning devices, terminal boards, wire connectors and other equipment required to achieve a complete, stand-alone subsystem shall be mounted on the instrument rack along with the associated vital processor units.
- I. Each vital processor unit shall be provided with vital serial communication capabilities. The number of vital ports shall be sufficient to allow inter-connection of the vital processor units to adjacent systems.

- J. Each vital processor unit cardfile(s) or pair of cardfiles shall contain printed circuit boards of the types described herein. Additional types of printed circuit boards required for the operation of the vital processor units shall be furnished and installed as required. Combination of functions among the board types shall be allowed only as specified herein.
1. The printed circuit boards shall be housed within a cardfile and be of the plug-in type. Keys shall be provided on the cardfile to prevent insertion of improper printed circuit board types.
 2. The cardfiles shall be factory mounted in a standard rack designed to accommodate standard EIA hole spacing. All wire connections to the cardfiles shall be via plug connected cables. The vital processor cardfile units, when mounted in the rack, shall have access from the rear.
 3. All I/O, including spares, shall be wired through Din Rail mounted terminal blocks installed within the same rack as the I/O points which they are connected for ease of access.
 4. No forced air ventilation shall be allowed.
- K. The VMIS shall not use any custom or semi-custom integrated circuits.
- L. The design shall provide that all cables or wiring leaving the instrument racks shall be routed through rubber boots or some other form of anti-chafing mechanism at the top of the racks and be provided with means to be neatly routed and securely fastened with tie straps.
- M. The hardwire DC inputs of the vital processors shall not respond to AC of any voltage level. The hardwire inputs shall be biased and shall not, under failure condition, respond to any voltage of improper polarity. Hardwire inputs shall be optically isolated from the 5 volt logic of the VMIS.
- N. The vital hardwire outputs of the vital processors shall provide security equal to, or greater than, conventional double-break relay circuits. The hardwire outputs shall be optically isolated from the logic of the VMIS.
- O. A hardware and firmware shall use a keying method rendering it impossible for any vital processor to operate with application dependent firmware designed for any other vital processor.
- P. Plug connectors shall comply with all of the requirements of Section 16857 – PLUG CONNECTORS FOR THE LIGHT RAIL SIGNAL SYSTEM.

2.2 DESIGN REQUIREMENTS

- A. The VMIS system will perform all vital functions for the location for which it controls. Non-vital functions will be performed in the NVMIS. Non-vital outputs to the vital application logic (Signal and switch controls) shall have the ability to be forced for the purposes of performing vital locking functional tests without interference from non-vital application logic checks. Functions or equipment related to the NVMIS shall not interfere with the safe operation of the vital processor.
- B. The vital microprocessor interlocking system (VMIS), as herein specified, shall be designed on the basis of closed circuit/loop principles, software diversity and use of proven vital hardware design techniques to achieve safety.
- C. Provide a system that is immune to levels of internal and external electrostatic and electromagnetic conducted or radiated interference including MBTA's radio system equipment and commercial broadcast frequencies such as used for television, radio, CB etc., that may have transmitters or other equipment operating in close proximity to MBTA's right-of-way.

- D. The physical and mechanical configurations of equipment and rack assemblies shall give high priority to the ease with which the units may be inspected, maintained, and removed. Location of all equipment shall be on racks as shown in the Contract Documents.
- E. All circuit boards shall have internal as well as external data and power surge protection, as required.
- F. The VMIS design shall be based upon solid-state microprocessor technology and shall not require any off-line storage devices for operation or start up. The processor proposed shall be a widely accepted design. The operation of the system shall be programmed in solid-state memory. In addition, other requirements as specified herein, shall be part of this system.
- G. System outputs shall be positively sampled using independent current/voltage sensors and compared to the requested value. The application software shall re-evaluate all software instructions for integrity based on most recent logic states. The processor shall continually retest all input and output states for any change of status and shall constantly test for proper instruction execution.
1. A vital relay shall be provided to de-energize all outputs and affect a systems shutdown in the event that any output fails to correspond to the requested state or through the sensing of a critical systems error. In such an event, it shall be ensured that the wayside interlocking signals will display a double red aspect and automatic signals display a single red aspect.
 2. The system shall attempt an automatic restart executing safety checks when shutdown is caused by an input/output failure. No automatic restart shall take place in the event of a processor failure after failover.
- H. The operating instructions for the VMIS shall be divided into application and executive portions.
1. The executive instructions shall be stored in solid-state read only memory (ROM) or solid-state programmable read only memory (PROM) devices and shall be referred to as the Executive Firmware. The application instructions shall be stored in solid-state EEPROM devices and use a jumper configuration method, as approved, and shall be referred to as the Application Firmware.
 2. The Executive Firmware and Application Firmware shall reside in separate memory devices.
 3. The system software shall draw a secure distinction between the executive and the application software such that it shall be impossible through the implementation of the application software to overwrite or otherwise modify the executive software.
- I. The system shall be capable of interconnection to a PC, via serial link or network connection that will permit observation of internal logic bits during testing and normal operation.
- J. Vital Processor Units shall be equipped with on-board diagnostics. These diagnostics shall quickly and reliably identify failed printed circuit cards.
1. Indications shall isolate a failure to a particular function, or to the interface between two functions.
 2. All on-board diagnostics shall be available for access by an external PC via serial link.
 3. Any diagnostics or monitoring of the system shall not have the ability to change executive or application software routines.
- K. Visual indications, such as LED lamps, shall be used to demonstrate that the system is

functioning properly and to indicate faults, state of individual I/O, serial/network links, etc.

- L. The unit shall be designed with convection cooling such that heat generating components (e.g., transistors with heat sinks and large wattage resistors) shall not be located next to other components that are affected by temperature.
- M. No failure of any component of the VMIS shall cause the vital interlocking system to fail in a less restrictive mode.
- N. Each unit shall have a unique site identification code. This code and any other site specific information shall be resident on either the unit's CPU board, the mother board (back plane), or a separate device connected securely to the unit. Where hardware settings are required, the hardware shall be located where the unique ID code cannot be inadvertently changed.
- O. All equipment shall be designed in a modular fashion to the greatest extent possible.

2.3 POWER REQUIREMENTS

- A. Equipment requiring non-interruptible power supply system will not be acceptable. The processor system source shall be 12 volts DC ungrounded supplied by a traditional battery-rectifier supply. If commercial AC power is required as input to racks, the voltage shall not exceed 120 VAC. Protection against surges, spikes and over-voltage shall be provided. The DB Entity shall protect all power feeds, input and output leads, and all other auxiliary equipment with lightning and surge protection as necessary.
- B. All connections to external circuits shall be designed to interface to standard signal equipment operating at normal voltages for the type of equipment. Any modifications or additions to the system to operate any device shall be the responsibility of the DB Entity.
 - 1. The units shall be designed for operation from a nominal input voltage of 12 VDC, and shall operate over the range of 9.5 VDC to 16.5 VDC. Equipment shall operate over the specified input voltage range without requiring any adjustment.
 - 2. The unit shall provide automatic restart of operation after a DC power failure. As the battery voltage gradually increases, the equipment shall not try to resume normal operation until the battery voltage reaches the lower limit of the operational voltage range.
- C. The DB Entity shall provide all internal logic level power supplies. All DB Entity supplied power supplies shall provide DC isolation and indicator LEDs.
- D. Each chassis, cabinet or sub-system shall have its own dedicated power supply. The DB Entity shall supply all such devices to include, but not be limited to, the power supply, power switches, fuses and surge protection.
- E. The DB Entity shall be responsible for selecting and supplying devices that shall not create electromagnetic interference that may affect any other MBTA system or that will be affected by any other EMI or radio systems.
- F. The power supplies selected shall have a proven reliable record in the application within the transit environment.
- G. All power supplies shall be designed for easy removal and replacement and not require any de-

soldering to remove or replace.

- H. The DB Entity shall provide for indication fusing and lightning and surge protection as the power enters the rack. Separately fuse power to each CPU (normal & standby) and to each of normal & standby input and output boards. An individual fuse shall be supplied for the energy to individual input and output circuit boards.

2.4 ARCHITECTURE REQUIREMENTS AND REDUNDANCY

- A. A second on-line operative unit shall be furnished and installed to provide a “hot” standby i.e. no requirement for running time before offline unit can take over, in the event of primary unit failure. The units shall be labeled “Normal” and “Standby.”
 - 1. The transfer from the normal to standby unit shall be seamless and automatic without special commands or programs. The transfer of control between normal and standby units shall not compromise continuity or protection of the operator controlled functions. These functions shall be designed in a fail-safe mode to prevent the clearing of signals into a protected section of track.
 - 2. There shall be no preference or default normal state in the transfer logic for normal or standby operation.
 - 3. Only one unit shall be enabled to output at any given time, this unit will be indicated as the “on- line” unit. The offline unit shall receive all inputs and execute all logic, but will have its outputs disabled. Transfer of control between the on-line and offline units shall only occur when the status and control panel is in the “Auto” mode and shall be seamless and instantaneous so as to not cause signals to go to stop or cleared routes to unlock. Only when the executive transfer logic determines that conditions are not favorable for instantaneous transfer of control, shall the system be required to place all signals to stop and run the longest approach time in order to enable its outputs and take control.
 - 4. The system shall include a status and control panel for bi-directional manual transfer and enable/disable of automatic transfer capabilities. The panel shall also include health and on-line indication for each unit as shown in the Contract Documents.
 - 5. Control of hot standby redundancy shall be implemented in executive software with no need for application software to address redundancy other than that required for proper interface and operation of the status and control panel.
 - 6. The redundant VMIS units shall execute the exact same logic/application when in their final configuration to support operations. There shall be no difference between the two systems.
 - 7. The power feeds to the redundant VMIS systems shall be isolated and separately fused so that a failure in one unit shall not affect the partner unit. The input/output circuits of each VMIS unit shall be separately fused and isolated so that the failure of either system will not impact the other.
- B. Each unit in the redundant VMIS system shall interface to an AC lamp module through vital direct outputs to control signal lighting energy to each LED unit in the wayside signals and TAK’s.

2.5 INPUT/OUTPUT REQUIREMENTS

- A. Inputs and outputs to the VMIS shall interface via direct input boards, direct output boards, and/or serial/network interface communications. The voltage type/level and vitality of the interface shall be as shown in the Contract Documents and implemented to comply with the requirements of these specifications and in accordance with applicable, recommended practices of the AREMA C&S

Manual.

- B. External apparatus requiring VMIS outputs via the hardwire interfaces shall include, but not be limited to, the following:
 - 1. Switch and Lock Movements,
 - 2. VMIS Transfer,
 - 3. Line Circuits,
 - 4. Lock Relay.

- C. External apparatus requiring VMIS inputs via the hardwire interfaces shall include, but not be limited to, the following:
 - 1. Track Relays,
 - 2. Switch Position and Locking (Back) Repeater relays,
 - 3. Line Relays (Lechmere to Science Park),
 - 4. VMIS Transfer,
 - 5. Vital Power Off Stick Relays,
 - 6. Maintenance PC,
 - 7. Status and Control Panel.

- D. Each input and output printed circuit board shall be equipped with a lighted status indicator on each port. The indicator shall be lighted when the respective port is energized.

- E. The vital processor units shall be provided with both double break vital output printed circuit boards, double break vital input printed circuit boards as specified herein. A sufficient number of these types of printed circuit boards shall be installed in each vital processor unit to accommodate the DB Entity's design. All inputs shall be double broke.

- F. The use of external relays as interface devices between the vital processor units and external circuits shall be as required by the DB Entity's design. Where proposed equipment requires external relays or other external devices, the DB Entity shall provide them at no additional cost to the MBTA.

- G. All input/output and interface wiring for either VMIS system (normal and standby) shall be designed to be completely isolated so that a failure of any component affecting one of the VMIS units will not impact the other system.

- H. Equipment shall operate normally and reliably, and accept inputs from standard vital relays in accordance with applicable, recommended practices of the AREMA C&S Manual. The unit shall provide outputs that operate standard plug-in vital, regular release relays of 500 ohms or less resistance from Alstom (GRS), Siemens (Invensys/Safetran), and Ansaldo (US&S). Equipment shall not normally require biased relays.

- I. The unit shall have isolated lamp driver outputs to power the signal lighting (LEDs - nominal 130 VAC operating voltage).

- J. Output and input functions shall be provided on different circuit boards. Any variations from this

shall be only as accepted by the MBTA.

- K. The dielectric requirements of the equipment shall be designed and manufactured to comply with recommendations as per AREMA C&S Manual, Part 11.5.1.
- L. All terminals shall be provided with independent surge and lightning protection so that each input and output is protected.
- M. The output circuit boards shall drive the vital relay loads directly and shall be proven in this application in not requiring any additional apparatus at the vital relay end of the circuit.
- N. All input circuit boards shall use opto-isolation on each input to the board.
- O. Wiring to all input circuit boards shall be double break as shown in the Contract Documents.
- P. Labels shall be provided for each input and output that clearly denote the respective function of each for ease of maintenance and troubleshooting. These shall be provided for all wiring and terminals and be complete with nomenclature and include a "to/from" designation.
- Q. All I/O points shall be clearly documented in the location book of plans, grouped by board.

2.6 OFFICE DEVELOPMENT SYSTEM

- A. The DB Entity shall provide a system that includes all tools, software and hardware systems that will permit the MBTA to maintain, modify, expand or reduce the system. This includes but is not limited to the modification of all aspects of the system such as changes to the design of the logic governing the interlockings, code systems address, baud rate, word count, number of input or output elements, circuit board expansion, or local control panel modifications.
- B. The DB Entity shall provide a complete and separate set of software and firmware that permits the complete development, simulation and debugging of the system and application software with real time monitoring capability.
- C. The software supplied shall be on an approved media with an unlimited site license.
- D. It is the intent of the MBTA to utilize graphical relay equivalents in the design change processing using the maintenance computer and/or laptop with the required programming equipment including but not limited to EEPROMs in the VMIS.
- E. The development system shall provide for modifications of signaling elements within each location. Each location's data and source code shall be partitioned into separate files. Each location's application and source code shall be supplied on both hard copy (4 copies) and an approved electronic media (4 copies).
- F. Development system software prepared by the manufacturer of the vital controller shall be provided. The development system shall be designed so that a signal engineer with no programming experience may modify or create the logic or data functions. The development system shall have a proven record of reliability with signal engineers in transit/railroad applications for a 5-year period.
- G. Training for the development system shall be included with that referenced in Section 16894 – TRAINING AND TRAINING MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- H. The office development software shall include the required PROM/EPROM drivers required to

program the PROM/EPROMs.

- I. The DB Entity shall supply two sets of the required EPROM programmer hardware, EPROM eraser, software and cables required to operate from a standard PC.
- J. The office development system shall be capable of producing files that may be used by the Field Diagnostic System to program EPROMs.
- K. All hardware and software supplied with the development system shall be demonstrated to be completely compatible with the hardware and software system provided for this Project.
- L. One complete development system shall be provided for the MBTA's use and one complete development system shall be maintained in perfect working order on-the maintenance PC's at the specific location.

2.7 FIELD DIAGNOSTIC SYSTEM

- A. The DB Entity shall provide a complete and separate system that contains all required software that permits the complete diagnostic and debugging of the field system and application software. The software shall be installed and capable of operating on the maintenance PC's and with the laptop computers provided for this Project.
- B. The Field Diagnostic System shall be capable of easily performing the following functions:
 - 1. Monitoring data line errors,
 - 2. Monitoring CPU status,
 - 3. Real time diagnostic of each input/output port as to the status and condition,
 - 4. Determining the version of software running,
 - 5. Determining the status of any internal equation or bit state with actual nomenclature labels,
 - 6. Determining the system status.
- C. The Field Diagnostic System shall be capable of displaying dynamic real time data on the display screen. The displays shall include the name of each internal equation or input/output and the logic value for each. The system that is in service shall continue to operate on-line while the Field Diagnostic System is connected and operating.
- D. Field diagnostic system hardware shall include, but not be limited, to providing the following as a minimum: 3 laptop computers as described in Section 16899 – TECHNICAL SUPPORT MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM and 2 maintenance PCs per CIH location as described in Section 16866 – NON-VITAL SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM;
- E. The Field Diagnostic System shall be capable of programming EPROM chips for the system.

2.8 EXECUTIVE FIRMWARE

- A. The Executive Firmware shall be stored on a ROM, PROM, or EPROM device and shall be replaceable without disturbing application dependent firmware.
- B. The Executive Firmware shall continuously test for a loss of control over the state of the hardwired outputs/inputs, a loss of control over RAM, a loss of vital data communications, and a

spontaneous change in the application dependent firmware.

- C. The Executive Firmware shall log all failures directly related to the VMIS and identify the faulty printed circuit card or function.
- D. All functions related to the hot standby redundancy shall be controlled by the Executive Firmware. Specialty application code related to hot standby management and control shall not be required.
- E. All functions required for system integrity evaluation, error logging, hardwire interface, timing, data communications, application logic execution, and the application of power to the vital controller shall be fully interleaved and executed by the Executive Firmware. Failure to pass any of the system integrity tests shall cause the system to cease all data communications and remove power, in a completely fail-safe manner, from the hardwire outputs.
- F. The vital microprocessor shall not allow invalid information to be transmitted to any external devices or subsystems that can create a hazardous condition. In no case may invalid information persist long enough to allow an unsafe condition to occur. Serial data transmission between subsystems shall incorporate approved data checking techniques and check sum values to ensure data integrity.
- G. Diagnostics shall act on current data only. Memory locations used to determine the proper state of inputs and outputs shall be cleared or overwritten prior to being reused during each cycle test to ensure the integrity of the check. The diagnostic checks shall be incorporated in the executive system's software and shall operate independent of the user application software for the system.
- H. Background diagnostic tasks shall run during application software wait states and shall serve to monitor and verify the integrity of the software execution. Synchronized tasks shall execute in the proper order. Checks shall be included to shut down the system in the event of an executive microprocessor overload.
- I. PROMs and/or EPROMs used shall be checked to ensure they have been unaltered during microprocessor execution. Check words and/or check sums shall be created for blocks of memory and/or logic equations to implement these tests.
- J. It shall be impossible through the implementation of the application software to overwrite or otherwise modify the executive software.

2.9 APPLICATION FIRMWARE

- A. The application firmware shall define the operation of the VMIS; the operation of the individual functions shall be as indicated on final designs and shall include, but not be limited to:
 - 1. Route Check,
 - 2. Signal Clearing,
 - 3. Signal Lighting,
 - 4. Time/Approach Locking,
 - 5. Route Locking,
 - 6. Switch Locking,
 - 7. Switch Control,

8. Switch Correspondence & Indication,
 9. Loss of Shunt Protection,
 10. All necessary data communication conditioning including the building of repeaters.
-
- B. The application firmware shall be keyed to the vital controller hardware rendering it impossible for any application dependent firmware to be executed in any vital controller other than the intended vital controller.
 - C. The application firmware shall be stored on an EPROM device and shall be replaceable without disturbing the executive firmware.
 - D. All application software shall have complete identification on the individual ROMs or other storage devices stating the software number, revision number, location, and all other information required to prevent the application of software to the wrong location.
 - E. The program shall be modularized in a logical and easily understood manner. Each module of the programs shall be fully annotated, including revision blocks, with plain English explanations of the function of each module and the methods and means it uses to accomplish its tasks. This shall include references to all related modules, required to take part in the execution of the instructions.
 - F. The internal states of each logic element shall be established by the system at power on or start-up reflecting real time field conditions without requiring any manned intervention at the location of the system.
 - G. The VMIS shall be capable of being programmed in Boolean and relay equivalents.
 - H. The application software listing for the system shall be provided in a readable hard copy printed in relay equivalent format.

2.10 CHASSIS CABINETS

- A. Any unused chassis slots shall be fully covered by blank removable plates or by a single piece cover made of the same material as used for the working circuit boards. All chassis shall have a solid protective cover on the front to protect the circuit boards and any switches or push buttons from accidental operation. The protective cover shall be removable. Provisions shall also be made to protect the backplane in an approved manner. The top portion of processor units shall be arranged so it prohibits its use as a shelf and having items such as tools, manuals, etc. placed upon it.
- B. The chassis or cabinet material shall be steel or aluminum or other non-corroding material as approved. Chassis shall be supplied with hinged rear panels that permit easy access to rear edge connectors.
- C. All chassis or cabinet internal edge connector to edge connector wiring shall be Tefzel wiring, unless approved otherwise.
 1. All backplane wiring methods and material are to be submitted for approval. This shall include, but not be limited to, wiring, connectors or motherboard.
 2. All wiring shall be twisted pairs where required to provide maximum isolation to EMI noise.

3. All support devices and internal chassis or cabinet elements shall be protected with an approved material to prevent wires from being cut or damaged.
- D. All chassis shall be flush mounted to the face of the rack unless otherwise approved.
- E. Any ventilation screens shall be easily removable for cleaning.
- F. All chassis or cabinets shall be completely covered or enclosed to prevent the entry of rodents. A complete detail of each chassis or cabinet shall be submitted for approval.
- G. Each chassis shall be grounded to the rack with a #10 AWG stranded green wire. No ground loops or series ground wires are permitted.

2.11 CIRCUIT BOARDS - GENERAL

- A. All circuit boards shall have a unique serial number clearly marked on each board. The board manufacturer's part number shall also be clearly marked on each board. All markings shall be of a permanent type.
- B. Each circuit board shall have all components clearly identified by a silk screening process. All markings shall be clear and easily readable. The markings shall include, but not to be limited to, polarity, switch position numbers, resistor identifications or integrated circuit identifications.
- C. Each circuit board shall be secured in the chassis in a secure manner such as captive screws or latching ejector tabs. Both the top and bottom of each board shall be secured.
- D. Each circuit board shall be coated with a moisture sealant after manufacture and testing.
- E. All boards will be newly manufactured for the purpose for which they are being utilized. The use of "re-worked" boards that change the original design or function of the board to fit the needs of this Project is prohibited.
- F. The DB Entity shall supply a minimum of one each of any extender card required to match each type of circuit board.
- G. The circuit boards shall be removable and be mounted on guide-ways or channels for ease of removal or insertion. The removal of any wire shall not be required to replace a circuit board.
- H. All circuit boards using any indicator LEDs shall have the LEDs mounted on the front edge of the board. The colors of the LEDs shall be as approved. Each LED shall be labeled on the circuit board in a permanent method.
- I. Each differing type of circuit board shall be uniquely keyed. The chassis slots for circuit boards of the same type shall be keyed to match the board and reject others. The keying methods shall be modifiable and submitted for approval.
- J. Each circuit board and chassis slot shall be provided to withstand a minimum arc-over potential of 600 volts between conductor and ground.
- K. All circuit boards shall have internal surge and polarity protection for power, data, control and indication inputs and outputs.

- L. All circuit boards and components shall be new. The use of refurbished material is not permitted.

2.12 SPECIFIC VITAL PROCESSOR UNIT PRINTED CIRCUIT CARDS

- A. Each vital processor unit shall be equipped with one central processing unit printed circuit card (CPS PCC). CPS PCCs throughout the VMIS shall be identical with the exception of the instructions stored in the Application Dependent Firmware EPROM and a keying system that shall prevent operation of the vital processor units when a CPS PCC from another vital processor unit is installed. This keying system shall be demonstrated to be designed according to accepted fail-safe principles. The CPS PCCs shall conform to the requirements shown below:
 - 1. The CPS PCCs shall contain the microprocessor, clock, random access memory (RAM), Executive Firmware, Application Dependent Firmware, data bus, address bus, and all other components of the computing portion of the system. Other printed circuit cards comprising the system shall be input-output adapters and interfaces only.
 - 2. The CPS PCCs may contain the hardware for the vital serial interface printed circuit cards as specified herein.
 - 3. The CPS PCCs shall not perform any of the functions or effect any of the connections to external devices specified for the input/output printed circuit cards.
 - 4. The Application Dependent Firmware EPROMs shall be mounted to the CPU printed circuit boards via sockets, the contacts of which shall be fabricated from commercial bronze or brass and plated with gold over nickel underplate.
 - 5. Wire jumpers and piggy-back boards shall not be permitted.
- B. Each vital processor unit shall be provided with vital serial/network data communication printed circuit boards (VSDC PCBs) as specified herein. The number of VSDC PCBs shall be sufficient to allow interconnection with the vital networks for communications with adjacent microprocessor units as allowed by these specifications and indicated in the Contract Documents.
 - 1. Each VMIS shall be equipped with VSDC's with enough capacity to be able to exchange individual parameters of vital information in an amount of 120% of the number required by the design without degradation in the performance of the system.
 - 2. A map of the parameters of vital information exchanged shall be contained in the application firmware.
- C. Each vital processor unit shall be equipped with vital input printed circuit boards (VI PCBs) as specified herein and as shown in the Contract Documents.
 - 1. VI PCBs shall be furnished and installed in sufficient number to accommodate all vital inputs within the vital processor units' scope of control including, but not limited to inputs as shown in the Contract Documents.
 - 2. The VI PCBs shall be capable of accepting inputs without the use of external or board mounted interface relays. Energy for the inputs shall flow directly from the relay contacts, line circuits, or signal equipment as described herein, through the specified cables, termination points and internal instrument house wiring.
- D. Vital timers shall be field settable and shall be selectable by means other than by modification to the application software designed for the interlocking. Vital timer selection switches shall be covered

and sealed to provide and insure the integrity of the settings and prevent accidental contact. Vital timers shall be furnished in a sufficient number to accommodate all vital timing functions within the vital processor unit's scope of control including, but not limited to:

1. Loss of shunt time for track repeater relays (TPSRs),
2. Approach/time locking timers: 30 sec to 10 minutes (TER),
3. Operate or release lag for the internal relays,
4. Output Enable timer for system transference.

2.13 COMMUNICATIONS PORTS

- A. Network data between vital microprocessors and other vital microprocessors shall be of a vital nature. Each VMIS shall be provided with vital serial/network communication ports. The use of external converters is prohibited, except as accepted by the MBTA.
- B. The system shall default to the most restrictive state unless a valid transmission of data is received.
 1. Transmitted data between subsystems shall be updated regularly to ensure the integrity of the communications link. Vital executive software in each microprocessor shall detect corrupted or inconsistent data received.
- C. Visual LED indicators shall be provided to indicate the status of communications between multiple vital microprocessors.

2.14 MANUALS AND DOCUMENTATION

- A. All required documentation shall be delivered to the MBTA upon final acceptance of submittals. All documentation shall be delivered in the form of 10 bound hardcopies (6 for the maintenance and engineering department and 4 for the training facility) and two (2) electronic copies on CD (.PDF format). The electronic copies shall come with the necessary software for viewing and updating the documentation by the MBTA.
- B. Deliver complete documentation of software development subsystems for applications programming to allow the MBTA to perform in-house modifications to the applications logic by personnel with a signal engineer classification.
- C. Deliver complete integrated circuit drawings of all boards to a component level and supply trouble-shooting procedures to a component level.
- D. Deliver complete copies of all maintenance manuals for the installed VMIS system, including specialty component/module documentation, complete with troubleshooting procedures and detailed parts lists. These manuals shall consist of two types, manufacturer generic and application specific. Both types shall be written so that an average, qualified technician is enabled by the reading thereof to maintain, repair, test and adjust the equipment. The application specific manuals shall include a complete description of the system operation, installation, alignment and adjustment procedures, and troubleshooting tables/logic charts to assist in locating malfunctions and locating failed components.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Instrument racks shall be arranged and mounted in central instrument houses as indicated in the Contract Documents in accordance with the accepted installation plans.
- B. The cardfiles shall be mounted in shock mounted instrument racks sized to accept standard 19-inch modular components. All wire connections to the cardfiles shall be via plug connected cables.
- C. All cables or wiring leaving the instrument racks shall be routed through rubber boots at the top of the racks and shall be neatly routed and securely fastened with tie straps.
- D. All I/O, including spares, shall be wired through Din Rail mounted terminal blocks installed within the same rack as the I/O points which they are connected for ease of access.
- E. The mounting of cardfiles and associated equipment shall provide for easy access to all test points, indicators, and adjustments.
- F. The normal and standby units shall be in the same row and shall be on adjacent racks.
- G. Mounting height of microprocessor equipment within a central instrument house or room shall be restricted to an area between 1.5 feet and 5.5 feet above the finished floor.
- H. Provisions for EMI mitigation (shielding) shall be made as determined by results of the DB Entity's investigation to ensure proper operation of equipment relative to the environment.

3.2 IDENTIFICATION

- A. Card files shall be supplied with a printed label which identifies the input and output ports on the PCB by the name assigned to the port in the application firmware.
- B. Ports shall be identified by the slot number of the PCB and the port number on the PCB.
- C. A method, as accepted by the MBTA, shall be used to mount a typed, or printed, name tag on a front plate of each rack or cabinet.
- D. All wiring and wire terminals shall be tagged in an approved manner.

3.3 FACTORY TESTING

- A. The VMIS shall undergo qualification testing in accordance with Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM and manufacturer's recommendations.
- B. The VMIS and all subsystems shall be tested in accordance with the approved Factory Test Procedure.
- C. The entire central instrument house shall be set up at the point of assembly, with all equipment installed. The racks and cabinets shall be pre-wired in accordance with the Design Documents. Simulate functions external to the CIHs where required for both interim and final (in-service) arrangements. All functions of the system shall be tested to determine that each function of the system operates as required.
- D. Make adjustments and correct defects in the CIH's wiring as necessary to obtain proper operation and satisfactory test results.

- E. All design changes found necessary to obtain proper operation shall be submitted to the MBTA for acceptance.
- F. The unit shall be subject to acceptance by the MBTA in respect of both hardware and software based on the provisions of this Section. Initial acceptance will be resultant from successful factory testing. The second and final acceptance will result from successful in-service operation as described herein.
- G. The DB Entity shall prepare and provide a complete and comprehensive system acceptance test procedure. The system acceptance test shall be sufficient for the MBTA to determine to its reasonable satisfaction that the unit performs properly as a whole, including but not limited to, all operational functions.
- H. The final system acceptance test shall commence after both the hardware and software have been successfully installed in the field.
- I. The final system acceptance (in-service) test shall be deemed passed only if and when:
 - 1. The system acceptance test has been successfully completed and no problems remain and all modifications, as a result of testing, are made final.
 - 2. The MBTA has successfully operated the unit for a period of not less than 30 consecutive days during which time a series of tasks and verification procedures have been performed as determined by the MBTA to be sufficient to enable the MBTA to determine that the unit operates in accordance with its functional specifications and its design specifications.
 - 3. Throughout the period specified in the above item, the unit has not failed and no problems have been discovered.
 - 4. In the event that problems are discovered during the system acceptance period or during any additional test period as provided herein, the time shall be extended an additional 30 consecutive days from the “acceptance date” date from which the DB Entity has notified the MBTA and said problems have been corrected.
- J. The “final acceptance date” shall be the day the system acceptance test has been passed pursuant to items H and I above.

3.4 FIELD TESTING

- A. The VMIS and subsystems shall be tested in accordance with Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM and manufacturer’s recommendations.
- B. The latest type test unit for testing vital microprocessor interlocking equipment, as recommended by the manufacturer, shall be provided to assist diagnosing the components, software and proper system operation.

3.5 CONFIGURATION CONTROL PROCEDURE

- A. The DB Entity shall follow a strict revision control procedure for VMIS software. This procedure shall be submitted for acceptance. At a minimum this plan shall include:
 - 1. Revision number structure and log to track revisions, reasons for revision, and review/acceptance status.
 - 2. Procedure and documentation for comparison and review of software changes to ensure that

- only intended changes were made to the application software including review and verification by independent checkers.
3. Procedure and documentation for limited retest of software revisions with required tests, procedures and test data sheets.
 4. Procedure and documentation for installation of software and verification of successful install of the proper version prior to testing.
- B. The DB Entity shall follow a strict revision control procedure for VMIS hardware. This procedure shall be submitted for acceptance. At a minimum this plan shall include:
- C. At the beginning of the factory test, the hardware configuration of the VMIS system and all components shall be recorded. The information recorded shall include the following for each component:
1. Description and number
 2. Serial number and revision level
 3. Rack location
- D. The hardware configuration information shall be maintained as comments in the program listing as well as on a plan in the plan books. It shall be updated with any changes and each update shall include a clearly worded reason for the change.

3.6 GUARANTEE

- A. For a period of 12 months commencing on the “final acceptance date,” the DB Entity shall guarantee that the unit is free from defects in design, material and workmanship and that the unit shall operate in the manner intended as described in these Mandatory Specifications, including but not limited to, the compatibility of the hardware with the software. The DB Entity’s guarantee hereunder shall extend to all elements of the unit supplied pursuant to this Mandatory Specification, whether supplied directly by the DB Entity or not.
- B. For the purpose hereof, a “design defect” shall include, but not be limited to the selection and arrangement of hardware, software and other related to similar elements of the system, whereby such inadequacies or weaknesses prevent a component of the system from providing fully satisfactory performance as intended by the design represented in the Contract Documents.
- C. Depending upon the nature of the defect and the equipment concerned, it shall be rectified promptly by the DB Entity on site, free of any cost to the MBTA, or returned to the DB Entity for repair or replacement free of any charge whatsoever, or at the option of the MBTA, it may be rectified by the MBTA in accordance with the DB Entity’s instructions. In this latter event, direct labor and material costs will be charged to the DB Entity.
- D. Work performed by the DB Entity, or items replaced by him under his guarantee, shall be similarly under guarantee for an additional 12-month period.
- E. Changes made to hardware or software under the guarantee shall also be made to spare items furnished or subsequently ordered from the DB Entity.
- F. Normal maintenance of the unit and repair of components by the MBTA, or under maintenance contract, in accordance with the DB Entity’s instructions or accepted practice, shall under no

circumstances relieve the DB Entity of these responsibilities under this guarantee.

- G. Where there is any conflict with the DB Entity's standard guarantee, the guarantee statements in this Mandatory Specification shall govern.

END OF SECTION

SECTION 16860

RECTIFIERS, BATTERIES AND BATTERY CHARGING EQUIPMENT FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing rectifiers, disconnect switches, batteries and battery charging equipment as specified herein.

1.2 QUALITY ASSURANCE

- A. Test each rectifier and battery charger before shipping to the job site. This factory testing shall be conducted in accordance with the DB Entity's Factory Test Procedure for rectifiers and battery chargers as accepted by the MBTA. Prior to shipment, a copy of the manufacturer's certification of compliance with factory tests shall be forwarded to the MBTA.
- B. Inspect each rectifier after it has been installed and correct deficiencies.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following for approval:
- B. Load calculations of each DC load. The calculations shall identify normal and worst case conditions for each load. Include results of testing for minimum five-day period under simulated load, 4 hours on-charge and 4 hours off-charge in calculations to ensure capability of battery bank to maintain connected load for 4 hours;
- C. Complete product and performance data for each type and size of rectifier, disconnect switch, storage battery and battery charger to be furnished. The submittal must show that the charging equipment is designed to work as a system with the batteries (type, size, etc.) being provided;
- D. Factory Test Procedure for each type of rectifier, disconnect switch, storage battery and battery charger to be furnished;
- E. Prior to installation of rectifiers, disconnect switches, storage batteries and battery chargers, certification of compliance with factory test requirements shall be submitted to the MBTA.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Rectifiers, disconnect switches and battery chargers shall be properly crated or securely mounted in the CIHs as determined by the DB Entity to prevent damage throughout delivery, storage and handling.
- B. Storage batteries shall be furnished, in a fully charged condition. Each storage battery shall be equipped packaged to prevent spillage of the electrolyte. Storage batteries shall be shipped separately from the CIH and enclosures.
- C. The DB Entity shall replace any equipment damaged, lost, or stolen at no additional cost to the Project.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Battery Chargers

1. Battery charging equipment shall be designed for continuous operation. Provide battery chargers suitable for operation with the number and types of batteries required for operation of the signal equipment being furnished.
2. All battery charging equipment as specified herein shall meet the applicable requirements of AREMA C&S Manual, Parts 9.2.1, Recommended Functional/Operating Guidelines for a Constant Voltage Battery Charger, and 9.2.5, Recommended Functional/Operating Guidelines for a Constant Current Battery Charger where applicable requirements of the AREMA Manual do not conflict with any requirements specified in this Section.
3. Provide chargers that deliver a stabilized output voltage, are temperature compensating, and output current limiting. Furnish chargers that automatically adjust their output current according to the load and the demand on the battery. Battery charging equipment shall be designed to deliver rated outputs for the batteries with input voltage of 100 to 130 Volts AC at 60 Hz, single-phase, two wire input.
4. Determine charger size and capacity based on submitted and approved load calculations. Normal and reserve chargers shall be provided in a load-sharing configuration. Individual battery chargers shall be capable of handling the entire calculated load plus 50%.
5. Chargers shall be equipped with appropriate filtering to maintain ripple voltage within manufacturer's recommended limits for the solid state equipment that it feeds with, or without, batteries connected.
6. Each charger shall be provided with an adjustment device to change the rate of output current.
7. Terminal markings for AC and DC terminals shall be permanent.
8. Indications shall be provided as shown in the Contract Documents.

B. DC Switch-and-Lock Movement Rectifiers

1. The DB Entity shall furnish and install 120 Volt AC to 120 Volt DC rectifiers to provide the required switch-and-lock movement motor control voltage. The switch-and-lock movement rectifiers shall be the manufacturer's standard for the type of switch-and-lock movement layout that the DB Entity proposes to furnish.
2. One switch-and-lock movement rectifier shall be provided for each switch-and-lock movement layout.

C. Disconnect Switches

Provide disconnect switches to operate signal power circuits as shown in the Contract Documents and for other approved devices as the signal design may require. Disconnect switches provided shall comply with all local codes.

D. Storage Batteries

1. The DB Entity shall furnish sealed lead acid gel filled storage batteries for all applications as specified herein.
2. The battery case shall be molded from flame retardant polypropylene, with separators of spun

glass microporous matrix

3. All batteries as specified herein shall meet the requirements of AREMA C&S Manual, Part 9 for lead acid batteries where the AREMA recommendations do not conflict with any requirements specified in this Section.
4. Storage batteries shall be sized to provide a minimum 4-hour standby capacity. The DB Entity shall calculate the loads based upon the equipment that the DB Entity proposes to furnish.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General

1. The DB Entity shall provide all mounting hardware, terminals, terminators, etc. for the installation of wall-mounted rectifiers, disconnect switches and battery charger units in the central instrument house.

B. Storage Batteries

1. The storage battery cells shall be placed in the battery enclosures on wooden trays and mounted on steel racks of a design and size that allows for visual inspection of each cell and easy access to terminal connections.

3.2 TESTS

Tests shall be performed in accordance with the requirements of this Section and those of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

3.3 PAINTING

Paint wooden trays and steel racks with two coats of approved acid resistant paint.

END OF SECTION

SECTION 16861

DC POWER SUPPLIES FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing redundant, direct current regulated power supplies of various voltages to supply energy to all signal system equipment as required.
- B. Power supplies for line battery (LB), B12, and B24 shall be provided in a Normal/Reserve configuration. Individual supplies shall be capable of supplying the entire calculated load plus 50%.
- C. The power supply output shall be isolated from ground to permit grounding of either positive or negative output terminals.
- D. Wiring shall be of sufficient size to carry the rated loads with a voltage drop of not more than 5% for secondary side circuits and 10% for signal power mains. The size of the wiring shall be rated to carry a load equal to 150% of the total load that can be reasonably imposed by the portion of the signal system to be fed.

1.2 QUALITY ASSURANCE

- A. The power supplies furnished under this Project shall undergo all tests and inspections required to ensure compliance with this Section.
- B. The factory test of power supplies or power supply components shall be the manufacturer's standard. Transformers shall meet the requirements of the latest revisions of AREMA C&S Manual Part 14.2.10, Recommended Design Criteria for Transformer, Dry-Type, Air-Cooled, where applicable and where the AREMA recommendations do not conflict with any requirements specified in this Section.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following to the MBTA for acceptance:

- A. Complete mechanical and circuit drawings of DC power supplies and protection to be furnished,
- B. Complete product and performance data of each type and size of DC power supply and related equipment to be furnished,
- C. Proposed location and method of mounting DC power supplies and storage batteries,
- D. Complete circuits for power alarms,
- E. Factory test procedures and forms,
- F. A signed certification of compliance with factory test requirements, prior to installation of the DC power supplies,
- G. Drawings for the complete power layout of feeders, transfer switches, fuses, busses indicating the size

of the individual units and their locations,

- H. Calculations to verify that the sizes of wiring shown on the Contract Documents, or proposed, are sufficient. Any variation in sizes of wiring from that shown on the Contract Documents must be approved, in writing, prior to the manufacture of the power supply equipment.
- I. Calculations to verify that the size of the DC signal power supplies required for the equipment are adequate. If the power calculations are found to be incomplete or inaccurate, they will be returned for completion, or correction, and will require re-submittal.

PART 2 - PRODUCTS

2.1 DESIGN REQUIREMENTS

- A. All semiconductors shall be silicon type with JEDEC numbers.
- B. Power supplies shall be designed so that the filter capacitors can be replaced without removing the supply from the rack on which it is mounted.
- C. Transformers shall not emit audible noise in excess of 45 db, referenced to 0.0002 dynes/cm² at a distance of two feet, at rated voltage and current.
- D. The power supplies shall be capable of withstanding 600 Volts, 60 Hertz applied for one minute between both input leads connected together and the case; between both output leads connected together and the case; and between both input leads connected together and both output leads connected together.
- E. The power supplies shall be designed for continuous operations.
- F. Input voltage shall be 120V AC plus or minus 15% , 60 Hz plus or minus 0.5Hz, single-phase, two-wire input.
- G. Failure detection circuitry shall include the alarming of failures that affect the ability of the power supply to deliver the rated load. A normally closed independent contact shall be provided for connection of external circuitry for alarm indication. The power supply front panel shall contain one voltage failure light, one output ammeter and output voltmeter. Meter accuracy shall be plus or minus 2% with nominal voltage readings at center scale.
- H. Dual power supplies located within the same enclosure shall be designed and installed so that a failed supply can be removed and replaced without causing the operating supply to be de-energized.
- I. All power supplies shall be clearly and permanently labeled with the manufacturer's name, serial number, part or model number, and the input and output rating.

2.2 PROTECTION REQUIREMENTS

- A. The power supply shall be so designed that it will not be damaged by operating at an input voltage range between zero and 140 V AC.
- B. A separate output filter and high frequency by-pass capacitor shall be located on the load side of the isolating diode.
- C. Reverse output current protection shall be provided to prevent shorting or sagging of tandem power

supplies in the event of filter capacitor failure.

- D. The power supply output terminal shall contain a non-conducting device or insulated safety shield to protect personnel from electrical hazards. The device shall protect and be rated not less than four times the output of the power supply.

2.3 MECHANICAL REQUIREMENTS

- A. The power supply shall be a panel/chassis combination with a perforated protective cover. The design shall be such as to provide natural convection cooling.
- B. The front mounting shall be designed to mount in a standard, 19-inch rack space with E.I.A. hole spacing.
- C. Terminal binding posts for input and output and alarm circuits shall be provided. Each terminal shall be insulated from the frame of the unit.

2.4 12V DC POWER SUPPLIES - GENERAL

- A. Output voltage shall be 12V plus or minus 1% with 120V AC plus or minus 1% input at a temperature of 25 degrees C. The output voltage shall be adjustable within a plus or minus 0.5V DC range of nominal by means of an adjustment control within the supply.
- B. The output voltage at 50% load shall not vary more than plus or minus two for an input line change of plus or minus 15% over a temperature range of minus 30 degrees C to (plus) 70 degrees C.
- C. The output voltage shall not vary more than the values as specified below due to load variation at constant input voltage and ambient temperature as referenced to the output voltage at 50% load:
 - 1. Plus 7% from 0% to 10% of maximum load,
 - 2. Plus 3% from 10% to 25% of maximum load,
 - 3. Plus or minus 2% from 25% to 75% of maximum load,
 - 4. Minus 3% from 75% to 100% of maximum load.
- D. With the worst combination of line, load and temperature variation as specified above, the output voltage shall not be less than 10.8 volts nor more than 13.5 volts.
- E. During the warm-up period to achieve power supply stabilization, output voltage shall not be greater than 14.5V DC. Warm-up time shall not exceed 20 minutes.
- F. Power supply output ripple shall not exceed 0.12V RMS and the noise shall be limited to 1.40 Volts peak-to-peak, at any frequency. During warm-up, ripple shall not exceed 0.9V RMS and the noise shall be limited to two Volts peak-to-peak.

2.5 TRANSFER SWITCHES

- A. The DB Entity shall furnish and install automatic transfer switches for each normal and alternate power supply except for those supplies that are operated in parallel or are equipped with internal transfer switches with redundant supplies.
- B. Transfer switches shall operate when they sense failure on the DC output.

PART 3 - EXECUTION

3.1 APPLICATION

- A. A means shall be provided to isolate each DC power supply for maintenance purposes, without interrupting the supply of power to the loads.
- B. Fuses providing overload protection for the DC power supplies shall be of the electrical indication type and shall be circuited to provide fuse failure alarm.

3.2 TESTS

- A. All power supply equipment shall be tested for rated output voltage and grounds in conjunction with the factory testing procedures, as accepted by the MBTA. Also, the DB Entity shall perform complete testing and adjustment of the total installed power systems as specified in Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Each alarm circuit shall be tested individually to assure that it indicates the proper alarm condition as shown on the Design Documents.

END OF SECTION

SECTION 16862

100 HZ FREQUENCY CONVERTERS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The work to be done under this Section shall consist of furnishing, installing, and testing 60 Hz to 100 Hz frequency converters and related frequency-synchronizing equipment.
- B. Equipment supplied shall be rugged, designed for high-reliability and long life in a transit system environment containing significant amounts of conductive rail dust and other airborne particulates.
- C. The equipment supplier shall have successfully manufactured and placed in-service similar equipment for railway application.

1.2 QUALITY ASSURANCE

Installation and equipment provided shall comply with the latest published issues in effect at the date of Project Award of the following applicable standards, codes, recommendations or requirements of the following organizations.

- A. American National Standards Institute (ANSI),
- B. American Railway Engineering and Maintenance-of-Way Association,
- C. American Society for Testing and Materials (ASTM),
- D. Institute of Electrical and Electronic Engineers (IEEE),
- E. Insulated Cable Engineers Association (ICEA),
- F. National Electrical Manufacturers' Association (NEMA),
- G. National Electric Code (NEC),
- H. Underwriters Laboratories, Inc. (UL).

1.3 SUBMITTALS

- A. Prior to the submittal of shop drawings, the DB Entity shall submit proposed manufacturers' product data for approval. The submitted product data shall include catalog and other descriptive information sufficient to assess the suitability of the proposed equipment for its intended purpose. Descriptive information shall include electrical ratings, features, environmental requirements, and approximate dimensions. Product submittals shall be clearly marked with dark ink so that the equipment and accessories being proposed are identified; "highlighting" of proposed items is not acceptable. Product submittals shall be clearly identified in transmittals as being Product Submittals.
- B. Prior to the purchase of the equipment, the DB Entity shall submit complete shop drawing and performance data specific to the equipment to be furnished and installed. The shop drawings shall include one-line, schematic, control and indication circuit and point-to-point wiring diagrams, arrangement drawings, dimensions, typical installation details and a complete parts list. Protective device ratings and time-coordination curves shall be provided for all protective devices to be

supplied (circuit breakers and fuses). Separate sets of shop drawings shall be provided for each different type and rating of equipment being supplied. The shop drawings shall be prepared in accordance with Section 16804 – DRAWINGS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications. Title block information shall include the name and number of the Project for which the drawings are being prepared, and the intended location for each piece of equipment.

- C. Prior to factory testing of the converter(s), the DB Entity shall submit a Factory Test Procedure for acceptance to the MBTA. Factory testing shall not commence until the Factory Test Procedure has been accepted in writing.
- D. Prior to delivery of the converter(s), the DB Entity shall submit five copies of the Certified Factory Test Report for acceptance by the MBTA.
- E. Also, prior to delivery of the converter(s), the DB Entity shall submit to the MBTA for acceptance a Field Test Procedure for on-site testing of the frequency converter(s) and connected circuits.
- F. Prior to delivery of the converter(s), the DB Entity shall submit five sets of converter operation and maintenance (service) manuals to the MBTA for acceptance. The manuals will contain, at minimum:
 - 1. Most recent versions of electrical schematics;
 - 2. Instructions for converter installation, synchronizing, start-up, operation, and maintenance;
 - 3. Instructions for servicing or replacing removable parts;
 - 4. Control settings;
 - 5. Troubleshooting instructions;
 - 6. Complete parts listing;
 - 7. Manufacturer telephone number for parts and service.

PART 2 - PRODUCTS

2.1 STATIC FREQUENCY CONVERTER

- A. Ratings
 - 1. Input
 - a. Nominal Voltage: 115 V AC $\pm 10\%$
 - b. Phases: One
 - c. Wires: Two
 - d. Frequency: 60 Hz (signal supply frequency)
 - 2. Output
 - a. Nominal voltage: 120 V AC, user-adjustable at least $\pm 10\%$
 - b. Phases: One
 - c. Wires: Two (floating)

- d. Maximum load regulation: \pm %, for a no-load to full-load change
 - e. Continuous (full) load rating at nominal input and output voltage: 4000 V AC
 - f. Two-hour overload capacity: 110% of continuous load rating at nominal input and output voltage
 - g. Frequency: 100 Hz, fixed, crystal-controlled with max. 0.1% accuracy
 - h. Minimum efficiency: 75% at full load
 - i. Harmonic distortion: less than 2% voltage and current THD (sinewave)
 - j. Power factor: rated full load shall be delivered to a power factor of 0.7 leading or lagging
3. Ambient Conditions for Converter Operation:
- a. Temperature Range: comply with AREMA Class C requirements unless otherwise accepted by MBTA.
 - b. Humidity Range: 0 to 95% non-condensing
4. Other Requirements
- a. Audible noise shall not exceed 45 dB at a distance of 10'.
 - b. The converters shall be capable of operating in the configuration as shown on the Contract Documents.
 - c. The converters shall automatically reset to normal operation after exposure to a momentary power outage, such as due to an upstream automatic transfer switch operation.

2.2 Additional Features

- A. Provide equipment for mounting with standard 19-inch rack and chassis with heavy-duty sliders.
- B. Front panel-mounted input on-off circuit breaker: fast-acting, 2-pole circuit breaker with 22,000 Ampere min. interrupting rating at 120 V AC.
- C. External Synchronization - Provide equipment having the following synchronization capabilities/features:
 - 1. Provide two wire, transformer-isolated input terminals for a 120 V nominal 100 Hz synchronizing signal.
 - 2. When a 120 V, 100 Hz reference signal is applied to the synchronizing terminals, the output of converter shall lock onto and track the reference signal.
 - 3. With no 120 V, 100 Hz reference signal, control of converter output frequency shall automatically switch to an internal 100 Hz crystal-controlled oscillator.
- D. Overload Protection
 - 1. Provide automatic current-limiting feature for sustained overloads in excess of the 110% two-hour rating. Current-limiting shall be a constant-current mode which provides maximum load current without distortion of output waveform. Converter shall automatically reset to normal operation after overload has been removed.
 - 2. Provide internal temperature sensor for activating over temperature shut-down of converter on

damaging over temperature.

- E. Short circuit protection: provide electronic short circuit protection which automatically opens converter output circuit upon detection of a short circuit, and auto reset upon removal of short circuit.
- F. Provide three front panel-mounted digital multimeters for output frequency (Hz), true-RMS voltage (V) and true RMS current (A), meter accuracy shall be 1% full-scale (± 1 digit) or better.
- G. Provide alarm contacts and panel lamps to indicate:
 - 1. Loss of converter output,
 - 2. Loss of 120 V AC reference signal,
 - 3. Over temperature condition,
 - 4. Out-of-phase condition between the 120 V, 100 Hz reference and the converter output
- H. Provide easily-accessible, removable filters for filtering of rail dust and other airborne particulates.
- I. All PC boards shall be conformally-coated (environmentally sealed).
- J. Cooling fans: any fans required for cooling of critical components shall be redundant, such that failure of a single fan will not cause over temperature shut-down of the converter.
- K. Provide transformer-isolated input and output stages with surge protection.
- L. All internal components where wires originate or terminate shall be identified by unique markings.
- M. All internal wiring shall be labeled and/or color-coded at all points of origination and termination.
- N. Large capacitors shall be automatically discharged through a resistance upon shut-down of converter.

PART 3 - EXECUTION

3.1 TESTING

A. Factory Testing

The following minimum tests shall be conducted at the factory in accordance with the accepted Factory Test Procedure. Each converter, identified by a unique serial number, shall be tested. The results of these tests shall be documented in the certified factory test report.

1. Point-To-Point Wiring Checks

The origin and termination points for all converter wiring shall be verified against the equipment shop drawings. Wire tags and color coding at wire origin and termination points shall be in agreement with the shop drawings.

2. Mechanical Inspection Checklist

All components and connections shall be inspected for proper markings and installation, and shall

be in agreement with the shop drawings.

3. Vibration Testing

Each converter shall be subjected to testing on a vibration table. After a period of five minutes of continuous vibration, the converter shall be inspected for loose parts and connections. Loose parts and connections shall be tightened.

4. Load Tests

- a. Each converter shall be tested at no-load and 10%, 25%, 50%, 75%, 100% and 110% of full rated output. For each load level, the following values shall be measured with laboratory-grade, calibrated precision instruments:

Input and output voltage, current, and watts,
Input and output frequency,
Output voltage distortion (%THD),
Efficiency (output Watts/input Watts).

- b. At each of the above load levels, the readings of the panel meters shall be recorded. The accuracy of the meters shall be calculated at each of the load levels.
- c. The output load regulation shall be calculated at each of the load levels.
- d. Provide verification of current-limiting operation mode by briefly subjecting the converter to a load in excess of 110%. Record input and output voltage, current, watts and frequency, and compare against expected values.

5. Burn-In Tests

Each converter shall be subjected to a continuous 100% rated load test for a duration of at least eight (8) hours without shutdown, current-limiting operation, damage, or failure.

The MBTA retains the right to witness the factory testing. Frequency converter tests shall be included as part of the overall factory test item included in the approved CPM as submitted by the DB Entity.

B. Field Testing

1. Field tests shall be performed in accordance with the accepted Field Test Procedure. Field tests shall include mechanical inspections, and operational checks for all converter functions.
2. All operational tests and circuit checks shall be recorded in accordance with the accepted Installation, Inspection & Field Test Procedures and the requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.

END OF SECTION

SECTION 16863

SIGNAL TRANSFORMERS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the procurement of signal transformers as specified herein.
- B. All transformers shall be air-cooled unless otherwise accepted by the MBTA.
- C. Transformers shall be provided for signal power isolation purposes, 100 Hz AC track circuits, signal lighting, and general purposes as required by the DB Entity.
- D. All transformers shall be rated to carry 125% of the total load continuously.
- E. Additional requirements for transformers are referenced in Section 16872 – TRANSFORMERS FOR THE LIGHT RAIL SIGNAL SYSTEM, and shall be followed where they do not conflict requirements of this Section.

1.2 QUALITY ASSURANCE

- A. Inspect and test each transformer prior to shipment. This inspection shall conform to the DB Entity's Factory Inspection and Testing Procedure as accepted by the MBTA.
- B. Transformers shall be in accordance with the latest revision of AREMA C&S Manual, Part 14.2.10, Recommended Design Criteria for Transformer, Dry-Type, Air-Cooled for single-phase transformers, where the AREMA recommendations do not conflict with any requirements specified in this Section.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following to the MBTA for acceptance:

- A. Drawings, wiring diagrams and catalog cuts with information regarding performance data of all the transformers being provided under this Project;
- B. A factory inspection and test procedure;
- C. Calculations for the sizes of transformers required for the loads created by the equipment being furnished and installed under this Project. One copy of these calculations shall be forwarded to the MBTA prior to shipment of the transformers.
- D. A field installation inspection and test procedure.

1.4 DELIVERY, STORAGE AND HANDLING

- A. 1.4.1 Transformers shall be protected from damage throughout delivery, storage and handling in accordance with the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM, and all other applicable provisions of these

Specifications.

- B. Damage to material resulting from improper storage or handling by the DB Entity shall result in replacement of all damaged material with new material by the DB Entity at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Basic Consist

1. Transformers shall be provided with sufficient primary and secondary voltage taps to adjust for varying feeder voltages between 90 and 125 Volts.
2. Transformers shall not emit audible noise in excess of 45 dB, referenced to 0.0002 dynes/cm² at a distance of ten feet, at rated voltage and current.
3. The primary and secondary taps shall be brought to terminals mounted inside the transformer case. An AREMA terminal connection for each primary and secondary tap shall be provided external to the transformer. All terminals shall be identified in an approved manner.

B. Track Transformers

1. The track feed transformers required for the power frequency track circuits shall be equipped with AAR terminal boards containing terminals for the primary and secondary leads.
2. The track secondary windings shall be arranged to provide for varying the voltage in one-volt steps up to a maximum of 18 Volts. The primary excitation shall be 120 Volts, 100 Hertz.
3. All track feed transformers shall have a volt-ampere rating sufficient to handle 125% of the maximum calculated operating load.
4. Track transformers shall not be susceptible to DC saturation by propulsion currents.

C. Signal Power Transformers

1. Transformers for signal power shall be single-phase with 480 or 208 Volt, 60 Hertz, primary windings; 120 Volt, 60 Hertz, secondary windings and with isolation properties as required.
2. The transformer windings shall contain Class H insulation with four 2-1/2% full capacity taps, two above normal voltage and two below normal voltage.
3. The transformer enclosures shall be of drip-proof construction and furnished complete with provisions for rack or wall mounting.
4. Signal power transformers required for each central instrument house location shall be rated for 125% of the calculated normal load. If required for wayside case locations, they shall be sized in accordance with the approved load calculations.

D. Housing Power Transformers

Housing power transformers for lights, receptacles, etc. in the central instrument houses shall be single-phase, rated for 125% of the calculated normal load with 60 Hertz primary windings for voltages as required and 120-Volt, grounded, 60 Hertz secondary windings.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Transformers shall be installed as shown on the Design Documents.
- B. Track transformers shall be rack- or wall-mounted and in accordance with the Design Documents.

3.2 TESTS

- A. The DB Entity shall test and inspect each transformer with its associated system in accordance with the approved factory test and inspection procedures.
- B. Prior to energizing for operations, all electrical equipment shall be rechecked for proper rating and operation. Cables and equipment shall be checked for circuit continuity and isolation. Ground connections shall be checked for ground resistance values.
- C. All operational tests and circuit checks shall be recorded in accordance with the accepted Installation, Inspection & Field Test Procedures and the requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.

END OF SECTION

SECTION 16866

NON-VITAL SUPPORT SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the final design, furnishing and installing of non-vital support systems at each CIH location under the Project. The major components specified herein are as follows:
 - 1. Microprocessor based Non-Vital Microprocessor Interlocking Systems (NVMIS) and associated hardware,
 - 2. Maintenance PC's,
 - 3. Ethernet Switches,
 - 4. Status and Control Panels,
- B. The MBTA preference is for an architecture that combines the VMIS and NVMIS from the same manufacturer to limit the hardware requirements. The DB Entity may however, propose an alternative or variations to this architecture.
- C. All equipment supplied shall be fully compatible with all other non-vital and vital equipment shown in the Contract Documents and as specified herein. If the DB Entity's proposed equipment requires the use of additional equipment not shown in the Contract Documents or specified herein to meet the requirements of the Project, said equipment shall be submitted for acceptance and, if accepted, shall be provided at no additional cost to the MBTA.
- D. Other work to be done under this Section shall include the preparation of design drawings for the various intersystem circuits and software models that integrate the NVMIS, Control and Indication Panels, Status and Control Panels, NVMIS I/O, Remote I/O, VMIS, Maintenance PC, Event Recorders and various data links.

1.2 QUALITY ASSURANCE

- A. The DB Entity shall certify, via environmental testing or test data therefrom, that all components of the non-vital system the DB Entity proposes to furnish will successfully operate, in an environment consistent with the AREMA C&S Manual of Recommended Practices Section 11.5.1 for a Class C environment without the use of environmental controls. If the DB Entity's proposed equipment is presently in service on the MBTA, in an identical application, this requirement (with the exception of EMI testing) shall be waved.
- B. All non-vital system components, assemblies and sub-assemblies, shall be fully factory tested in accordance with accepted Factory Test Procedures. A DB Entity's representative with intimate knowledge of the systems used and the specific application being tested shall conduct all testing as required by the MBTA.

1.3 SUBMITTALS

- A. The following plans and information shall be submitted for acceptance prior to fabrication and factory wiring of the vital and non-vital systems equipment:

1. A comprehensive systems diagram (block diagram) describing all major components, functions interfaces, links, and associated software;
 2. Catalog cuts and descriptive literature for all materials the DB Entity proposes to use to implement the design as specified herein and as shown in the Contract Documents. As a minimum, this information shall be provided for each block in the systems diagram;
 3. A detailed data communications matrix describing the type of data, origin, destination, medium, and communication format for all functions performed by the vital and non-vital systems;
 4. A fail-over/fault matrix describing the self-detectable faults for each component supplied and the DB Entity's recommended actions based on these faults.
 5. Complete wiring and cabling drawings with all interfaces and data links including remote input/output functions and the equipment required for the interfaces and/or data links clearly indicated;
 6. A complete and comprehensive operational description;
 7. Plans showing arrangement and assembly with complete keyed part lists;
 8. A complete Qualification Test Procedure for each component of the system that fully demonstrates that the equipment proposed meets all functional and environmental requirements;
 9. A Factory Test Procedure designed to demonstrate that the system will be tested to verify that it performs all functions in accordance with these Specifications and Contract Documents;
 10. A Field Test Procedure designed to demonstrate that the system will be tested to verify that it performs all functions in accordance with these Mandatory Specifications and Contract Documents after installation;
- B. Submit, for approval all manuals and documentation required by these Mandatory Specifications. Upon approval of the content, organization and format all documentation required by these Mandatory Specifications shall be delivered to the MBTA.
- C. Factory test reports complete with results for all tests shall be submitted for review and approval prior to shipping equipment to the site.
- D. Field test reports complete with results for all field tests shall be submitted for review and acceptance prior to final acceptance.
- E. Provide submittals of all software to be supplied for the Maintenance PC's.

1.4 DELIVERY, STORAGE AND HANDLING

- A. The non-vital support systems shall be properly installed in the rack and CIH at the manufacturer's point of shipment.
- B. The DB Entity and the MBTA or MBTA representative shall inspect each item for shipping damage prior to installation. All damage incurred in transit or caused by mishandling or improper storage shall be repaired or replaced at the MBTA's option with no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The non-vital support systems equipment shall be designed to be rack mounted inside the Central

Instrument House (CIH). The DB Entity shall design, furnish and install intersystem circuitry and equipment to affect an operable interface with the systems specified herein and as shown in the Contract Documents.

- B. The electrical components, unless otherwise specified herein, shall be rated to operate at power, voltage and current levels twenty percent above and below that level which the components will be subject to in normal service.
- C. Miscellaneous Equipment: All internal wiring, plug connectors, terminal boards, mounting hardware, special tools and apparatus required to effect a complete installation shall be furnished in accordance with applicable sections of these Mandatory Specifications.
- D. All hardware furnished under these Mandatory Specifications shall consist of rigid components designed specifically for electrified rapid transit or similar harsh industrial environments.
- E. All hardware and software provided shall be of a consistent and identical version and/or revision level from location to location throughout the entire Project.

2.2 NON-VITAL MICROPROCESSOR INTERLOCKING SYSTEM (NVMIS)

- A. The NVMIS systems shall consist of normal and hot standby (redundant) microprocessor units physically located on racks in each of the CIH's.
- B. In addition to the "Normal" and "Standby" units, a third cold standby unit will be rack installed complete with all (same count) boards specific to the NVMIS units installed and running at that location.
- C. The NVMIS system shall be modular with all components being housed in structurally secure racks or backplanes. Each module shall consist of one or more printed circuit boards attached to a durable plastic face assembly. The units shall be available for installation directly in a standard 19-inch rack.
- D. Each NVMIS system shall, as a minimum, contain modules of the types described herein and as further required by the DB Entity's design. Wherever possible, all modules performing similar functions shall be interchangeable in order to minimize spare parts inventory. In all cases, both the normal and stand-by units shall have identical hardware configurations.
- E. The NVMIS backplane shall support two different backplane busses per module slot:
 - 1. High speed, PCI-based for fast throughput of advanced I/O
 - 2. Serial backplane for serial modules.
- F. The system shall be so designed that disconnection of field wiring is not necessary for replacement of assemblies. Universal removable terminal strips shall be utilized to connect field wiring to the individual circuit board assemblies.
- G. The NVMIS shall be protected against all types of power surges as specified in Section 16897 – MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- H. The NVMIS shall utilize solid-state microprocessor technology and shall not require any off-line storage devices for operation or start-up. The operation of the system shall be programmed in solid-state memory. The processor shall perform and the design shall be based upon the recognized

signal industry entrance-exit functions as commonly supplied for a route-setting system. In addition, other functions as specified herein shall be part of this system.

- I. The NVMIS shall receive inputs from the various control devices on the Local Control Panels and from OCC, and shall process control outputs to the VMIS for routing to the field equipment. The NVMIS shall also receive inputs from the VMIS and process outputs for indications on the Local Control and Maintainer Panels as well as OCC.
- J. The NVMIS shall include, but not be limited to, I/O processing for controls and indications as specified herein and as shown in the Contract Documents.
- K. All hardware and software supplied with the development system shall be demonstrated to be completely compatible with the actual hardware supplied. Demonstration of compatibility must include backup documentation from the vendor of each type of hardware and software.
- L. All NVMIS modules shall be accessible from the front of the cabinet and be easily replaceable. Each module shall contain its own identity.
- M. NVMIS Communications:
 - 1. The NVMIS shall communicate with the MBTA Operations Control Center (OCC) via normal and stand-by fiber optic, serial communications links, utilizing the MODBUSRTU protocol for this link. The DB Entity's equipment will be required to utilize or emulate this protocol for serial communications with OCC. If the DB Entity chooses to emulate this protocol, the emulator shall not introduce communications issues that would adversely affect the operation of or require custom modifications to OCC or the field equipment as it presently operates.
 - 2. Each NVMIS will be required to communicate via Ethernet network with all nodes on the networks as required by the DB Entity's design and as specified herein. Each network connection (two system-wide Ethernet busses) shall be via a dedicated Ethernet card. Therefore, each NVMIS shall be equipped with a minimum of two Ethernet cards.
 - 3. Each NVMIS (on-line and off-line) will be responsible to monitor the health of each Ethernet bus to which it is connected. Utilizing the diagnostic bits of the ethernet adapters, network health shall be monitored at the application level by setting up a "heartbeat". If an unhealthy state is detected, then the on-line NVMIS shall indicate the defective bus as "unhealthy" on the status and control panel for that particular network and initiate a local network fail-over to the off-line bus. If the system-wide bus shows some failure, then the on-line NVMIS shall indicate the defective bus as "unhealthy".
- N. NVMIS Software:
 - 1. The application logic shall be developed in relay or ladder logic in the NVMIS.
 - 2. A logic development application shall be provided that shall enable the MBTA to design, test, simulate and execute changes to the NVMIS application logic as well as adjusting the NVMIS configuration from the Maintenance PC via Ethernet connection or from a laptop via serial link. No special communications boards shall be necessary in the Maintenance PC or PC compatible laptop to communicate with the NVMIS, with the exception of the required network and serial cards. The software package shall be prepared, assembled and delivered with a site license for each NVMIS location furnished under this Project. The DB Entity shall install the software on the laptops provided under this Project and on each of the Maintenance PC's in each CIH.
 - 3. Programming equipment, location specific ladder logic lists and comprehensive user

friendly manuals and maintenance/troubleshooting manuals shall be included in the software package.

4. Training for the use of the development application shall be as specified in Section 16894 – TRAINING AND TRAINING MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM.
5. Application Program Logic:
 - a. The logic shall be a collection of programmed routines and functions necessary to perform the functions as specified herein and as shown in the Contract Documents.
 - b. Logic contacts shall be capable of being referenced any number of times within the application logic.
 - c. Logic shall provide for multiple programmable timers and counters. Each timer shall have selectable time bases of 1.0 seconds, 0.1 seconds, or 0.01 seconds. The timer and counters shall have limits so as to avoid the need for cascading in order to implement the design.
 - d. Single precision, double precision, relational and floating-point arithmetic operations shall be provided by the program logic.
 - e. Table, move, conversion, bit and bit matrix data operations shall also be provided by program logic.
 - f. The ability to “dump” blocks of logic states with their associated time and date stamps to the Maintenance PC shall be provided. The implementation of this “dump” shall occur during each scan cycle and shall have a minimal effect on the scan time.
- O. Non-vital event recording shall be performed by each NVMIS individually base on the following requirements:
 1. Each NVMIS unit will be responsible to date and time stamp its own event data and transmit the data to the Maintenance PC via the system-wide Ethernet bus. Recording of events shall be implemented in such a way as to not excessively burden the available NVMIS processor time with overhead for event recorder communications operations.
 2. The data shall be stored in segregated data structures (one for normal and one for standby) on a dedicated hard disk drive resident in the Maintenance PC. The data structure shall be first in first out (FIFO) and events shall be stored and not overwritten for a minimum period of 7 days.
 3. Data format shall be such that access, reporting and analysis can be performed utilizing the latest version of Microsoft Access or approved equal.
 4. All functions in the NVMIS applications software, shown as coils in the equivalent logic, as well as all external Non-Vital Relays that may be required by the DB Entity’s design shall be recorded. The DB Entity shall recommend any additional points for recording based on the specifics of the equipment supplied and any additional application logic required by this equipment (including fail-over logic).
 5. Sizing of all event recorder related hardware and software shall be calculated based on the requirements stated herein and shall include a minimum of 20% spare capacity. The DB Entity shall base the number of trains/day on 30-second headways for 21 hours per day.
 6. Once per day a baseline recording of all event recorder inputs shall be performed. In between baseline recordings, only changed states shall be recorded.
- P. The NVMIS fail-over logic shall be designed by the DB Entity to meet or exceed the following requirements;

1. Logic shall not give preference to either unit as a “default” nor shall it utilize any form of master- slave configuration
2. Fail-over initiation shall be based on the DB Entity’s recommendations as submitted and accepted by the MBTA.
3. Upon power up, an off-line unit, shall interrogate the on-line unit and perform redundancy checks to determine the logic is equal between each unit by transferring I/O states and data values in each CPU scan to determine that it is ready for a “hot” fail-over should one occur.

Q. Power Supply Modules

The NVMIS system, if separate from the VMIS architecture, shall operate from a nominal 24 V DC battery system. The NVMIS power supply shall be multi-purpose 40 watt supply that operates under a voltage range of 18 V DC to 30 V DC.

R. Central Processor Unit (CPU)

1. CPU shall be modular and shall not occupy more than two available slots when mounted in the system cabinet. The CPU module shall solve all application logic, store the application program and numerical values related to the application processes and logic, and interface to all I/O systems.
2. The central processing units shall contain the master clock/calendar function and clock/calendar shall be accessible by the application logic for date and time stamping of events.
3. Memory shall contain solid-state memory circuits programmed with the instructions for the system operation. The register values and application program shall be stored on battery backed Complementary Metal-Oxide Semiconductor (CMOS) static RAM. All timing functions shall be handled by the central processing unit from the stored program in CMOS. The memory module shall also be equipped with adequate Random Access Memory (RAM) for temporary data storage and retrieval.
4. The CPU shall have two independent, onboard serial ports accessed by connectors on the front of the module. These ports shall provide serial interface to external devices.
5. The CPU at a minimum shall have LED indication status lights for the following functions:
 - a. CPU OK
 - b. Outputs Enabled
 - c. I/O Faults
 - d. Battery Status
 - e. System Faults
 - f. I/O Force
6. A minimum of 1 MB of application memory shall be available for the user program. Executive level operations performed by the CPU shall not consume application memory.
7. There shall be a long life lithium battery used to maintain the contents of the CMOS memory in the CPU. The battery shall have a minimum life of six months while maintaining the memory status (loaded) and 6 years minimum while power is applied to the CPU and memory. An external battery or combination of energy packs and flash memory can be utilized provided it allows for the same life cycle.
8. Visual indication of the battery condition shall be supplied as well as an entry in the fault table for

the CPU.

- S. System Diagnostics - Each NVMIS shall be equipped with extensive self-diagnostic capabilities. These capabilities shall include but not be limited to:
 - 1. Information on the status of the CPU, Memory, Communications, and I/O,
 - 2. The ability to time stamp and log system and I/O faults into dedicated fault tables,
 - 3. Faults shall have the ability to be configured in two levels: fatal or diagnostic. Fatal faults shall be logged and initiate fail-over while diagnostic shall only be logged,
 - 4. All diagnostic information shall be accessible from the Maintenance PC or through a serial communications (maintenance) port for access by a laptop. The information available shall include the nature of the fault, the address and the timestamp,
 - 5. The diagnostic information shall also be available to the application logic.
- T. Security - Passwords to provide differing levels of access privilege for the NVMIS shall be available.
 - 1. Four levels of access privilege shall exist.

TABLE 1

Access Level	Access Description
4	Change Password
3	Write Logic/Configuration, Override I/O
2	Write Data, Clear Fault Tables
1	Read PLC Only

2.3 MAINTENANCE PC's

- A. The DB Entity shall provide rack mountable industrial grade PC's with rack mountable flat panel monitors for use as the Maintenance PC's. Two of these units shall be installed in each CIH and shall be identical in make and manufacture.
- B. The minimum criteria for the hardware is as follows:
 - 1. Two Flat Panel Monitors, one for each Maintenance PC
 - a. Class I Division 2 Rated
 - b. 17" minimum viewable area Color TFT Display (1280 X 1024)
 - c. NEMA 4/4X/12 sealed front panel
 - d. Rack Mounted
 - 2. Latest Generation Intel, AMD or approved equal processor operating at fastest clock speed available
 - 3. 8 GB RAM
 - 4. 2 – 1 TB Solid State Drives (second drive to be used for long term storage of event recorder data).
 - 5. 4 USB ports (minimum of front access port, either on the front of the PC or the monitor)

6. 2 - 10/100 Base-T Ethernet Cards
 7. 2 Serial Ports
 8. 1 DVI video port to drive flat panel display
 9. 120 V AC power
 10. UL listed for hazardous locations
- C. All Maintenance PC's provided under this Project shall be provided with a standard optical track ball.
- D. All Industrial PCs provided under this Project shall be provided with a standard keyboard.
- E. The keyboard and track ball shall be installed on a rack mounted slide out tray beneath the associated computer.
- F. The interconnection and communications of the Maintenance PC shall be specified herein.
- G. All PCs shall be configured with the same software, unless otherwise noted. The DB Entity shall provide a licensed copy of all software necessary to support, maintain and implement changes to the systems provided. The minimum software requirements are as follows:
1. A version of Windows or current equivalent as accepted by the MBTA that is compatible with all supplier proprietary software that will be utilized under this Project.
 2. Latest Version of Microsoft Office
 3. Latest Version of PC Anywhere or current equivalent
 4. Network troubleshooting and maintenance software
 5. VMIS and NVMIS Maintenance & Troubleshooting Software
- H. Maintenance PCs shall be the primary troubleshooting and maintenance tool in each CIH. They will serve as a maintenance and programming tool for the logic controllers and shall have the capability to interface directly to the event recorders.

2.4 ETHERNET SWITCHES

- A. Ethernet Switches for all field applications shall be Moxa EDS-510A series or approved equal.
- B. The unit shall be equipped with a minimum of 3 single mode fiber Ethernet ports with SFP modules and 7 copper Ethernet ports.
- C. The switch shall support the MSTP(IEEE 802.1s) protocol to allow for redundancy at the VLAN level.
- D. Units shall be din rail mounted in the same rack as the maintenance PC.
- E. Units shall comply with AREMA Class C environmental requirements.

2.5 STATUS AND CONTROL PANELS

- A. Status and Control Panels as shown in the Contract Documents shall be provided to indicate the health and on-line status of normal and standby logic controllers and ethernet networks, as well as control the fail- over of the normal and standby logic controllers.
- B. These panels shall be equipped with LED health and on-line indications and a three-position control

knob as shown in the Contract Documents and as specified herein. The function of the LED's and switches shall be as indicated in the Contract Documents.

2.6 MANUALS AND DOCUMENTATION

- A. All required documentation shall be delivered to the MBTA upon final acceptance of submittals. All documentation shall be delivered in the form of 10 bound hardcopies (4 for the maintenance and engineering department and 6 for the training facility) and two (2) electronic copies on CD (.PDF format). The electronic copies shall come with the necessary software for viewing and updating the documentation by the MBTA.
- B. Deliver complete documentation for all software provided for the Maintenance PCs.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Instrument racks shall be arranged and mounted in central instrument houses as indicated in the Contract Documents and in accordance with the accepted installation plans.
- B. All equipment shall be mounted in standard 19-inch shock mounted instrument racks. If rack mounting is not an option, the equipment shall be shelf mounted within the rack.
- C. The mounting of equipment shall provide for easy access to all test points, indicators, and adjustments.
- D. Maintenance PCs monitors shall be mounted at eye level with their associated keyboard and track ball at standard shelf height (34-36 inches from finished floor).
- E. All of the Status and Control Panels shall be rack mountable and installed in the rack with the redundant logic controllers.
- F. Each major component specified herein shall have a typed, or printed, name tag on a front plate of each rack and cabinet to clearly identify the component using the same wording as that appearing in the contract documents.
- G. Provisions for EMI mitigation (shielding) shall be made to ensure proper operation of equipment relative to the environment.
- H. All wiring and wire terminals shall be tagged in an approved manner.

3.2 FACTORY TESTING

- A. The non-vital support systems shall be tested in accordance with the accepted Factory Test Procedure.

3.3 FIELD ACCEPTANCE TESTING

- A. The non-vital support systems shall be tested in accordance with the accepted Field Test Procedure and meet the requirements of Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM, of these Mandatory Specifications.

END OF SECTION

SECTION 16869

MAINTAINER AND LOCAL CONTROL PANELS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies requirements for furnishing and installing Maintainer's Panels and Local Control Panels as required for the Project.
- B. Panels shall be mosaic tile panels with levers and LED indicators as shown on the contract plans.
- C. Maintainer's Panels shall be provided at non-interlocking locations and shall provide only the indications for the area within the limits of CIH control, and also various system and power health indications. Faceplate configurations will reflect the actual physical track configurations for the local area.
- D. Local Control Panels shall be provided at interlocking locations and shall provide controls and indications for the area within the limits of CIH control, and also various system and power health indications. Faceplate configurations will reflect the actual physical track configurations for the local area.

1.2 QUALITY ASSURANCE

Comply with the requirements of Volume 1 Section 4 and Volume 2 Subsection 2.5.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and 2.8, the DB Entity shall submit the following to the MBTA, for both panel types, for his acceptance:

- A. Manufacturer's drawings and catalog cuts for panel housings.
- B. Detailed/scaled internal panel layouts showing all internal accessories, wall space for dressing/running wire conductors, methods/materials for securing wiring and components to backboard/terminals.
- C. Typical installation drawings and installation procedures for Maintainer's and Local Control Panels.
 - 1. Additional and/or alternate locations for panel placement may be required to suit the DB Entity's design and/or installation method. Drawings describing the locations where non-standard placements shall be submitted to the MBTA for acceptance prior to mounting within the CIH.
 - 2. Additional installation drawings/procedures are to be submitted in instances where the typical details do not apply.
- D. All associated panel hardware and installation materials.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage during delivery, storage and handling. Comply fully with

the requirements of Section 16801 – BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

- B. Damage to material, resulting from improper handling by the shipper or the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 GENERAL

A. Terminals:

1. The Maintainer's and Local Control Panel enclosures shall be hard-wired to Wago or approved equal terminals to enable connection of the cabling from the panels to I/O points located within the CIH. Interconnecting cables shall be in accordance with these Specifications.
2. The hardwired panel shall interface with remote I/O controlled form the redundant NVMIS through means as determined by the DB Entity's design.

B. Panels:

1. The Maintainer's and Local Control Panels will be hardwired mosaic tile panels manufactured by Mauell Corporation or an approved equal.
2. The panel shall be mosaic grid tiling, using 24MM tile that snaps into a solid steel grid.
3. The background color of the mosaic tiles shall be light gray.
4. The track diagram, symbols and lettering are to be engraved and filled in solid black.
5. Letters inside LEDs that indicate color are not to be engraved.
6. The panel(s) shall be oriented to match the actual field location when facing the panel(s).
7. The panels shall be capable of being completely powered-off and disabled when not in use.
8. The panels are to be wall mounted.
9. The panels shall be constructed with a continuous hinge on the bottom edge to facilitate access to internal components when the panel is opened.
10. The Local Control Panel shall have a hinged and lockable glass cover that is able to be locked.
11. The panels shall include LED Indicator Lamps, Lamp Boxes and Terminal Blocks.
 - a. Light Emitting Diodes (LEDs) shall be directly compatible with the lamp boxes utilized within the panels and shall provide sufficient illumination to be visible under ambient CIH lighting conditions. Replacement shall be accomplished from the rear of the hinged panel faceplate. There are to be no special tools required to perform LED replacements.
 - b. Lamp boxes shall be an integral part of the panel.
 - c. Wire and cable terminating blocks shall be terminated as described in these Specifications.
 - d. A panel light "On/Off" toggle switch shall be provided on the panel. The "On/Off" toggle switch shall be used to extinguish all panel indication lights.
 - e. A lamp test button shall be provided for each panel. Upon initiation of the test button,

all lamps shall be lit. The test routine shall cycle through each color, turning off indications of other colors while the cycled color is lit.

12. Indicators

All illuminated indicators shall be designed, provided, and installed as required in these Specifications. Displays shall be provided by means of individual unit type LEDs that shall display the colors defined in these Mandatory Specifications and Contract Documents.

13. Track Indicator

- a. Track indicators shall display a line-of-light along align route. There shall be two indicator colors for each interlocking track indicator. Panel lights shall indicate all operations as noted below, when panel light "On/Off" toggle switch is activated. Panel indications shall be as follows:
 - 1) ABS Track Circuit indicators shall normally be DARK. When track circuit occupancy is detected, or if track circuit relay drops from a connection or equipment failure, the indication shall illuminate RED.
 - 2) Approach and Exit Track Circuit indicators shall normally be DARK. The indicator shall function as an approach or exit indicator to and from the adjacent locations. The track circuits between locations that are not located within the CIH where the panel exists shall be grouped together to form one indication. When track circuit occupancy is detected, or if a track circuit relay drops from a connection or equipment failure, the indication shall illuminate RED.
 - 3) Interlocking Track Circuit indicators shall normally be DARK with no route aligned. When a route is aligned, the indicators shall illuminate WHITE such that the indicators display a line of white lights along the aligned route. When track circuit occupancy is detected, or if a track circuit relay drops from a connection or equipment failure, the indication shall illuminate RED.
 - 4) When a route is called by requesting an entrance at a signal, the entrance signal indicator shall illuminate RED, the track indicator adjacent to the entrance lever shall illuminate WHITE and all available exit points shall be indicated by illuminating FLASHING-WHITE indicators located in the track circuits adjacent to exit point signals. When an exit signal has been selected all other available exit indicators shall extinguish. After the switches are in correspondence and the route is established, all interlocking track circuit indicators in the route shall illuminate WHITE to display a line-of-lights along the aligned route. The entrance signal indicator shall change from RED to GREEN. The interlocking track circuit indicators that display a line of WHITE indicators along the aligned route shall change to RED when track section is occupied. This RED indicator shall extinguish when the track section becomes unoccupied. When a route is canceled, the WHITE indicator shall remain illuminated until expiration of time locking.

14. Signal Indicators

- a. Signal indicators shall operate as follows:

The indicator located in the head of each signal shall normally be RED with signal at Stop. The indicator shall illuminate GREEN when the signal is cleared with the route established. The indicator shall return to RED when the signal has been set to Stop by either passage of a train, canceling the route, or after time has expired for a canceled route. While signal time is running the indicator shall illuminate FLASHING-RED.

- b. Signal Fleeting indicators shall normally be DARK when fleeting is off. The indicator shall illuminate FLASHING-GREEN when fleeting is requested. The indicator shall illuminate GREEN when fleeting is turned on. The indicator shall return to DARK when fleeting is canceled.

15. Switch Indicators

- a. Lock Indicator shall normally be DARK when associated switch is unlocked. When associated switch is locked the indicator shall illuminate RED.
- b. The indicator associated with switch position shall be illuminated WHITE when switch is in correspondence in either the Normal or Reverse position.
- c. The indicator associated with switch position shall be illuminated FLASHING-WHITE when switch is out of correspondence in either the Normal or Reverse requested position.
- d. When a switch or a crossover is controlled by hand operation in signal territory, the WHITE indicator associated with the switch shall FLASH WHITE indicating the switch is not in correspondence.

16. Terminal Operation Mode Indicators (Local Control Panel)

- a. The Manual indicator shall illuminate RED when the interlocking is operating in Manual Control Mode and be DARK when operating in Automatic Control Mode.
- b. The Auto indicator shall illuminate WHITE when the interlocking is operating in Automatic Control Mode and be DARK when operating in Manual Control Mode.

17. Platform Service Mode Indicators

- a. The In indicator shall illuminate WHITE when Platform In-Service Mode is active and be DARK when Platform Out-of-Service Mode is active.
- b. The Out indicator shall illuminate RED when Platform Out-of-Service Mode is active and be DARK when Platform In-Service Mode is active.

18. Control Transfer Mode Indicators (Local Control Panel)

- a. The Local indicator shall illuminate WHITE when the interlocking is operating in Local Control Mode and be DARK when operating in Remote Control Mode.
- b. The Remote indicator shall illuminate WHITE when the interlocking is operating in Remote Control Mode and be DARK when operating in Local Control Mode.

19. Blocking Mode Indicators

- a. The Switch Block indicator shall normally be DARK. The indicator shall be illuminated BLUE while switch blocking is in effect for the associated switch.
- b. The Signal Exit Block indicator normally be DARK. The indicator shall be illuminated BLUE while signal exit blocking is in effect for the associated signal.

20. Alarm Indicators

- a. Alarm indicators shall normally be DARK. When an alarm is detected the corresponding indicator shall illuminate RED. Alarm indicators are shown on Contract Drawings for indicating the following conditions:
 - 1) AC Power
 - 2) DC Charger
 - 3) Fire / Smoke
 - 4) Intrusion
 - 5) Blown Fuse
 - 6) LB12 Power (Normal)
 - 7) LB12 Power (Reserve)

21. Condition Indicators

- a. Starting Lights
The Starting Lights indicator shall be illuminated WHITE when starting lights are on and DARK when starting lights are off.
- b. Maintainer Call
The Maintainer Call indicator shall be illuminated WHITE when the maintainer call is on and DARK when the maintainer call is off.
- c. Switch Heater
The Switch Heater indicator shall illuminate WHITE when all switch heaters are on. The indicator shall illuminate FLASHING-WHITE when at least one switch heater is on but not all switch heaters are on. The indicator shall be DARK when all switch heaters are off.
- d. Wayside Push Button Disable
The Wayside Push Button Disable indicator shall normally be DARK. The indicator shall illuminate RED when the wayside push buttons are disabled.
- e. AC Power (Normal)
The AC Power (Normal) indicator shall normally be illuminated WHITE. In the event that normal AC power becomes unavailable, the indicator shall go DARK.

- f. AC Power (Reserve)
The AC Power (Reserve) indicator shall normally be illuminated WHITE. In the event that reserve AC power becomes unavailable, the indicator shall go DARK.
- g. NVMIS Health (Normal)
The NVMIS Health (Normal) indicator shall normally be illuminated WHITE. If the normal NVMIS becomes unhealthy, the indicator shall go DARK.
- h. NVMIS Health (Standby)
The NVMIS Health (Standby) indicator shall normally be illuminated WHITE. If the standby NVMIS becomes unhealthy, the indicator shall go DARK.
- i. VMIS Health (Normal)
The VMIS Health (Normal) indicator shall normally be illuminated WHITE. If the normal VMIS becomes unhealthy, the indicator shall go DARK.
- j. VMIS Health (Standby)
The VMIS Health (Standby) indicator shall normally be illuminated WHITE. If the standby VMIS becomes unhealthy, the indicator shall go DARK.
- k. VMIS Ethernet Health (Normal) (Maintainer's Panel only)
The VMIS Ethernet Health (Normal) indicator shall normally be illuminated WHITE. If the normal VMIS Ethernet becomes unhealthy, the indicator shall go DARK.
- l. VMIS Ethernet Health (Standby) (Maintainer's Panel only)
The VMIS Ethernet Health (Standby) indicator shall normally be illuminated WHITE. If the standby VMIS Ethernet becomes unhealthy, the indicator shall go DARK.
- m. NVMIS Ethernet Health (Normal) (Maintainer's Panel only)
The NVMIS Ethernet Health (Normal) indicator shall normally be illuminated WHITE. If the normal NVMIS Ethernet becomes unhealthy, the indicator shall go DARK.
- n. NVMIS Ethernet Health (Standby) (Maintainer's Panel only)
The NVMIS Ethernet Health (Standby) indicator shall normally be illuminated WHITE. If the standby NVMIS Ethernet becomes unhealthy, the indicator shall go DARK.

C. Panel Enclosure:

1. Panel enclosure shall be constructed of minimum 16-gauge steel.
2. Frame shall be reinforced to provide rigidity required to maintain alignment.
3. Accurately machined surfaces shall be provided to assure proper positioning.
4. Steel shall be accurately rolled and have a smooth finish. Joints shall be formed to a tight fit with abutting edges flush and securely welded. Joints shall be welded their full length and dressed flush on exposed surfaces. Spot welding shall be used when practicable in preference to screws or rivet fasteners.
5. Screw or bolt holes shall be drilled and countersunk. All bolts, nuts, washers and screws shall

be chromate zinc plated. The finished work shall be strong, rigid and neat in appearance. Surfaces shall be smooth and free from warp and buckles.

6. Terminal mode operation controls and indications shall be incorporated in the Local Control Panel, with indications only in the Maintainer's Panel.

D. Unit Levers:

1. All control panel levers shall be of the unit type. The term "unit type" shall be understood to mean that each unit may be completely and easily removed from the control panel without interfering with operation of any other unit.
2. In order to facilitate quick replacement of unit levers, all contacts on each lever assembly shall be connected to the plug portion of a locked, quick-detachable, keyed connector in order that all like units shall be interchangeable. Only the required wires shall be provided in the wiring tree and connected to the other side of the connector. Plug portion of the connector shall be an integral part of the lever assembly. Each plug portion assembly shall be protected by a dust cover. Material used in fabrication of dust covers shall not support combustion.
3. All control panel unit levers shall be push-pull, turn right, turn left, and center return type. The same lever type shall be provided for all applications unless otherwise specified. Blocking devices shall be provided to prevent operation of levers, one for every lever.
4. Unit levers shall be provided for all controls except as noted in these Mandatory Specifications and Contract Documents.

E. Transfer of Control Lever:

1. The Transfer of Control lever shall be provided on the Local Control Panel to enable transfer of control to/from remote (OCC) and local (LCP) control.
2. The lever shall operate as follows:
 - a. Lever is turned to the LEFT: a request for local control is initiated.
 - b. Lever is turned to the RIGHT: the request for the local control is canceled.

F. Switch Control Lever:

1. The Switch Control lever shall be provided on the local control panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is turned to the LEFT: a normal switch call is requested.
 - b. Lever is turned to the RIGHT: a reverse switch call is requested.
 - c. Lever is PULLED: the switch call is canceled.

G. Terminal Operations Control Lever:

1. The Terminal Operations Control lever shall be provided on the Local Control Panel as shown

on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.

2. Control inputs from the Local Control panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is turned to the LEFT: the interlocking shall operate in Automatic Control Mode.
 - b. Lever is turned to the RIGHT: the interlocking shall operate in Manual Control Mode.

H. Signal Control Lever:

1. The Signal Control lever shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is PUSHED: signal request or exit is initiated.
 - b. Lever is PULLED: signal request is canceled.
 - c. Lever is turned to the LEFT: signal fleeting is enabled.
 - d. Lever is turned to the RIGHT: signal fleeting is canceled.

I. Switch Heater Control Lever:

1. The Switch Heater Control lever shall be provided on the Local Control Panel as shown on the Contract Drawings or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is turned to the LEFT: switch heater request is initiated.
 - b. Lever is turned to the RIGHT: switch heater request is canceled.

J. Maintainer Call Lever:

1. The Maintainer Call lever shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is turned to the LEFT: Maintainer Call request is initiated.
 - b. Lever is turned to the RIGHT: Maintainer Call request is canceled.

K. Blocking Control Lever (Switch and Signal Exit):

1. The Blocking Control lever shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is PUSHED: block is activated.
 - b. Lever is PULLED: block is canceled.

L. Platform Service Control Lever:

1. The Platform Service Control lever shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The lever shall operate as follows:
 - a. Lever is turned to the LEFT: the platform is placed out-of-service.
 - b. Lever is turned to the RIGHT: the platform is placed in-service.

M. Emergency Release Push Button:

1. The Emergency Release push button shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. The push button shall be red in color and have a lockable cover.
3. The Emergency Release push button allows local control to take control of the interlocking without OCC acknowledging the request for local control.

N. Next Train Control Switch:

1. The Next Train Control switch shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The switch shall be a three-position toggle switch that controls the Next Train Sign at the station platform. The switch shall function as follows:
 - a. In the CENTER position the Next Train Sign will function automatically.
 - b. In the UP position the Next Train Sign will illuminate for platform two.

c. In the DOWN position the Next Train Sign will illuminate for platform one.

O. Train Start Light Control Switch:

1. The Train Start Light Control switch shall be provided on the Local Control Panel as shown on the Contract Documents or the DB Entity may submit an alternate placement to the MBTA for acceptance.
2. Control inputs from the Local Control Panel shall be enabled only when the interlocking is in local control.
3. The switch shall be a two-position toggle switch that controls the Start Lights at turn back locations. The switch shall function as follows:
 - a. In the UP position the Start Lights will be on.
 - b. In the DOWN position the Start Lights will be off.

P. Local Control and Maintainer's Panel:

1. The control panel shall be wired with single conductor, not smaller than No. 22 AWG, 19 strand, insulated 600-volt service wire. Wiring harness shall allow clear access to all levers, pushbuttons, switches and indicators.
2. Panel enclosure shall be completely finished using an enamel or lacquer paint. Finish color of console cabinet shall be Gray ANSI-61, or MBTA accepted equal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Local control and indication panels shall be located in the central instrument house.
- B. Location of panel shall permit convenient use by an operator sitting in front of it.
- C. The panels shall be mounted with sufficient space so that the access doors can be opened without interference with house structure or wall-mounted equipment.
- D. Any damage caused during installation shall be repaired. Restored finish shall be equivalent to factory finish and performed in a manner satisfactory to the MBTA.

3.2 TESTING

- A. Local control and indication panels shall be tested in accordance with these Mandatory Specifications.
- B. Local control and indication panel tests shall consist of controlling wayside functions from the local control panel. All controls and indications on the respective panel shall be tested.

END OF SECTION

SECTION 16870

BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies basic materials and methods of installation applicable to signal electrical work.
- B. The electrical work required for the Project electrical systems shall include, but not be limited to the following:
 - 1. Furnish and install 480 V ac three phase 3 wire with ground from the station substation to utility transformer to each CIH; and 2 each 480 V ac single phase two wire from separate wayside signal power feeds to two separate 480 V single phase to 240/120 V ac single phase transformers. The transformers feed redundant 120/240 V ac single phase two wire signal power services to each CIH.
 - 2. Furnish and install 2 wire ungrounded power feeds from the Overhead Contact System to distribute 600V dc power to the snowmelter control cases.
 - 3. Furnish and install snowmelter control cases and track switch heaters including conductors, raceways and associated appurtenances.
 - 4. The DB Entity shall coordinate with the MBTA to identify service locations prior to signal equipment installation. The DB Entity shall install all equipment and provide all cabling from source to load for all signal equipment.

1.2 SUBMITTALS

- A. The submittals required for the materials and methods for electrical work to be performed are specified within the respective sections of these Mandatory Specifications.

1.3 REGULATORY REQUIREMENTS

- A. The DB Entity shall comply with the requirements of all national, state and local codes, laws and ordinances, and all rules and regulations of public administrative authorities having jurisdiction over the work where the requirements do not conflict with these Mandatory Specifications.
- B. The latest published issues of the standards, codes, recommendations or requirements of the following listed organizations in effect at the date of the Notice-To-Proceed where the requirements do not conflict with these Mandatory Specifications. In case of a conflict, the more stringent shall apply.

AASHTO	American Association of State Highway and Transportation
Officials ANSI	American National Standards Institute
AWS	American Welding Society
ASTM	American Society for Testing and Materials
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronic Engineers
IES	Illuminating Engineering Society

MEC	Massachusetts Electrical Code
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
UL	Underwriter's Laboratories, Inc.

1.4 QUALITY ASSURANCE

- A. The DB Entity shall repair or replace any equipment damaged; lost or stolen prior to Contract Final Acceptance by the MBTA, at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. All equipment, devices, material, etc. shall be new and of the most modern type, including latest improved designs to provide the highest degree of safety and reliability capable of being integrated into the system and subsystems specified within these Mandatory Specifications.
- B. The material and apparatus required for the work to be performed is specified within the respective sections of these Mandatory Specifications.

PART 3 - EXECUTION

3.1 GENERAL

- A. Work shown on the Contract Documents and defined in these Mandatory Specifications shall be performed by the DB Entity and shall include all work complete from the final detailed design to furnishing, installing and testing of the specified electrical equipment and systems.

3.2 INSTALLATION

- A. The installation of the various equipment and materials specified herein shall be in accordance with the respective Sections of these Mandatory Specifications.

END OF SECTION

SECTION 16871

GROUNDING FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing a complete system neutral and equipment grounding system for electrical systems.
- B. The intent of this section is to provide a grounding system and materials for both electrical and signal power applications with a completely operable electrical system to support the new signal system.
- C. Equipment grounding includes snowmelter control cases, power service equipment manholes and handholds and other electrical apparatus.

1.2 SUBMITTALS

- A. The DB Entity shall submit the following for approval:
 - 1. Catalog cuts and descriptive literature for all materials as specified herein.

1.3 QUALITY CONTROL

- A. Electrical equipment such as snowmelter control cases, power service equipment, electrical manholes and hand holes and other electrical apparatus requiring grounding shall meet the resistance test value specified below.
 - 1. Resistance Test Value. The maximum allowable value for electrical apparatus specified above shall be 25 ohms or less. If it is found that the resistance value exceeds 25 ohms, the DB Entity shall install additional ground rods in series until the resistance value reaches 25 ohms or less. Additional ground rods shall be spaced no less than 10' apart.
- B. If a conflict arises between this Section and referenced Standards, the most restrictive shall apply as determined by the MBTA.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage throughout delivery, storage and handling. DB Entity shall comply fully with the requirements of Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM
- B. Damage to material resulting from improper handling by the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the MBTA.

PART 2 – MATERIALS

2.1 MATERIALS

- A. Ground rods - Copperweld Corp, or approved equal.

1. Ground rods shall be copper-clad steel. The rod shall be at least a 10' x 3/4" ground rod.
- B. Ground wire
1. Sizing of ground wire shall be in accordance with the MEC, except where sizes specified herein are larger than those required by MEC; UL listed, Label A for lightning protection conductors. Grounding cable shall be continuous without joints or splices throughout its length. Ground wire shall be minimum bare, soft-drawn #6 copper wires.
- C. Cadweld connections - Erico Corp., or approved equal.
1. All ground wire connections to ground rods will be of the exothermic weld type, no mechanical connections are permitted.

PART 3 – EXECUTION

3.1 EQUIPMENT GROUNDING

- A. Ground Electrodes (Rods)
1. Ground rods shall not protrude above finished grade to prevent a tripping hazard.
 2. Separate grounding conductors shall be provided for all circuits as required by these Mandatory Specifications.
- B. Electrical Manhole and Hand hole Frames
1. Electrical manhole and hand hole frames shall be grounded.
- C. Signal Houses and Snowmelter Control Cases
1. All signal houses, cases and snowmelter control cases shall be grounded.
- D. Fencing
1. Fencing shall be grounded.
- E. Metering Cabinet
1. Metering cabinet if required for the primary power service shall be grounded in accordance with the Power Company's requirements.

END OF SECTION

**SECTION 16872
TRANSFORMERS FOR THE LIGHT RAIL SIGNAL SYSTEM**

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing general purpose transformers for general purposes, for signal power and for signal house utility power.
- B. Transformers shall be in accordance with this Section and Section 16835 – SIGNAL AND UTILITY POWER SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- C. Transformers to be furnished and installed shall consist of dry-type, self-cooled shielded isolation transformers for house utility power and signal power feeds.

1.2 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and 2.8, the DB Entity shall submit a description of materials and methods of installation to be furnished under this Section.

1.3 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage throughout delivery, storage and handling. Materials shall comply fully with the requirements of Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Damage to material resulting from improper storage or handling by the DB Entity shall result in replacement of all damaged material with new material by the DB Entity at no additional cost to the MBTA.

PART 2 - MATERIALS

2.1 GENERAL PURPOSE TRANSFORMERS

- A. General Requirements. This Article specifies the general requirements for furnishing general purpose, dry-type transformers for miscellaneous requirements as specified herein and as shown on the Contract Documents.
- B. Ratings
 - 1. Voltage: Primary, 480 V AC single-phase. Secondary, 120/240 V AC single-phase four wire grounded, as required by the DB Entity's design.
 - 2. KVA Rating: Single-phase 60 Hz sized as required by the DB Entity's design. KVA ratings shall be sized for 125% above peak demand load plus 25% spare capacity for future expansion.

2.2 SIGNAL POWER TRANSFORMERS

- A. General Requirements. This article specifies the general requirements for furnishing transformers for signal equipment housings for signal power and auxiliary power supply as specified herein.
 - 1. Transformers shall be designed, manufactured and tested in accordance with all applicable ANSI,

NEMA and IEEE standards.

2. Transformers shall be UL listed and bear the UL label.
3. Transformer core shall be constructed with high-grade, non-aging, silicon steel with high magnetic permeability and low hysteresis and eddy current losses.
4. Primary and secondary windings shall be copper. Secondary windings shall be isolated from the primary windings.
5. The complete core and coil assembly shall be provided with a UL and CSA recognized 200 degrees C insulation system, using a vacuum-pressure impregnation process. The impregnated coils shall be free of corona up to 150 percent of rated operating voltage.
6. Transformers shall be factory equipped with solderless pressure terminals suitable for copper wires. Terminals shall be two-hole NEMA type. A visible ground wire shall connect the core to a solderless pressure-type ground lug on the enclosure.
7. Transformers shall be of the non-ventilated exterior pad mounted type suitable for the dust and environment of an operating rail transit system
8. Transformers shall be thoroughly inspected and tested before shipping. Tests shall be performed in accordance with ANSI/IEEE C57.12.91 and shall include resistance measurement, voltage ratio and polarity, phase rotation, no-load losses and excitation current, applied voltage dielectric test (hi-pot) and induced voltage dielectric test (double voltage).

2.3 **TRANSFORMER SAFETY LABELING**

- A. Signs which read “DANGER 480 VOLTS – KEEP OUT” shall be affixed to each 480 V AC transformer enclosure door in accordance with NEMA ST 20 Standards.

2.4 **TRANSFORMER NAMEPLATES**

- A. Nameplates shall be affixed to each transformer enclosure with information as specified in NEMA ST 20 Standard.

PART 3 - EXECUTION

3.1 **GENERAL**

- A. Transformers shall be installed in accordance with the DB Entity’s Design Documents, manufacturer’s recommendation and the MEC.

END OF SECTION

SECTION 16873

DISTRIBUTION AND BRANCH CIRCUIT PANEL BOARDS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies basic requirements applicable to installing wiring and materials for branch circuit panel boards.
- B. The intent of this Section is to provide branch circuit panel boards to supply and distribute both electrical power and signaling power associated with installation of the new signal system furnished under this Project.
- C. See Section 16835 – SIGNAL AND UTILITY POWER SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM, for additional requirements.

1.2 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsections 2.7 and 2.8, the DB Entity shall submit a description of materials and methods of installation to be furnished under this Section.

1.3 DELIVERY, STORAGE AND HANDLING

- A. Materials shall be protected from damage throughout delivery, storage and handling. Materials shall comply fully with the requirements of Section 16801 - BASIC TECHNICAL REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Damage to material resulting from improper handling by the DB Entity shall require the DB Entity to replace all damaged material with new material at no additional cost to the MBTA.

PART 2 - PRODUCTS

2.1 CIRCUIT BREAKERS

- A. Circuit breakers for the various panel boards shall be the thermal magnetic, molded case, bolt-in type with voltage ratings for the intended use. The number of poles and ampere ratings shall be sized and verified by the DB Entity.
- B. Lighting and Appliance Branch Circuit Panel Board Circuit Breakers
 - 1. Circuit breakers for lighting and appliance branch circuit panel boards furnished for signal equipment housings for 120 V AC signal and utility power shall be of the thermal magnetic, molded-case type, two-pole, rated at 240 V AC. The DB Entity shall verify Ampere ratings.
- C. 480 V AC Applications
 - 1. Circuit breakers if utilized for 480 V AC signal and utility power feeds shall be of the thermal magnetic, molded-case, bolt-in type, two-pole, rated at 480 V AC. Circuit breakers shall be

self-contained in a NEMA enclosure suitable for the environment. The DB Entity shall verify Ampere ratings.

- D. Circuit breakers shall be of the indicating type, providing “on”, “off” and a “tripped” position of the operating handle. When the breaker is tripped automatically, the handle shall assume a middle position between “on” and “off”. All multi-pole breakers shall be of a design that an overload on one pole automatically causes all poles to open.

2.2 ENCLOSURES

- A. Enclosures shall be provided according to the environment, and shall be NEMA Type 12 minimum with a continuous stainless-steel hinge.
- B. Enclosure Labeling
 - 1. Panel board doors shall be labeled with the equipment name. Labels shall be stenciled on adhesive-type decals.
 - 2. Panel board door interior shall be provided with an attached card or other approved label by which to identify the branch circuit and the corresponding equipment to which it is connected.

2.3 PANEL BOARDS

- A. Panel boards shall be provided with 25% (minimum) spare circuit breaker spaces for future expansion.

2.4 BRANCH CIRCUIT PANEL BOARDS

- A. General
 - 1. Each CIH and wayside signal case shall be provided with one-branch circuit panel board properly sized and provided with the appropriate branch breakers for the utility power supply. Small cases upon acceptance from the MBTA may be exempt from the utility power panel board requirement.
 - 2. Each CIH and wayside signal case shall be provided with one-branch circuit panel board properly sized and provided with the appropriate branch breakers for the signal power supply. Small cases upon acceptance from the MBTA may be exempt from the utility power panel board requirement.
- B. Panel boards shall be rated for 120/240 V AC single-phase three wire and shall contain thermal magnetic, molded case, circuit breakers. Panel boards shall contain 25% (minimum) spare circuit breaker spaces for future expansion.

PART 3 - EXECUTION

3.1 ENCLOSURES AND PANEL BOARDS

- A. Enclosures and panel boards shall be installed in accordance with the DB Entity’s Design Documents, manufacturer’s recommendation and the latest edition of the MEC.

3.2 CIRCUIT AND CIRCUIT BREAKERS

- A. DB Entity shall ensure the proper function and coordination of trip for each circuit and circuit breaker.

END OF SECTION

SECTION 16876

DISTRIBUTION AND BRANCH CIRCUIT PANEL BOARDS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing a grounding system for CIH's, signals, wayside signal cases, junction boxes, and any other wayside equipment or apparatus as hereinafter specified or shown on the Contract Documents.
- B. The grounding system shall preclude any closed loop grounding arrangement.
- C. Ground connection to the track rails or use of the neutral conductors of the power company or AC signal supply system shall not be permitted.
- D. Related work: see Section 16871 – GROUNDING FOR THE LIGHT RAIL SIGNAL SYSTEM.

1.2 QUALITY ASSURANCE

- A. All grounding systems furnished and installed as herein specified shall be inspected and any deficiencies noted shall be corrected. The inspection shall be conducted in conformance with the requirements of the DB Entity's factory test installation and inspection procedures as described in Section 2.7 accepted by the MBTA.
- B. Tests of the grounding system shall be in conformance with the requirements of Section 16871 – GROUNDING FOR THE LIGHT RAIL SIGNAL SYSTEM and any other relevant sections of these Specifications.

1.3 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following to the MBTA for acceptance:

- A. Circuit and schematic drawings showing design details of CIH and wayside signal and case grounding.
- B. Factory test, installation and inspection procedures for grounding of all equipment.
- C. Field installation, inspection and testing procedures for grounding of all equipment.

PART 2 - PRODUCTS

2.1 MATERIALS FOR WAYSIDE HOUSINGS AND SIGNALS

- A. Ground rods, clamps, and ground wire shall be as specified in Section 16871 – GROUNDING FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. Ground bus bars for the central instrument houses and wayside cases shall be made of hard drawn pure copper having a minimum conductivity of 98% per ASTM B187-73. The minimum cross-section dimensions of this bus shall be eight inches by eight inches by one-half-inch thick.

- C. The bus bars as installed shall be free from sharp edges.

PART 3 - EXECUTION

3.1 EQUIPMENT GROUNDING

- A. Each instrument rack and entrance rack in the CIH's shall be grounded to overhead grounding bus bars that shall be installed continuously along each row of racks. The grounding bus bars shall be mechanically and electrically attached to all cable trays. Each rack shall be connected to a grounding bus bar by means of a copper strap. Grounding studs shall be provided on both the grounding bus bar and each rack to allow for easy individual disconnection of any rack from the grounding system. Each grounding bus bar in the CIH's and wayside cases shall be directly connected to the prime ground bus by means of No. 6 AWG copper connector without any intermediate termination.
- B. A prime ground bus bar, equipped with sufficient facilities to make all the grounding connections specified, shall be furnished and installed in the central instrument houses. This prime ground bus bar shall be approximately one (1) foot long and shall be mounted on insulating stand-offs on a wall of the central instrument house approximately four (4) feet above the floor. The DB Entity shall connect this prime ground bus bar by means of a No. 6 insulated wire between the bus bar and the (temporary) prime ground to accommodate factory testing.
- C. Run ground conductors separately from other conductors in tray or wireway. Where AC power conductors exist, the equipment ground conductors shall be bundled with them. Signal reference grounds, if required, shall be run separately from equipment and other grounds.
- D. All insulated ground wires shall have green insulation, unless otherwise approved.
- E. For testing of surface grounds refer to Section 16898 – SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- F. The DB Entity shall make a ground connection for each CIH, item of signal equipment and cable messenger. The connection shall be made to a DB Entity furnished and installed ground or an MBTA accepted connection determined on a location specific basis.

END OF SECTION

SECTION 16894

TRAINING AND TRAINING MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies training for personnel as designated by the MBTA. The training shall be sufficient to cover all systems and equipment provided under this Project and shall be based on a working model using the Union Square CIH location as a reference base. Training shall concentrate primarily on the operation and maintenance aspects associated with, but not limited to, the track circuit, vital and non-vital aspects of the VMIS, and application specific equipment furnished under this Project.
- B. Classes shall be scheduled to accommodate MBTA work schedules (day as well as night-shift). Training shall be scheduled in accordance with the milestones of the approved CPM to offer technical classes. The training schedule shall incorporate the following:
1. Engineering Training - One technical course shall be prepared and structured for the comprehensive training of eight engineers over a one-week period. This course shall be scheduled in accordance with the approved CPM.
 2. Maintenance Training - Another technical course shall be prepared and structured for maintenance/troubleshooting training of eight students (per session) over a one-week period. Four (4) of these week-long sessions shall be scheduled to provide training prior to the first location being placed in service.
 3. Operations Training - A general signal system course shall be prepared to instruct/inform operations department and management personnel in the capabilities and operation of the new signal system. This two-day course offering shall be provided for two classes of up to ten people and shall be scheduled in accordance with the approved CPM prior to commissioning of the system for full in-service operation.
- C. The quality of the training program shall be such to ensure competence in the operation and maintenance of the new signal system being provided. Training shall reference as guidelines:
1. FRA "Rules, Standards and Instructions for the Installation, Inspection, Maintenance and Repair of Automatic Block and Interlocking Systems", as set forth by the Office of Railroad Safety of the Federal Railroad Administration, and any supplements thereto which shall become effective before this Project is awarded,
 - a. Industry standards and recommendations as written in the AREMA C&S Manual.

1.2 SUBMITTALS

- A. Submit the initial draft of the training program(s) schedule and training program plan for review within sufficient time to accommodate the milestone dates in the approved CPM (including the provision of accommodating contractual requirement review & approval time).
1. Show all major training activities in chart form, including submittal of instructor and student materials and training reports.

2. Support the schedule with narrative description as necessary to fully convey its impact and relationship to other Project events, including the factory/field/interim installation and testing of such system.
 3. Submit the training program plan in narrative form, supported with tables, charts, schedules and graphs, as are necessary to fully convey and describe the DB Entity's plan for accomplishing the training.
 4. Schedule training times so as not to interfere with MBTA operations.
- B. Submit to the MBTA, 90 days prior to the start of the training classes, all course outlines, syllabus and manuals required to describe the content (systems, subsystems and components covered) and requirements of the training program for approval
 - C. Submit the student materials containing a quality photocopy and an electronic copy (PDF format) of all software and visual training aids to be used by the instructor.
 - D. Submit the names of the competent engineers familiar with the application and design of the system provided to be used as instructors in the training program.
 - E. Submit for approval the proposed equipment and rack layout for training equipment to be provided.
 1. Submit a factory test procedure for the training equipment and system to be provided under this Project at the MBTA's training facility.
 2. Submit an on-site field test procedure for the training equipment and system to be provided under this Project at the MBTA's training facility.
 - F. Submit training reports in accordance with the training program schedule. Submit each report following the last day of the training session to which the report applies.

1.3 QUALITY ASSURANCE

All changes or modifications to field equipment during testing and installation shall be reflected in the training facility equipment and/or design.

PART 2 - PRODUCTS

2.1 CLASSROOM TRAINING EQUIPMENT

- A. The DB Entity shall furnish each of the following as a complete system, in working order, for demonstration of the new signal systems in the MBTA training facility:
 1. Redundant Vital/non-vital microprocessor interlocking systems as specified in Section 16859 – VITAL MICROPROCESSOR INTERLOCKING SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM,
 2. One local control panel, maintainer's panel and one maintenance PC as specified in Section 16866 – NON-VITAL SUPPORT SYSTEMS FOR THE LIGHT RAIL SIGNAL SYSTEM and 16869 – MAINTAINER AND LOCAL CONTROL PANELS FOR THE LIGHT RAIL SIGNAL SYSTEM,
 3. One rack complete with the amount of 100 Hz, phase selective track circuits included within the representative interlocking prescribed in this training specification as specified in Section 16819 – TRAIN DETECTION FOR THE LIGHT RAIL SIGNAL SYSTEM, power supplies,

relays, network equipment, and other components required to build and integrate the above systems into a training module resembling a working GLX field location.

4. Other equipment recommended by the DB Entity that is necessary for form a complete and comprehensive training program for the Project system.
 5. Provide one laptop PC of a type as described in Section 16899 – TECHNICAL SUPPORT MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM.
- B. The design shall include all control and indicating facilities so that the instructor can easily manipulate all equipment as well as induce/simulate failures. Provide simulation panel/board to facilitate control and indicating operations of signals, switches, track circuits, etc. This simulator shall be a portable unit designed for testing and creating field and track related operations/failures. It shall be a half rack set-up, with wheels and a 100' plug coupler cable to connect to the permanent rack set-up or external track. This unit shall use toggle switches, microprocessor controls, and status indications to simulate track circuit failures, signal failures, power failures, open circuits, and microprocessor failures.
- C. Provide two complete sets of test equipment required to perform diagnostics of the track circuit, power supplies and specialty systems furnished with this Project. One set shall be supplied for permanent use at the training facility and the other for portable use.
- D. One copy of the most current version of each AREMA Signal and Communications Manual (on CD and Hardcopy) and a bound copy of FRA part 236.

PART 3 - EXECUTION

3.1 GENERAL

- A. The DB Entity shall provide all engineering, materials, software, drawings and labor necessary to facilitate the pre-fabricated construction of the training module at the factory. Installation and operation of the training program at the MBTA training facility will require simple interconnection of training components of the pre-tested training system with minimal wiring. This training program shall, at minimum, provide instruction relating to the processor systems and track circuit systems being furnished and their integration with each other to provide a complete application/site specific signal and interlocking control system.
- B. As stated previously, the Union Square location shall be used as a reference base for the instruction course material. The course shall be structured to emulate the actual Union Square as much as practicable. Any major change/revision to system interface, design, application, etc. for the design of the overall Project shall be reflected in the training program. The DB Entity shall be required to provide training updates (re-instruction) at the discretion of the MBTA in the event of a significant design change.

3.2 TRAINING (ON MBTA PREMISES)

- A. Training Aids - Provide a video-based set of signal instructional aids for the maintenance of each major subsystem or piece of equipment compatible with present MBTA training facility audiovisual equipment.
- B. Training Program Plan Development - Develop a training program plan responsive in all respects to this Section. Provide for the following:

1. Develop student and instructor materials including course outlines and objectives, lesson plans, training aids, and student manuals (including site specific troubleshooting manuals);
 2. Develop training schedules including dates, location, and equipment requirements of each course to be presented, jointly with the MBTA;
 3. Present training to the MBTA, and to others as designated by the MBTA. Provide training sufficient to ensure that proper installation, operation and maintenance may be performed by the trainees.
- C. Training Program Course Development - Develop courses of instruction in system familiarization, operation, and maintenance as follows:
1. Design a course to provide maintenance and engineering personnel with a functional understanding of the complete signal system. Cover the functions of all subsystems. Give particular emphasis to system operation with respect to the integration of each system element within the total signal system.
 2. Design a course to provide maintenance and engineering personnel with the knowledge and skills required in the performance of reprogramming, troubleshooting, adjusting and re-testing signal equipment. Provide instruction in the use of all special test equipment provided, whether portable or stationary, including built-in features.
 3. Design a separate, abbreviated course for instruction of MBTA Operations and/or management personnel. This course shall be designed to be less technically intensive and of shorter duration than that being provided for the engineering and maintenance personnel. This course shall provide an overall understanding of the signal system, its capabilities and limitations and focus on its use as an operational tool for management of train traffic and customer service.
- D. Training Material Development
1. Provide a course outline with learning objectives. Provide a topic outline for each subsystem and include a section devoted to system fault analysis and troubleshooting. State the learning objectives for each topic.
 2. One complete set of plans for the Union Square interlocking location for reference in the Training Facility.
 3. Develop a set of lesson plans for each subsystem corresponding to the topic outline containing the following information:
 - a. Lesson title,
 - b. Time,
 - c. Objectives,
 - d. Training aids required,
 - e. Instructing sequence (outline),
 - f. Summary.
 4. Operations and maintenance class instruction shall utilize visual aids as well as operational equipment, test equipment, and associated documentation. Also, the DB Entity shall utilize troubleshooting and fault isolation charts developed for training purposes.
 5. The primary source of student instructional material shall be the applicable system operation and maintenance manuals. Develop specific student notebooks for each course containing such material as: additional drawings, descriptive information, and laboratory procedures

necessary to ensure that all learning objectives are met in an orderly and timely manner. Arrange student notebook material by subsystems and sequenced according to the topic outlined.

6. The DB Entity shall provide five (5) hardcopies and two (2) electronic copies (PDF) of all student instructional materials.

E. Training Program Presentation

1. Conduct training by qualified DB Entity instructors at facilities provide by the MBTA.
2. Conduct maintenance laboratory training utilizing installed system equipment provided by the DB Entity that has been accepted. Restore such equipment to normal operating condition at the end of each training day. Use of the system equipment for training purposes shall not void or otherwise modify any equipment warranty provision.
3. In the event system equipment is not in operating condition at the scheduled time for training requiring such equipment, the MBTA shall have the right to delay or reschedule training sessions or reduce the duration of the training sessions. Equitable adjustments for delay or reduction in training will be determined in accordance with the provisions of the Contract Documents.
4. Training normally provided by the DB Entity at the DB Entity's facilities shall not be construed to satisfy the training requirements specified herein.
5. MBTA supervision personnel will have the right to monitor training sessions. Evaluations of course and instructor shall be made for analysis, of instructor critiques, coverage of materials in time allotted.
6. Prepare and submit a training report to the MBTA subsequent to the completion of each training session. This shall be a narrative explaining who attended, the material covered, and the instructor evaluation results.
7. Perform all training at MBTA facilities that will be made available without charge to the DB Entity.

END OF SECTION

SECTION 16897

MISCELLANEOUS COMPONENTS AND PRODUCTS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 SCOPE

- A. The work to be done under this Section consists of the furnishing and/or installing miscellaneous components and products to be used on this Project. The DB Entity shall not install any item without the MBTA's acceptance.

1.2 QUALITY ASSURANCE

- A. All miscellaneous components and products used on this Project shall be:
 - 1. New and free of manufacturing defects;
 - 2. Clearly and permanently labeled with value or type identification.
- B. All electrical components shall be rated to operate at power, voltage, and current exceeding by 20-percent those which the components will be subject to in service, unless otherwise specified herein.
- C. All electrical components shall be rated to operate in a Class C environment as specified in the AREMA C&S Manual Section 11.5.1.

1.3 SUBMITTALS

- A. Performance data or a sample of each type of component or product proposed as an equivalent to those herein specified shall be submitted.
- B. The DB Entity shall obtain the MBTA's written acceptance obtained for any such equivalent type component or product he proposes to use.

1.4 DELIVERY, STORAGE, HANDLING

- A. Make provisions and be responsible for delivery, storage, and handling of all materials and equipment required of this Project in accordance with the requirements of these Mandatory Specifications.
- B. Properly package all material, equipment, and their components at the manufacturer's factory before shipment. Replace any material or equipment damage, lost or stolen, at no additional cost to MBTA.
- C. Protect all miscellaneous components and products from damage, throughout the delivery, storage and handling.

PART 2 - PRODUCTS

2.1 PRINTED CIRCUIT CARDS

- A. Printed circuit (PC) cards shall be of glass epoxy construction. Card material shall meet the requirements of NEMA Type FR-4. Cards shall have sufficient thickness to permit easy insertion and

removal, and shall be physically keyed to protect against incorrect interchange. Circuits shall be formed by etching. Conductor material shall be copper and shall be protected from exposure to air.

- B. PC cards containing components that may be damaged in the event a plug connector or plug-in unit is removed while the equipment is energized shall be clearly marked or labeled with a warning note and means provided to remove power to the PC cards.
- C. Components mounted on the PC card, weighing more than one-half ounce or with a displacement of more than one-half cubic inch, shall have a mechanical supporting attachment to the card which is separate from all electrical connections.
- D. Stacking or piggy-backing of printed circuit card sections in order to accomplish changes or modifications to wiring or components on printed circuit cards shall not be allowed.

2.2 PRINTED CIRCUIT CARD CONNECTORS

- A. Connectors shall have gold plating a minimum thickness of 0.000050 inch.

2.3 CIRCUIT BREAKERS, FUSES AND FUSE CLIPS

- A. Fuses and circuit breakers shall be of suitable capacities to protect the various pieces of signal apparatus from the effects of short circuits or overloads. All circuit breakers and fuses required for the equipment and systems shall be in accordance with these Mandatory Specifications.
- B. Circuit fuses shall be non-renewable, and shall be of the fiber-case, time-lag, fusion type. The circuit breakers and fuses shall be the correct size and rating for circuit current interruption and shall protect the electrical equipment and circuits from short-term and long-term overloads.
- C. In dc branch circuits, where fusing is impractical, a protective resistance unit shall be furnished. All fuses shall be centrally located on the power distribution panel and power racks.
- D. Fuse clips shall be so constructed that they shall retain their resilience under all installation and service conditions to assure a positive contact between the clips and the fuse.

2.4 DIODES

All diodes to be furnished under this Project shall carry a JEDEC number or shall be available from more than one manufacturer and shall be used within the published Mandatory Specifications for such number. All diodes shall be silicon type, unless otherwise accepted by the MBTA.

2.5 RESISTORS

All resistors, other than those required for electronic circuits, shall be in accordance with AREMA Signal Manual Part 14.2.15.

2.6 REACTORS

All reactors, other than those required for electronic circuits, shall be in accordance with AREMA Signal Manual Part 14.2.20.

2.7 SIGNAL MOLDED TERMINAL BLOCKS

Signal System terminal blocks shall be in accordance with the applicable requirements of AREMA Signal Manual Part 14.1.5.

2.8 SIGNAL TERMINAL BINDING POSTS

Signal System Terminal binding posts, other than those required for supervisory control circuits, shall be in accordance with AREMA Signal Manual Part 14.1.10.

2.9 TERMINAL POST INSULATORS

- A. All terminal posts, located on terminal boards in the wayside cases and central instrument house used to terminate 120V or greater shall be provided with a protective insulator.
- B. The type of insulator shall be individual for each terminal post, and shall be fire-resistant.

2.10 INSULATED TEST LINK

- A. Insulated test links shall be the gold nut type that does not require the sliding of links to open.

2.11 LIGHTNING ARRESTERS AND EQUALIZERS

- A. Lightning arresters and equalizers shall be mounted on three post porcelain or approved type base and shall be in accordance with AREMA Signal Manual Part 14.1.9.

2.12 TERMINALS FOR WIRES AND CABLES

- A. All solderless terminals shall be in accordance with AREMA Signal Manual Part 14.1.1, or as specified herein.
- B. Terminals shall be of the solderless crimp-on type. Samples of all solderless terminals shall be submitted for approval.
- C. All stranded copper wire shall be fitted with an approved type of terminal at all points where the wires are to be terminated on terminal binding posts.
- D. The terminating means shall be of five types:
 - 1. A lug for terminating heavy wires or signal power wires;
 - 2. A solderless insulated terminal similar to AMP, Inc. Catalog No. 35628, Hubbel, Thomas & Betts or approved equal, for terminating No. 16 and No. 14 AWG stranded wires;
 - 3. A solderless insulated terminal similar to AMP Catalog No. 35627, Hubbel, Thomas & Betts or approved equal, for terminating insulated wires Nos. 12-10;
 - 4. A solderless insulated terminal similar to AMP Catalog No. 150247, Hubbel, Thomas & Betts, or approved equal for terminating other stranded vital circuit insulated wires No. 20-16 AWG having a maximum diameter of 0.200 inches;
 - 5. A solderless insulated terminal, similar to AMP Catalog No. 320554, Hubbel, Thomas & Betts or approved equal, shall be furnished for No. 8 studs and similar to AMP Catalog No. 320571 Hubbel, Thomas & Betts or approved equal, shall be furnished for one-quarter inch studs for non-vital circuit insulated stranded wires No. 22 - 16 AWG having a maximum diameter of 0.125 inches.

- E. Where flag type terminals are required they shall be similar to AMP Catalog No. 322313, or approved equal, for terminating No. 16 and No. 14 AWG stranded wires. Other pre-insulated terminals shall be similar to those shown in AMP Product Bulletin No. 109-1.
- F. The terminals shall be for attaching to the ends of the conductor in such a manner that the flexibility of the conductor will not be destroyed and the possibility of breakage at the terminal will be reduced to a minimum.
- G. Terminals shall be for attaching to the wire with a tool made by the manufacturer of the terminal and recommended by him for the terminals being furnished.
- H. The tool shall be equipped with a ratchet device to insure proper indentation of the terminal and which will not release until proper indentation is complete. The DB Entity shall furnish three such tools.

2.13 TAGGING FOR CABLES, WIRES AND EQUIPMENT

- A. Except as otherwise specified in this Section, both ends of each cable and each cable wire and all single wires that terminate in the wayside cases, junction boxes, switch mechanisms, central instrument housings on entrance racks, and any equipment of the signal system outside of such locations shall be permanently identified with a tag. Tags shall not obscure connecting links used between terminal binding posts. Tags shall be installed so that they may be read with a minimum of disturbance of the tags and wiring. Each conductor of the cable shall be rung out and identified before applying the tag.
- B. Tags for wire and cable identification and for identification of transformers, resistors, reactors and other components shall meet the following requirements and shall be subject to the acceptance of the MBTA:
 - 1. Sleeve Type Tags:
 - a. Tags for identification of individual cable conductors and field-installed wires within the wayside cases and central instrument housings, switch mechanisms, switch layout junction boxes, base of signal junction boxes and similar applications shall be the sleeve type similar to those as manufactured by TYCO Electronics or Raychem Corporation, RPS-1K-8-4/2.0-9, Brady, Panduit or an approved equal. The application of the conductor nomenclature shall be in accordance with the manufacturer's instructions and shall result in a permanently bonded and legible identification.
 - 2. Tags for cables shall be similar to the PANDUIT flag type, or approved equal.
 - 3. Flat Plastic Tags:
 - a. Tags for identification of vital relay plug boards, individual transformers, resistors, reactors, terminals, and other miscellaneous components within the wayside cases, central instrument housings and outside terminal cases and snowmelter cases shall be the flat plastic laminated type.
 - b. These tags shall be one and one-half inches long by three-quarter inch wide with one, five--six-tenth inch hole located in the center of the width. The distance from the edge of tag to the hole shall be approximately nine thirty-seconds of an inch. The untreated tag shall be milk white "vynilite", or approved equal.
 - c. The identifying nomenclature space shall allow for three rows of lettering, and the tag material shall be capable of receiving typed-on characters by conventional means. The height of the lettering shall be not less than one-eighth inch.

4. After lettering, both the face and back side of the tag shall be covered with a clear plastic coating, "vinylite", or approved equal, of at least one hundredth of an inch thick.
 5. The nomenclature applied to tags to go on entrance racks and boards shall show the terminal post identification on the top line. The functional nomenclature shall appear on the bottom line, or, if required, on the middle and bottom lines. The terminal posts shall be identified by geometry coordinates, such as rack, row and post number.
- C. Wrap Around Tags. Tags for identification of the individual wires of plug-in relays, within the signal instrument house and the wayside cases shall be the split sleeve or wrap around, self-adhesive type.
- D. Flag Marker Tags. Tags for identification of wires and conductors in junction boxes shall be flag marker tags of the miniature locking type.

2.14 PRESSURE SENSITIVE LABELS

- A. The rows and columns on entrance racks shall be identified by pressure-sensitive labels bearing the geometric coordinates.

2.15 HARDWARE

- A. All mounting hardware exposed to the elements and used for signal equipment, cases, conduit, hangers, brackets, clamps, etc., shall be hot-dip galvanized, except as otherwise accepted by the MBTA.

1. Galvanizing:

- a. The hot dip process of galvanizing shall be used. All parts shall be pickled so that all scale and adhering impurities will be removed. The zinc coating shall be of commercially pure zinc, and shall be continuous and thorough. It shall not scale or blister or be removable by any of the processes of handling or installation. The finished surface shall be free from fine line cracks, holes, or other indications of faulty galvanizing. It shall be smooth and free from adhering flux and other impurities. The edges and ends of parts shall be free from lumps and globules. Parts shall be coated with at least two ounces of zinc per square foot of galvanized surface, after all bending, cutting, drilling, and final fabrication.
- b. In order to avoid destruction of resilience encountered in the hot dip process of galvanizing, all lock-washers shall be cadmium plated.

2. Cadmium Plating

- a. All nuts, bolts, and washers used for the mounting of equipment within finished enclosures shall be cadmium plated or stainless steel. As an alternate, the DB Entity may submit another type of plating or non-corroding metal for the MBTA's acceptance.
- b. Cadmium plating shall be an impervious, dense, hard, fine grained, continuous, closely adhering coating of commercially pure cadmium, free from capillaries and shall completely cover the surface of the part in a smooth, bright layer. Plating on raised or prominent portions shall show no evidence of blackness or loose crystalline structure. It shall have a minimum thickness of six ten thousandths of an inch and shall withstand the salt spray test for at least 1,000 hours or an equivalent test accepted by the MBTA.

2.16 FLEXIBLE CONDUIT AND HOSE

- A. Hose for track circuit leads, switch and lock movements, cc boxes and electric locks shall be braided cordura rayon, vari-purpose hose, internal tube neoprene cover or MBTA accepted equal. The hose shall be clamped at both ends with stainless steel clamps. Clamps are not required for track risers.
- B. Flexible conduit: Where the MBTA permits the use of flexible conduit it shall be type UA or approved equal.

2.17 STAINLESS STEEL CLAMPS

Clamps for clamping hose at each end shall be stainless steel.

2.18 SECURITY

Enclosure doors for CIH's, cases, etc. shall be provide with a padlocking handle and a three-point latch mechanism to ensure that the doors cannot be locked until completely closed. Doors shall be provided with a two-position retaining device to secure door(s) when open.

2.19 CAM LOCKS, PADLOCKS AND KEYS

- A. Cam locks, and keys shall be with key change in accordance with MBTA standard for signal equipment requiring locks. A minimum of 12 keys shall be included for cam locks.
- B. Padlocks for signal apparatus requiring padlocks shall be as follows, or MBTA approved equal:
 - 1. Switch Padlock:
 - a. Model 0880 as manufactured by Sargent and Greenleaf for the MBTA complete with 13-1/2" chain.
 - 2. Signal and Miscellaneous Padlocks:
 - a. RACO type locks as accepted by the MBTA.

2.20 SEALING COMPOUND

Sealing compound for use in sealing cable entrances shall be in accordance with AREMA Signal Manual Part 15.2.15.

2.21 PAINT AND FINISH

All paint and painting procedures shall be in accordance with applicable requirements of AREMA 1.5.10., where the AREMA requirements do not conflict with any requirement of these Mandatory Specifications.

2.22 CABLE ENTRANCE PIPES

- A. Cable entrance pipes for ground-mounted wayside signal cases or junction boxes shall be galvanized steel, three feet-six inches (3'-6") long, threaded on one end, reamed and chamfered and shall be furnished complete with one (1) locknut and one (1) bushing for each such pipe. One spare entrance pipe assembly shall be furnished for each ground mounted wayside case. Cable entrance for CIH shall be as shown on the Contract Documents.

2.23 GROUND RODS AND WIRE

- A. Ground rods shall be copper-clad steel, of the non-rusting type as manufactured by Copperweld Corporation, or approved equal. The rod shall be at least eight feet in length and at least five-eighths inch diameter for signal equipment. Ten feet in length and at least three-quarters inch diameter minimum for service equipment.
- B. Internal ground wire, from the equipment to the ground bus shall be insulated No. 6 or 10 AWG stranded copper wire, as specified within the detail sections of the Specification. Insulated ground wire shall be colored green.
- C. A grounding bus of nickel plated hard drawn pure copper shall be provided in each signal instrument house and wayside instrument case. The minimum dimensions of this bus shall be eight inches by eight inches by one-half inch thick. A minimum of twelve, three-eighths inch holes shall be drilled and tapped in the bus and twelve, three-eighths inch by one-half inch long hex head nickel plated bronze studs with one washer each shall be installed.

2.24 RUBBER MATS

Rubber mats shall be furnished for installation in the Signal Instrument House. Rubber mats shall meet the applicable sections of ANSI-STANDARD C-37-14 and NEMA-Standard ICS-1970.

2.25 SWITCH CIRCUIT CONTROLLER LAYOUTS

- A. Switch Circuit Controllers shall be Alstom (GRS) Model 7, Ansaldo (US&S) Model U-5, Siemens SSC-402, or approved equal.
- B. The DB Entity shall submit drawings of his proposed switch circuit controller layout for approval. If such switch circuit controller layout comprises a portion of a larger layout, requiring a drawing submittal, the switch circuit controller layout submittal may be considered as a part of the total drawing submittal.
- C. Switch circuit controller layouts shall be furnished and installed complete with connecting rod, switch point lug, cable entrance, and all bolts, nuts, washers, and fastenings.

2.26 CABLE LASHING WIRE

Cable lashing wire shall be required to lash the aerial cable to the messenger wire as specified in Section 16808. Cable lashing wire shall be constructed of galvanized steel and have a diameter of 0.091”.

2.27 LUBRICATION

Lubrication for switch tie plates for all switch-and-lock movement layouts installed by the DB Entity shall be an approved lubricant, similar to the soy-bean oil presently used.

2.28 ENVIRONMENTAL PROTECTION

Projection as hereinafter specified, for machined- finished surfaces, threaded rods and nuts and other parts that are susceptible to rusting, shall be a corroding preventive compound, NO-OX-IDE No. 90918, Sanchem, Ideal, or MBTA accepted equal. The product shall have sufficient body to resist weather and rusting for at least six (6) months. Two gallons or equivalent weight shall be furnished by the DB Entity.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. All material and apparatus specified herein shall be installed in accordance with the detail of respective technical sections of these Mandatory Specifications and in accordance with the Contract Documents.

END OF SECTION

SECTION 16898

SIGNAL SYSTEM TESTS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the minimum tests and inspections that the DB Entity shall perform to demonstrate that systems, subsystems, assemblies, subassemblies, and components supplied under this Project are in compliance with the Mandatory Specifications. In addition to the signal systems these tests also include, but are not limited to: testing of the electric service, the HVAC system, the fire alarm system, and integration testing with the track, traction power, and communication systems.
- B. The work shall include the costs of the DB Entity's personnel and any special equipment and assistance required to conduct all tests and complete the required documentation.
- C. In the event that the system does not meet the Contract Documents, necessary corrections shall be made and any and all tests or re-tests to prove compliance shall be included in the work, without any additional costs to MBTA.
- D. Test work specified elsewhere in these Mandatory Specifications shall be construed as related to and inclusive with the testing described herein.
- E. The DB Entity shall notify the MBTA sixty days in advance of any major cut-over and two weeks prior to field tests that require the presence of the MBTA, their designated representatives, and/or any other regulatory agency. Where requirements for notification may vary or conflict within these Mandatory Specifications, the longer advance time for notification will take precedence.
- F. Factory testing shall be complete and comprehensive to the point, that upon completion of the cable terminations during field installation, the CIH, all interfaces (including OCC), and other equipment provided shall operate as designed and require no re-wiring, re-programming, or unusual adjustment. Factory testing shall be complete so that field adjustment shall be required solely in the areas of setting up track circuits and making the mechanical adjustments to switch, signal and other wayside equipment.
- G. Tests and inspections shall be made both during the factory assembly/installation and the field installation phases. These tests shall consist of, but not be limited to, circuit breakdown tests, wiring verification tests, continuity tests, resistance tests, voltage and current tests, time tests, operating tests, simulation tests, and other electrical and mechanical tests and inspections.
 - 1. The MBTA reserves the right to witness any or all tests and inspections in the DB Entity's plants or other manufacturing facilities. The MBTA shall be advised a minimum of sixty days in advance of each factory test.
 - 2. All accepted system and subsystem tests to demonstrate that the assembly/installation meets these Specifications and design requirements shall be completed prior to any operational testing of systems or subsystems.
- H. The work shall include necessary disconnecting and re-connecting required for testing purposes.
- I. The DB Entity shall ensure that qualified technical assistance is provided during testing, cut-overs and other designated milestones identified in the CPM during the field installation phase of the Project.

- J. Testing plans and procedures shall account for and incorporate any interim signaling arrangements as required by phased or partial installation schemes.

1.2 STANDARDS AND REGULATIONS

- A. Standards – AREMA C&S Manual, Part 2.4.1 "Instructions for Inspection and Test of Signal Installations Before Placing in Service".
- B. Regulations - Federal Railroad Administration, Rules, Standards and Instructions for Railroad Signal Systems, Part 236.

1.3 QUALITY ASSURANCE

- A. All test procedures and inspection procedures shall be subject to the acceptance of the MBTA and shall comply with all FRA rules and regulations and AREMA recommendations.
- B. Provide a listing (matrix) of all testing required for each component of the procedures as accepted for all testing required for acceptance. The DB Entity shall design the matrix in a manner that shall allow an immediate reference to the status of the testing and the remaining time to complete. One matrix shall be provided for factory testing and another for field testing. Tests to be included in the matrices shall include, but not be limited to, the following:
 - 1. Preliminary Verification Tests,
 - 2. Ground Resistance Tests,
 - 3. Pre-Test Inspection,
 - 4. Cable Resistance tests,
 - 5. Vital Relay Tests,
 - 6. Point to Point and Mechanical Inspection Test,
 - 7. Energy Distribution Tests,
 - 8. Vital and Non-vital Circuit Breakdown Tests,
 - 9. Impedance Bond Checkout Test,
 - 10. Switch Machine Adjustment & Operational Test,
 - 11. Power frequency Track Circuit Adjustment & Test,
 - 12. Signal/TAK Adjustment & Check-out Test,
 - 13. Line Circuit Verification,
 - 14. Interlocking Functional Tests – Vital & Non-Vital,
 - 15. Control & Indication Panel Test,
 - 16. Wayside Aspect verification Test,
 - 17. OCC Functional Test
 - 18. Snowmelter Check-out Test,
 - 19. Power Test,
 - 20. Failover Tests,
 - 21. Event Recorder Check-out Tests – Vital & Non-Vital,

22. Fire Suppression Discharge Test.

- C. Satisfactory performance of the factory testing will not waive the requirement for performance of the same or similar tests as part of the field installation testing procedures without specific written authorization from the MBTA.
- D. Test equipment of the proper type, capacity, range and accuracy shall be supplied by the DB Entity to perform the required tests and inspections. This equipment shall be in good working order and properly calibrated within 180 days of the time the tests or inspections are conducted. The calibration of each instrument shall be certified by a recognized testing facility. Instruments, not calibrated within the last 180 days will be considered as non-certified. Tests conducted with non-certified instruments will be rejected.
- E. Each component and unit of the wayside signal system shall have an inspection performed at its point of manufacture and evidence of this inspection and acceptability shall be indicated on the item where practicable.
- F. The work shall include all tests required to ensure the proper and safe operation of all systems and subsystems and to prove the adequacy and acceptability of the total assembly/installation specified herein. The tests to be performed shall cause each system and subsystem to be sequenced through its required operations, including the imposition of simulated conditions to prove that the assembly/installation complies with all specified fail-safe requirements.
- G. The MBTA will have the right to witness any or all field tests conducted. The MBTA shall be notified in writing prior to each field test. No part of the signal system shall be placed in service without an authorized representative of the MBTA witnessing and certifying successful completion of the in-service test procedures by signoff on the completed test forms.

1.4 SUBMITTALS

In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and Subsection 2.8, the DB Entity shall submit the following:

- A. Within 180 days after receipt of Notice to Proceed, submit:
 - 1. An outline and initial (draft) procedures for the factory tests to be performed on each type of component or unit and a matrix showing each test and the equipment to be checked, together with samples of test record forms and matrices as hereinafter specified.
 - 2. The numbers of each type of component or unit to be tested to demonstrate the adequacy of design and quality control.
- B. At least 60 days prior to the scheduled factory testing of the first location, and in accordance with the approved CPM, submit detailed test procedures for acceptance of the MBTA. The detailed test procedures submittal shall also include all pertinent information regarding the simulating devices and the methods of simulation to be employed in effecting a complete functional/operational series of tests.
 - 1. Provide a complete set of “test data sheets” as part of the detailed test procedures submitted. These data sheets shall contain all information required to successfully perform the tests, including identifying acceptable ranges of test results and pass/fail criteria.
- C. Within 360 days after receipt of Notice to Proceed, the following shall be submitted:
 - 1. An outline of the field tests and their specific detailed procedures to be performed at each

- location and a matrix showing each test and the equipment to be checked, together with samples of test record forms and matrices as hereinafter specified;
2. A line diagram showing the grouping and sequencing of system and subsystem tests identifying individual field tests. This line diagram shall also show time relationships for all activities and indicate relative manpower (staffing) requirements.
- D. At least 90 days prior to the scheduled performance of each test a detailed test schedule(s), as described herein, shall be submitted for acceptance of the MBTA.
1. The detailed test schedule(s) for significant cut-over and testing activities shall outline the DB Entity's activities by task, expected duration and associated manpower requirements;
 2. Within the projected schedule, a description of expected transportation impact should be addressed. Requests for track & power outages, flagging, etc. should be identified in sufficient detail.
- E. The results of each test as herein specified, both factory and field shall be recorded and the completed data package including all forms and marked plans shall be furnished to the MBTA within 5 days of completion of the test. Certified test results shall also be furnished for tests performed by any subcontractors when such tests are required within this Section.
- F. All test reports shall be checked and approved by the DB Entity prior to submittal to the MBTA.
- G. Test reports shall document the calibration date of each instrument used during the test.
- H. Upon completion of all tests specified herein, the DB Entity shall submit a letter signed by an authorized representative, certifying that all tests have been performed and passed.

PART 2 - PRODUCTS

2.1 SITE TEST EQUIPMENT AND MATERIALS

- A. The DB Entity shall have all test instruments and equipment necessary to conduct the required tests, including two spare sets of all equipment, available and ready for use not less than one week in advance of test need. "Ready for use" shall mean properly matched for test parameters, properly calibrated, properly programmed, sufficiently supplied with leads, probes, adapters, stands etc. necessary to conduct the particular test in a completely professional manner.
- B. All temporary or interim test related materials, special tools, connections, jumpers, etc. shall be furnished and available not less than one week in advance of the test need. This shall also include all versions of software, programming (PROMs, EPROMs, etc.), hardware, relays, etc. required to accommodate temporary or interim signaling arrangements.

PART 3 - EXECUTION

3.1 FACTORY TEST PROCEDURES

- A. Confirmation shall be provided by the DB Entity that all required factory tests of systems, subsystems, assemblies, subassemblies, and components supplied under these Contract Documents have been performed. These tests shall verify design and nameplate ratings and adequate and proper performance.
- B. All systems, subsystems, and equipment shall be inspected and tested. These tests will include at a minimum: breakdown, functional and operational testing. Simulation shall be required to

facilitate complete operational testing.

- C. When test results are not recorded on a test data plate affixed to the equipment or unit, certified test reports shall be furnished for each item at the time of delivery in a form and format suitable for regular office file record keeping.
- D. Each component and unit shall be inspected at its point of manufacture and evidence of this inspection and acceptability shall be indicated on the item where practicable.
- E. All tests shall comply with and reference the appropriate sections of the FRA and AREMA manuals.
- F. Prior to conducting testing, the DB Entity shall have identified any test(s) requiring a simulator and shall provide documentation within the submittal package relating to the circuit logic within the simulator and the operation of the simulator in the circuit under test.
- G. Confirmation shall be provided by the DB Entity that all required factory and product tests of trough systems, cable, and cable system components supplied under this Project have been performed. These tests shall verify design and specified ratings as well as adequate and proper performance. The DB Entity shall be responsible for maintaining such records and having them available for inspection until such time as they are turned over to the MBTA upon Contract Final Acceptance.
- H. Certified test reports shall be furnished for each item at the time of delivery in a form and format suitable for regular office file record keeping.

3.2 FACTORY TESTS AND INSPECTIONS

Factory tests and inspections shall include as a minimum the following:

- A. Vital Relay Tests
 - 1. All DC and AC vital relays and logic shall be factory tested and inspected in accordance with AREMA C&S Manual, Parts 6.4.1. and 6.4.5, respectively.
- B. Central Instrument Houses and Wayside Cases
 - 1. Each central instrument house and wayside case shall be wired complete at the point of assembly, with all equipment installed.
 - 2. An operational and wiring verification test shall be made in accordance with the approved circuit plans. The DB Entity shall use green for verified circuits, brown for contact verification, red for added changes and yellow for deletions.
 - 3. Functions external to the housing shall be simulated where required.
- C. Point to Point and Mechanical Inspection Test

All circuitry shall be checked for accuracy against the accepted circuit drawings. Tests may be done with energy on or off and shall verify the following:

- 1. Point to Point wiring;
- 2. During wire verification test, a wire count on each terminal, relay contact, etc. shall be taken to ensure that only the number of wires called for on the accepted circuit plans is present at each terminal, relay contact, etc. Any discrepancies found shall be corrected;

3. Verify tags and nomenclature;
4. Verify that all components, relays, resistors, etc. are the same as called for on the accepted circuit drawings and located in proper positions;
5. Verify that each plug coupler connection is the proper plug location from end to end using an electrical continuity check;
6. Verify each component or device is installed in the proper location per the layout plans and Manufacturer and part numbers match material references in the accepted book of plans.

D. Energy Distribution Tests

1. "Energy-Off" tests shall include but not be limited to the following:
 - a. All fuses shall be removed;
 - b. Verify that circuit breaker size compares to that of the accepted circuit plans;
 - c. All energy distribution shall be checked using resistance test instrument acceptable to the MBTA, to verify agreement with the accepted plans;
 - d. Verify wire gauge with that called for on the accepted circuit drawings. All discrepancies shall be corrected and accepted by the MBTA;
 - e. Each energy bus shall be tested to all energy buses to ensure that no crosses exist.
2. Energy-On" Tests - Upon completion of the energy-off tests, the following checks and tests which shall be performed. These tests shall include but not be limited to:
 - a. Insert fuses for power supply feeds and verify proper size according to the accepted circuit drawings;
 - b. Turn on energy feeds and test operation of power transfer for proper operation;
 - c. Each AC voltage input shall be measured and recorded;
 - d. Each power supply or charger output voltage shall be measured and recorded;
 - e. Verify that the proper voltage is present at all distribution points;
 - f. Check circuit power failure alarms, and all other alarms that indicate to Central Control;
 - g. Check battery fluid level and specific gravity of all cells, if applicable and based on manufacturer's recommended installation/maintenance instructions.

E. Vital and Non-Vital Circuit Breakdown Tests

1. This test shall verify that internal wiring is installed in accordance with the accepted plans and that the result of each circuit is as intended (i.e. relay picks, input energizes, etc.). The test shall check each vital or non-vital circuit, when energized, will become de-energized with the breaking of each contact point in the circuit.
2. Where applicable, all vital circuits shall be tested to ensure that the opening of each contact in a control circuit cuts off the control current under the conditions shown on the accepted plans following through all multiple circuits and cut arounds. When a circuit is broken by a relay contact twice or when it is broken by some other relay contact, whose coil circuit is opened by opening the relay, the wires in the circuit shall be disconnected in addition to opening the relay.
3. Adjustments and corrections of defects in the house wiring shall be made as necessary to obtain proper operation. All design changes found necessary to obtain proper operation shall be

submitted in writing to the MBTA for acceptance.

F. Interlocking Operational Tests

1. This operational test shall verify all interlocking functions versus the approved location Route and Aspect Chart as well as all controls and indications on the local control panel. Interlocking functions to be verified include route setting, signal aspects, and locking functions. Operation of adjacent locations, wayside signals, switch machines, and train movements will be verified or modeled through the use of simulators.
2. The Interlocking Processors shall be tested using the manufacturer's recommended procedures and test equipment as accepted by the MBTA. Interactive diagnostics shall be performed to monitor interlocking logic operation and system parameters (input and output states, logic expression results, non-vital controls and indications, vital timing functions, etc.). The test shall verify that the correct output or function is executed (turned on) when the controlling input is operated.

G. Control and Indication Panels

1. The factory tests to be performed shall include:
 - a. Local Functional Factory Test – A comprehensive operational test to verify each control and indication to and from the control and indication panels in the CIH are functioning as intended by the accepted design. The DB Entity shall submit a written test procedure and completed test forms for approval prior to this test.
 - b. Configuration Control/Revision Test – Prior to each test procedure the DB Entity, with MBTA representatives shall prove that the hardware and software configuration of each interlocking processor is consistent with the last entry in the revision control log. The DB Entity shall submit a written test procedure and completed test forms for approval prior to this test.
2. Adjustments and correction of defects found in the control panel(s) necessary to obtain proper operation shall be made.
3. Perform all network tests required to simulate final "in-service" operation. These tests shall include verification that the serial links and other communications are functioning properly.

H. Wayside Aspect Verification Test

Perform all tests required to test and demonstrate the proper function the design to display the proper wayside aspects under all realizable field conditions.

I. Fail-Over Tests

Perform all tests required to test and demonstrate the proper function of the fail-over of all normal/standby vital and non-vital redundant systems.

J. Event Recorder Test

Perform tests and simulation to verify all bits are recorded and time stamped properly in each event recorder. Also that each event recorder is set up properly and all available reports can be accessed and downloaded.

K. Other Factory Tests

Factory tests and inspections of other components, products and subsystems may be found in the respective technical sections of these Mandatory Specifications.

3.3 FIELD TEST PROCEDURES

- A. The quality of the installation shall be demonstrated by field tests for continuity, insulation resistance, resistance of ground connections, circuit breakdown, visual inspection, and any other tests required by these Specifications. These tests shall be performed prior to any operational testing of systems or subsystems.
- B. The DB Entity's test procedures package shall include pre-approved, pre-printed data sheets and/or inspection sheets for each test. When completed by the field test personnel and checked for accuracy and completeness, the sheet shall be submitted as the test report.
- C. When tests require specific meter or test instrument readings, the pre-printed data sheet shall show the allowable range of values, for each part of the test. The test report shall also contain a check-off system for each action and a blank space adjacent to the expected value in which to record the test readings.
- D. The test report shall also contain a final description sheet on which the DB Entity shall record discrepancies found and action taken. This documentation shall be furnished to the MBTA.
- E. All test reports shall be dated and signed by the responsible employee of the DB Entity or subcontractor on the day the test is performed. Space shall also be provided for the signature of the witnessing inspector.
- F. The report shall show the specific test instruments used on each test, with the instruments identified by name, type, serial number, and calibration due date.
- G. Should an error be discovered during field testing, due to field wiring and connections that do not agree with the accepted circuit plans, the DB Entity may correct such errors without prior acceptance of the MBTA. The DB Entity shall not, however, make any changes that affect safety of operation of the approved circuit(s), as designed, without prior written acceptance of the MBTA.
- H. The MBTA will make all final determinations as to whether or not the entire test, shall be re-run when any specific field test does not meet the requirements specified for the test.
- I. Any changes made after completion of test procedure shall be re-tested in accordance with the applicable test procedure.

3.4 FIELD TESTS AND INSPECTION

Field Tests shall include as a minimum the following:

- A. Preliminary Verification Tests

The DB Entity shall use the accepted drawings to confirm all existing circuitry at tie in locations is up to date and accurate on the as-in-service plans. The scope of this test may be limited to the areas that will be impacted or changed by the interface to the Project systems. This documented examination shall utilize MBTA provided as-in-service plans and/or pre-approved forms and be conducted by the DB Entity. The process shall include the inspection of existing CIRs, wayside signals,

junction boxes and cases required to be interfaced with or requiring modified wiring and confirm that:

1. All individual wiring is terminated as indicated by the provided documentation package;
2. The terminated wires contain the number of conductors on each terminal as indicated by the approved documentation package;
3. That all cables include the number of wires and are the wire gauge indicated by the approved documentation package;
4. That the existing nomenclature tags are in conformance with the approved documentation package;
5. Availability of spare components, space, or relay contacts;
6. That the number of cables entering and leaving is in conformance with the approved documentation package.

B. Resistance of Ground Connections

All grounding connections shall be tested to determine that the ground resistance is not greater than 15 ohms using the approved Ground Resistance test method. All ground connections shall be tested.

C. Pre-Test inspection

The DB Entity shall verify all field installed equipment is installed per the approved material location and installation plans.

D. Cable Resistance Tests

The test procedure for testing of insulation resistance shall include tests to verify the following:

1. All wire and cable installed along the right-of-way and the wire and cable entering or leaving wayside instrument cases and houses shall be tested after installation, including termination, to ensure that insulation of wires and cable and connected equipment meet the specified resistance value. A direct reading instrument, having a 0-Megohm to 200- Megohm scale range and a self-contained DC power supply rated 500 Volts (minimum) to 1000 Volts (maximum), shall be used to measure the insulation resistance. Resistance between individual conductors and conductors to ground shall not be less than 1 Megohm for 600V-class cable and no less than 100 Megohm , for 1000V-class cable. Power sources, made grounds and connections to the rails shall be disconnected from the circuits during testing;
2. The point used as ground shall be the most convenient ground available;
3. Insulation resistance test values shall be recorded on approved Insulation Resistance Record Forms and turned over to the MBTA upon acceptance of this test requirement.

E. Vital Relay Tests

All DC and AC vital relays and logic shall be factory tested and inspected in accordance with AREMA C&S Manual, Parts 6.4.1. and 6.4.5, respectively.

F. Point to Point and Mechanical Inspection Test

All field installed circuitry or portions thereof shall be checked for accuracy against the accepted circuit drawings. Tests may be done with energy on or off and shall verify the following:

1. Point to Point wiring;
2. During wire verification test, a wire count on each terminal, relay contact, etc. shall be taken to ensure that only the number of wires called for on the accepted circuit plans is present at each terminal, relay contact, etc. Any discrepancies found shall be corrected;
3. Verify tags and nomenclature;
4. Verify that all components, relays, resistors, etc. are the same as called for on the accepted circuit drawings and located in proper positions;
5. Verify that each plug coupler connection is the proper plug location from end to end using an electrical continuity check;
6. Verify each component or device is installed in the proper location per the layout plans and Manufacturer and part numbers match material references in the accepted book of plans.

G. Energy Distribution

These tests shall be conducted on all energy busses:

1. Energy-Off Tests

- a. With all power to wayside instrument house or case off, the following checks and tests shall be performed. These shall include but not be limited to:
- b. All fuses shall be removed.
- c. Verify that circuit breaker size compares to that of accepted circuit plans.
- d. All energy distribution shall be checked using resistance test instrument acceptable to the MBTA, to verify agreement with the accepted plans.
- e. Compare wire gauges with those called for on the accepted circuit drawings. All discrepancies in wire sizes shall be replaced with the proper size wire.
- f. During energy distribution breakdown, a wire count on each terminal, relay contact, etc. shall be taken to ensure that only the number of wires called for on the accepted circuit plans is present at each terminal, relay contact, etc. Any discrepancies found shall be corrected and additional wires, if found, shall be removed.
- g. Tags shall be verified for proper nomenclature and terminal location.
- h. Each energy bus shall be tested to all other energy busses to ensure that no crosses exist.

2. Energy-On Tests

Upon completion of the energy-off tests, the following checks and tests which shall be performed. These tests shall include but not be limited to:

- a. Insert fuses for power supply feeds and verify proper size according to the accepted circuit drawings.
- b. Turn on energy feeds and test operation of power transfer for proper operation.
- c. Each AC voltage input shall be measured and recorded.
- d. Each power supply or charger output voltage shall be measured and recorded.
- e. Verify that the proper voltage is present at all distribution points.
- f. Check circuit power failure alarms, and all other alarms that indicate to Central Control.

- g. Check battery fluid level and specific gravity of all cells as applicable per manufacturer's recommended installation/maintenance procedures.

H. Vital and Non-vital Circuit Breakdown

All circuits not checked during factory test or modified after factory test shall be checked for accuracy against the accepted circuit drawings. The vital circuit breakdown test consists of three major steps; wire counts, continuity and finally, contact verification. A copy of applicable drawings shall be used as data sheets for this test. Green and brown colored pencils are required for documenting this test on the data sheet. Green circled numbers indicate wire counts at connection points. Green tracing on circuit conductors indicate continuity verifications. Brown check marks indicate contact verifications.

1. **Wire Counts:** The first step is to make a physical count of number of wires connected at each point in the circuit, for all circuit points worked on by personnel for the maintenance or modification being tested. The number of wires connected at each point must agree with the drawing. For each verified connection point, write and circle the number of wires found connected to that point next to it on the data sheet. Resolve any discrepancies before proceeding to the next step;
2. **Continuity:** The second step is to verify continuity of the circuit conductors as drawn, one conductor at a time. If, according to the drawing, a conductor is electrically connected to more than two points and it is impractical to separate those multiple terminations, verify the continuity to each of those points. Perform this test on each conductor that is connected to any of the circuit points worked on by personnel for the maintenance or modification being tested. To perform this portion of the test, all relay contacts, slider straps and termination points to which the conductor(s) is connected must be verified open. (Removing vital relays from their plug boards may simplify the opening of relay contacts, however, this method may become complicated when processor I/O circuits are involved.) Also, confirm that no energy is present on the conductor. Verify the continuity of the conductor from one end to the other. For each conductor so verified, trace the conductor on the data sheet for its entire length using green pencil. Resolve any discrepancies before proceeding to the next step;
3. **Contact Verification:** The third step of the vital circuit breakdown test consists of applying the vital circuit's normal energy under the conditions required to energize the vital component. Some of the conditions may have to be simulated. If conditions are simulated, as much as possible they should be simulated outside the circuit being tested by forcing relays or other devices to the desired state. Specific details of each method used to simulate conditions must be approved and documented in the logbook, immediately, during the tests. One at a time; each relay contact, circuit controller contact, slider strap and test link in the circuit, must be opened to interrupt the circuit current and verified to de-energize the vital relay or device.

In cases where a contact under test is intended to provide a circuit shunt, such as that of a circuit controller shunt contact, an ohmmeter must be used at the relay coil or other vital device to verify the circuit makes and breaks the shunt as intended. In cases where the circuit load is a motor or other high current device, a voltmeter may be used to simulate the motor. When a meter is used in place of the normal load, it should be placed as close as practical to the load device, and never in the portion of the circuit that was modified or repaired.

This contact verification test must be performed for all circuit points worked on by personnel for the maintenance or modification being tested and one circuit point further into each circuit branch. As each contact is verified, write a brown pencil checkmark next to the

contact on the drawing. Resolve any discrepancies before proceeding to the next step. Immediately following the test, review the logbook and verify that all simulations used during the test have been restored to normal configurations. After the vital circuit breakdown test verifies that the circuit is wired as it is drawn, perform all applicable functional tests to verify the circuit functions in a safe manner.

3.5 Impedance Bond Checkout Test

Test per the manufacturer's recommended procedures, as accepted by the MBTA. Tests shall include mechanical verification of all connections.

A. Switch-and-Lock Movement

Tests shall be performed by the DB Entity on all switch-and-lock movements. These tests shall include, but not be limited to the following:

1. Check continuity of field wires to switch-and-lock movements to verify proper nomenclature in junction boxes and switch circuit controllers;
2. Adjust throw bar so that proper tension is placed on switch points in both directions;
3. Manually crank switch machine normal and adjust lock rods and point detector rods to allow switch machine to lock up with no obstruction. Repeat above for switch machine in reverse position;
4. Turn on switch machine power and call switch machine normal and observe in field that switch machine corresponds to position called and observe in wayside instrument housing that proper switch correspondence is energized/TRUE;
5. With switch machine called normal, check gaps on circuit controller contacts to see that they meet equipment specifications. Operate machine reverse and repeat;
6. Break down each contact in switch circuit controller and observe that proper switch correspondence "relay" drops. Repeat this procedure for both positions of the switch;
7. Place ammeter in series with motor control energy and adjust clutch such that it causes overload relay to pick up in conformance with the manufacturer's specification with 1/4-inch obstruction in switch point;
 - a. With a 1/4-inch or greater obstruction in the switch point ensure the overload relay energizes in less than ten seconds but greater than 7 seconds.
 - b. Record current reading.
 - c. Repeat for opposite position.
 - d. Confirm that overload relay will not pick with a 1/8-inch obstruction.
8. Insert the hand crank and observe switch mechanism cannot be operated by power. Remove crank, restore latch and verify that switch mechanism can be powered;
9. With the switch machine in the hand-throw mode place a 1/4" obstruction in the open point.
10. Using the hand throw lever move the switch point against the obstruction and assure the hand-throw lever cannot be moved to the full normal or reverse position. This test shall be made for the normal and reverse position;
11. Dog leg test for crossovers. Have crossover called for normal. Observe crossover is actually normal in the field. Observe that normal correspondence relays are up and reverse

correspondence relays are down. Go to the far end and crank switch over to the reverse position, observe both normal and reverse correspondence relays are down. Restore crank contact and observe that switch goes normal in field and observe normal correspondence relays are up and reverse correspondence relays are down. Repeat this procedure for the near end machine and repeat procedure for the reverse position;

12. Floating locking test. Ensure that the point detector will detect an obstruction independently from the lock rod. This shall be conducted with the locking rod floating so as not to cause the circuit controller to fail while the point detector is tested.

B. Power Frequency Track Circuits

Tests shall be made to assure that all power frequency track circuits are properly installed and the complete circuit is adjusted in accordance with the accepted detail test procedure and MBTA standard test forms. Each track circuit shall be tested in accordance with the manufacturer's accepted test procedure and shall include tests to verify the following:

1. Each track circuit shall be tested for defective insulated joint protection;
2. Each track circuit shall be tested for shunting sensitivity. A 0.25-ohm shunt strap shall be placed across the rails at the transformer end, midpoint, relay end, and all fouling points. The track circuit shall meet the requirement of FRA Rule 236.56, except with the track relay to be in the de-energized position with the 0.25-ohm shunt. This test shall be performed after the final track circuit adjustment has been made. Value of current required to pick up the track relay shall be recorded;
3. Each track relay shall be tested to assure that the proper phase relationship exists between the track energy being received and the local source used for comparison using the methods accepted by the MBTA.

C. Signal and TAK Layouts

Tests shall be performed on all signal and TAK layouts. These tests shall include, but not be limited to the following:

1. Check continuity of field wires and verify all nomenclature;
2. Apply energy to signal lighting circuits and adjust all LED unit voltages to 10% less than the nominal rating;
3. A functional test of signal lighting circuits must be performed after appropriate megger and circuit breakdown test(s) are complete, and whenever any signal lighting circuit conductors in the train control room, CIH, junction box or signal head are disconnected/connected during maintenance or modification. The signal lighting test must verify that the correct signal head illuminates with the proper color with voltage applied to the entrance rack for each head;
4. Verify all TAK control lines through manipulation of available controls and simulation of track circuit occupancies;
5. Sight signals for maximum visibility from a distance of 1000' at a height of 7' above top of rail, adjust as required.

D. Line Circuits

The purpose of this test procedure shall be to verify the integrity of line circuits (including vital serial data) between central instrument locations. These tests shall include, but not be limited to,

the following:

1. All nomenclature shall be verified and circuit based line circuits tested for continuity.
2. Each circuit or line equation shall be tested by manipulating the feed end and observing the proper result on the receive end. Manipulation of line circuits/equations shall be through real world facilities (shunting track circuits, clearing/cancelling of signals, alignment of switches, etc.)

E. Interlocking Functional Tests

The purpose of this test procedure shall be to verify the integrity of all routes and all vital interlocking functions. These tests shall include, but not be limited to, the following:

1. Loss of shunt tests;
2. Switch correspondence;
3. Detector locking;
4. Approach Locking;
5. Route Locking;
6. Indication locking.

F. Local Control and Indication Panels

A comprehensive operational test to verify each control and indication to and from the control and indication panels in the CIH are functioning as intended by the accepted design. The DB Entity shall submit a written test procedure and completed test forms for approval prior to this test.

1. The DB Entity, with MBTA representatives present in the CIH (field) and at OCC, shall perform a field test of each location to the OCC;
2. The field tests to be performed shall include:

a. Wayside Aspect Verification Test

- 1) For controlled signals, each possible route must be established and the signal aspects observed and verified to be correct for the established route from the wayside track location. After the correct aspect for the route is verified, verify that de-energizing the appropriate relay(s) or inputs causes the signal aspect to change to Red-over-Red.
- 2) Wayside automatic signal aspects shall be verified through manipulation of available controls and simulation of track circuit occupancies.
- 3) All tests shall be compared versus the approved Route and Aspect Charts.

b. OCC Functional Test

The DB Entity shall work with the MBTA to completely test the OCC interface, controls and indications. This test shall include but not be limited to:

- 1) Configuration Control/Revision Test – Prior to each test procedure the DB Entity, with MBTA representatives shall prove that the hardware and software

configuration of each locations interlocking processor is consistent with the last entry in the revision control log. The DB Entity shall submit a written test procedure and completed test forms for approval prior to this test.

- 2) OCC Bit Verification Test (Bit Bang) – Each indication/control bit shown on the CBA sheets shall be forced to ensure proper indication/control at the OCC and in the Normal and Standby interlocking processors. The DB Entity shall submit a written test procedure and completed test forms for approval prior to this test. The CBA sheets included in the Contract Documents for each location shall be used as a base for the test forms.
- 3) OCC Functional Field Test – A comprehensive operational test to verify each control and indication to and from OCC is functioning as intended by the accepted design. The DB Entity shall submit a written test procedure and completed test forms for approval prior to this test.

G. Track Switch Snowmelter Layouts

Tests shall be required on all electric track switch snowmelter layouts. These tests shall include but not be limited to the following:

1. Check continuity of all field wires as shown on the approved plans and verify proper nomenclature.
2. Check indications at (contactor) control cases by manually picking up all contactors and observing the indication relay in central instrument house. Open each contactor, one at a time, observing that the indication relay drops out when each contactor is open.
3. Apply energy to control relay and observe that it picks up.
4. Turn on controls and verify that the heating elements are operating and that all the current indications are functional as shown on the accepted plans. Perform these tests from the CIH and also from the OCC.
5. Test all safety devices included in the snowmelter layout.

H. Power Tests

The following power tests shall be made and recorded:

1. The voltage of the main power feeders shall be measured and recorded;
2. Perform functional tests of the automatic transfer switching arrangements;
3. Check all power supplies, battery chargers, and batteries for correct setting and quantities and include arrangements for testing various load sharing scenarios. Test the backup time on battery backed up systems.

I. Fail-Over Tests

Perform all tests required to test and demonstrate the proper function of the fail-over of normal/standby vital and non-vital redundant systems.

J. Event Recorder Test

Perform tests and simulation to verify all bits are recorded and time stamped properly in each event recorder. Also, that each event recorder is set up properly and all available reports can be accessed and downloaded.

K. Fire Suppression Discharge Test

Fire suppression or the environmentally approved equal discharge test for the CIH fire detection system shall be performed in accordance with the manufacturer's recommendation and accepted test procedure.

END OF SECTION

SECTION 16899

TECHNICAL SUPPORT MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies providing technical support materials required for this Project. Materials such as replacement parts for switch and signal layouts as well as printed circuit cards and other electronic components associated with track circuits and microprocessor logic systems shall be provided to enable immediate replacement so that operation of revenue service may be maintained in the event of component failure(s).
- B. Other materials such as vital & non-vital processors, track circuit equipment and control panels shall be provided complete with installation to comprise a training module for use at the MBTA's Signal Training Facility. See Section 16894 – TRAINING AND TRAINING MATERIALS FOR THE LIGHT RAIL SIGNAL SYSTEM for additional description of that work.
- C. Test equipment, including such items as laptop computers, shall also be provided for monitoring, troubleshooting and implementing logic changes.

1.2 QUALITY ASSURANCE

The quality of the technical support materials shall meet the requirements and be of the same quality as specified within the applicable sections of these Mandatory Specifications.

1.3 SUBMITTALS

- A. In accordance with the requirements of Volume 2 Technical Provisions Subsection 2.7 and 2.8, submit for acceptance of the MBTA, a list of recommended technical support material items where the items included are by DB Entity recommendation.
 - 1. The DB Entity shall also furnish apparatus tabulation sheets and include a complete list of all assemblies such as relays, printed circuit cards, impedance bonds, transformers, rectifiers, power supplies, switch machines, heater cases, etc.
 - 2. This list shall consist of forms listing the items by line, part number, part location, field location, and according to use (with) referencing other assemblies.
 - 3. In addition to the replacement components and parts, the listing shall also contain the items required and recommended for testing and troubleshooting. Diagnostic equipment and extender cards shall be included.
- B. Submit schematic drawings and component lists associated with manufacturer produced test equipment.

1.4 DELIVERY, STORAGE AND HANDLING

- A. All technical support materials described herein shall be packaged to prevent deterioration of the product from environmental conditions as well as protecting them from the hazards of transport. Any items having a limited shelf life shall be clearly identified on the storage container with the expiration date. Comply fully with the requirements of Section 16801 – BASIC TECHNICAL

REQUIREMENTS FOR THE LIGHT RAIL SIGNAL SYSTEM.

- B. All computer equipment as described within this Section (three laptops) is to be delivered at the end of the Project.

PART 2 - PRODUCTS

2.1 SUPPORT MATERIALS

- A. The following support materials shall be furnished upon approval:
 - 1. For the type of plug-in relays furnished, both vital and non-vital, provide 20 of each special tool for inserting or extracting contacts;
 - 2. Two impedance bonds;
 - 3. Seven of each type of vital and non-vital processor unit printed circuit board and two power supplies provided with the interlocking processor systems;
 - 4. Two sets of equipment comprising a complete AC Double Rail Track circuit;
 - 5. Three rugged duty laptop computers configured with minimum criteria as follows:
 - a. Processor - Intel Core i7-6700HQ; Clock Speed – 3.5 Ghz.
 - b. Memory – 16 GB
 - c. Ports – HDMI, 1 serial, 2 USB, 10/100/1000 Ethernet (RJ-45)
 - d. 1 TB Solid State Drive
 - e. Cache – 6MB cache.
 - f. Display – 15.6" LED Display
 - g. Software - Latest release of Microsoft Windows 10 Professional, Microsoft Office 2016 Professional.
 - h. All software for maintenance and programming of interlocking processors and other electronic equipment provided under this Project.
 - i. Docking Station
 - j. Carrying Case
- B. The DB Entity shall provide all pertinent reference material or manuals for all of the above.
- C. The DB Entity shall also prepare a list of technical support materials recommended by him in addition to the required materials specified above, complete with prices for MBTA acceptance.

2.2 TOOLS AND TEST EQUIPMENT

- A. Standard Tools and Test Equipment. Provide the required assortment of tools, gauges, and other equipment for testing, adjusting and repairing relays as normally used in a relay repair shop.
- B. Special Tools and Test Equipment
 - 1. Provide all special tools and test equipment to be used on equipment furnished under this Project, including but not limited to, the interlocking processor and a relay test fixture.

2. Furnish as a minimum the following items as special tools and test equipment:
 - a. One complete set of switch-and-lock movement adjusting tools for each pair of switch-and-lock movements provided, including point gauge;
 - b. One pole mounted storage case for each set of switch-and-lock movement adjusting tools specified herein. Provide an approved pole mounted storage case and foundation capable of being installed adjacent to a switch-and-lock movement;
 - c. The required assortment of tools for removing plugboard contacts, for removing plug-in relays and for applying cylindrical tags on wires in quantities sufficient for use in testing the signal system prior to placing it in operation.
 - d. Four adjustable shunt straps (0.06 - 0.25 ohm).

PART 3 - EXECUTION

3.1 DB ENTITY TASKS

- A. Prepare the manufacturer's recommended list of technical support materials, including the required items, as described in this Section.
- B. Hardware
 1. All special tools shall be contained in sturdy, weather resistant, portable (if applicable), nonmetallic bags or cases.
 2. Indelibly mark with an identifying name or number all bags or cases.
 3. Place a detailed list of the contents of each tool kit in a waterproof enclosure inside each case or bag.
 4. Provide tools to be used on electrical equipment with insulated handles.

3.2 DELIVERY

- A. All technical support materials shall be delivered concurrently with the first items delivered under this Project and in accordance with the schedules as derived from the CPM milestones.
- B. The number of crates, packages, and packing lists shall be submitted to the MBTA for acceptance prior to shipment.
- C. Technical support materials shall be shipped to a site as designated by the MBTA.

3.3 TESTS

- A. All applicable factory and field tests for replacement systems, parts and components shall be conducted in exactly the same manner as for other like items furnished under this Project.

END OF SECTION

Exhibit 2A.2

MBTA Base Specifications

Exhibit 2A.2

BASE SPECIFICATIONS PREFACE

The Base Specifications are provided as pdf and word electronic files in the Exhibit 2A.2 – Base Specification.

The amendments listed herein apply to the Base Specifications. The DB Entity shall amend the Base Specifications as necessary, as part of the Design Documents and/or Construction Documents in order to demonstrate how the design and construction shall be completed. The DB Entity shall not amend any warranty requirement or the quality management sections in the MBTA Base Specifications.

These revised specifications shall be submitted, in redline/strikeout format, as well as blackline/clean versions, to the MBTA, who will review the proposed edits for any changes to the design intent or construction delivery process. The MBTA's comments shall be incorporated by the DB Entity before formal issuance of the documents at the next design development per Volume 2 Section 2.7.

Where calendar day milestones are shown in the Base Specifications and are not in accordance with another Contract Document, that other Contract Document shall govern.

The following amendments apply to the Base Specifications:

- A. All contact with MBTA staff or offices except for personnel assigned to the Project shall be through the MBTA's Authorized Representative;
- B. The word "Authority" shall be replaced by MBTA;
- C. References to "plans" or "contract plans" shall mean those Design Documents and/or Construction Documents prepared by the DB Entity, such as site plans, detour plans, materials sampling plans, utility relocation plans etc.;
- D. References to "Proposal" or "proposal" shall be interpreted to mean the Contract Documents;
- E. Unless specifically stated otherwise in the Contract Documents, sampling, testing and inspections specified to be done by the Engineer or other MBTA staff, shall be performed by the DB Entity's QA Engineering Firm;
- F. "Submission" or "submittal" used in the Design Documents and/or Construction Documents shall be subject to review and acceptance per Volume 1 Contract Documents;
- G. All references to "the Engineer" or "the Engineer-in-Charge" shall mean the DB Entity's Engineer of Record;
- H. All references to "Contractor" shall mean DB Entity / Design-Builder;
- I. References to "Contract Award" shall mean Notice to Proceed;
- J. In each Specification delete Part 4 Measurement and Payment;
- K. Where calendar day milestones are shown in the Base Specifications and are not in accordance with another Contract Document, that other Contract Document shall govern.

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SECTION 02015

GEOTECHNICAL INSTRUMENTATION

PART 1 - GENERAL

1.1 ORGANIZATION OF SECTION

A. Layout and Scope of Document

The specification is divided into four sections:

PART 1 – GENERAL
PART 2 – PRODUCTS
PART 3 – EXECUTION
PART 4 – MEASUREMENT AND PAYMENT

Part 1 presents requirements for geotechnical instrumentation and construction monitoring. Part 1 also provides general description and the requirements for providing instrumentation services including qualifications, contractors, quality assurance, submittals, schedules, and other information. Part 2 provides descriptions and specifications for the monitoring instruments. Part 3 presents requirements for installation methods of monitoring instruments. Part 4 presents measurement and payment requirements for the work.

1.2 PRE-CONSTRUCTION SURVEY

- A. The Design-Builder shall conduct pre-construction surveys including photography (video and image), measurements, and examination of the existing structures in accordance with Volume 2 Technical Provisions Exhibit 21 “Additional Project Requirements”.

1.3 DESIGN OF GEOTECHNICAL INSTRUMENTATION PROGRAM

- A. Design-Builder shall engage the services of a qualified Geotechnical Instrumentation Engineer to design the geotechnical instrumentation program. The Design-Builder shall prepare and submit to the MBTA, a design submittal describing the geotechnical instrumentation program for review and approval. The design submittal shall be submitted 60 calendar days before start of construction. The design submittal shall include drawings showing the planned location and type of instrumentation, details of instrumentation installation and protection, an instrumentation schedule, quantities, threshold and limiting values to protect work and property, and contingency plans presenting required actions for exceedances of threshold and limiting values,

1.4 CONSTRUCTION MONITORING STAGE

- A. The Design-Builder shall conduct monitoring during construction in accordance with the geotechnical instrumentation program designed by the Geotechnical Instrumentation Engineer.
- B. Monitoring shall be performed to:
1. Record the influence of construction on adjacent structures.
 2. Enable activation of a plan of action in response to the monitoring in order to mitigate risk.

3. Examine ultimate and serviceability limits of existing and constructed structures.
4. Control construction fill impacts to allow for a safe rate of progress.
5. Install and use instruments aimed at the post construction, long term monitoring of the constructed facilities (such as settlements and inclination).

C. Method of Approach

Settlement – Acceptable instruments include:

1. Mechanical settlement plates,
2. Electro-Mechanical (vibrating wire measuring change in pressure) settlement plates,
3. Surveying reference points.

Deflections / Lateral Deformations

1. Inclinometer casing for inclinometer probe readings (vertical and horizontal),
2. In-place single or multi-directional inclinometers (e.g. change in longitudinal or transverse track geometry),
3. Displacement transducers for continuous high accuracy monitoring,
4. Surveying reference points.

Pore Water Pressure – Pore water pressure measurements are required for establishing the construction influence on the state of water pressure and, hence, knowledge of both shear strength and settlement rate. Acceptable instruments include:

1. Standing pipe piezometers for manual reading,
2. Single or multiple vibrating wire piezometers that can be read manually, discretely or continuously (at specified time intervals).

Strain / Force – Acceptable instruments include:

1. Strain transducers that can be attached in various ways (e.g. weldable, rebar elements, and stand-alone concrete placed elements),
2. Load cell, direct force measuring elements in line with the measured load and the applied element.

Vibrations – Design-Builder shall monitor vibrations at locations where impact (e.g. pile driving) or large machinery vibrations (e.g. movement, compaction) may affect adjacent structures. Acceptable instruments include seismographs and geophones depending on the sensitivity and purpose (e.g. data loggers, strip charts, or manual periodic readings).

1.5 POST CONSTRUCTION MONITORING STAGE

- A. The Design-Builder shall conduct post-construction monitoring where impacts are expected to continue beyond the construction completion.

1.6 DESCRIPTION

- A. The Work of this Section includes furnishing, installing and maintaining geotechnical instrumentation, protecting instrumentation from damage, and collecting, reducing, processing, plotting, interpreting and reporting instrumentation data. The Work includes maintaining and monitoring existing

instrumentation installed by others, and also includes any additional instrumentation required as part of the response actions covered under section 3.23 “Interpretation of Data and Response Values”.

B. Responsibilities of the Design-Builder.

1. The responsibilities of the Design-Builder shall include:
 - a. Prior to commencing work, the Design-Builder shall perform a building condition survey as outlined in Volume 2 Technical Provisions Exhibit 21 “Additional Project Requirements”.
 - b. Furnish components of instrumentation and data acquisition system (DAS) that are to be installed during construction.
 - c. Furnish portable readout units for the Design-Builder’s use.
 - d. Install instruments and data acquisition systems.
 - e. Protect from damage and maintain instruments and DAS installed by the Design-Builder, and existing instruments installed by others. Repair or replace damaged or inoperative instruments.
 - f. Maintain and calibrate portable readout units for the Design-Builder's use.
 - g. Collect, reduce, process, plot, and report data from instruments installed by the Design-Builder, and existing instruments installed by others. These tasks are referred to herein as the Design-Builder’s monitoring program.
 - h. Provide access to the Design-Builder’s Geotechnical Instrumentation Engineer for data collection.
 - i. Coordinate with the Geotechnical Instrumentation Engineer to verify consistency of collected data.
 - j. Implement remedial measures based on Geotechnical Instrumentation Engineer’s interpretations of monitoring program data.

C. Qualifications of the Design-Builder’s Independent Geotechnical Instrumentation Subcontractor

1. Geotechnical instrumentation work involves highly specialized tasks. The Design-Builder shall engage an independent instrumentation subcontractor who shall be responsible for furnishing and installing all geotechnical instrumentation, maintaining and calibrating instrumentation as required, collecting, reducing, processing, plotting, interpreting and reporting data to the Lead Geotechnical Engineer. The Design-Builder’s independent instrumentation subcontractor shall meet the qualifications specified herein.
2. The independent instrumentation subcontractor’s staff shall include a qualified Geotechnical Instrumentation Engineer who is a registered Professional Engineer in the Commonwealth of Massachusetts, who has a minimum of a Bachelor of Science degree in civil engineering, and who has at least five years of direct field experience in installation and monitoring of the types of instruments specified herein. The Geotechnical Instrumentation Engineer shall:
 - a. The Geotechnical Instrumentation Engineer shall coordinate all activities with the Design-Builder’s Lead Geotechnical Engineer during all phases of the geotechnical instrumentation program.
 - b. Prepare detailed step-by-step procedures for all instruments used including installation, data collection, and removal or decommissioning procedures.
 - c. Review and sign all submittals.
 - d. Be on site and supervise at least the first two installations of each type of instrument.

- e. Conduct at least the first two activities of each of the following tasks for each instrument specified herein: pre-installation acceptance tests, post-installation acceptance tests, field calibration, data collection, data reduction, processing, plotting, and interpreting.
 - f. Supervise the preparation of submittals.
3. The staff of the Design-Builder's instrumentation subcontractor shall include a Superintendent who shall be in responsible charge full-time on site during the geotechnical instrumentation program. The Superintendent shall have at least 4 years of direct field experience in installation and monitoring of the types of instrumentation specified herein, and shall have supervised instrumentation programs of similar magnitude in similar subsurface conditions.
 4. The person in responsible charge of the surveyors shall be a Registered Land Surveyor in the Commonwealth of Massachusetts with a minimum of 3 years of experience in deformation measurements of the types and accuracies specified herein. The field survey party chief shall have a minimum of one year of experience in deformation survey measurements of the types and accuracies specified herein.
 5. Acceptance of the Design-Builder's instrumentation subcontractor and surveyors, including the Geotechnical Instrumentation Engineer, the Superintendent, the field survey party chief, and all other field and office personnel shall be subject to the review of the Lead Geotechnical Engineer.

D. Quality Assurance

1. A factory calibration shall be conducted on all instruments prior to shipment. Provide certification to indicate that the test equipment used for this purpose is calibrated and maintained in accordance with the test equipment manufacturer's calibration requirements and that, where applicable, calibrations are traceable to the National Institute of Standards and Technology.
2. Make a final quality assurance inspection prior to shipment. During the inspection, complete a checklist to indicate each inspection and test detail. Provide a completed copy of the checklist with each instrument.

Design-Builder shall provide the manufacturer's warranty for each portable readout unit furnished for the MBTA's monitoring program, and such warranty shall be in place for the contract duration.

E. Submittals

1. All submittals shall be in digital format (e.g. PDF). Within 3 weeks after the Notice to Proceed, the Design-Builder shall submit to the MJBTA's for review.
 - a. Qualifications of the independent instrumentation subcontractor to include relevant experience on projects of this type and magnitude.
 - b. Resumes of Geotechnical Instrumentation Engineer and Superintendent, sufficient to define details of direct site experience.
 - c. Resumes of person in responsible charge of surveyors and field survey party chief, sufficient to define direct site experience.
 - d. Resumes of other field and office geotechnical instrumentation and survey personnel to be assigned to the project, other than clerical staff.

- e. Manufacturers' product data, including instruction manual and including any requests for consideration of substitutions, as specified herein, and warranty provisions.
2. At least 45 days prior to commencing installation of the first of each type of instrument, the Design-Builder shall submit to the MBTA for review the following items pertaining to that instrument type:
 - a. Sample pre-installation acceptance test record sheet.
 - b. A monitoring schedule, if different from Table 1 in Section 3.19.I.
 - c. Detailed step-by-step procedure for installation, including post-installation acceptance test, together with a sample installation record sheet. The procedures shall be bound and indexed. The installation procedures shall include, as applicable:
 1. The method to be used for cleaning the inside of casing or augers.
 2. Specifications for proposed grout mixes, including commercial names, proportions of admixtures and water, mixing sequence, mixing methods and duration, pumping methods and tremie pipe type, size and quantity.
 3. Drill casing or auger type and size.
 4. Depth increments for backfilling boreholes with sand and granular bentonite.
 5. Method for overcoming buoyancy of instrumentation components during grouting.
 6. Method of sealing joints in pipes and inclinometer casing to prevent ingress of grout.
 3. Within 2 weeks prior to installation of support of excavation submit excavation sequence and monitoring schedule for in-place inclinometers. It is intended that the in-place inclinometers monitor the initial condition prior to installation.
 4. Within 5 workdays after receipt of each instrument at the site, the Design-Builder shall submit to the Geotechnical Instrumentation Engineer, copy of factory calibration, manufacturer's test equipment certification, completed copy of quality assurance checklist, and warranty for each portable readout unit furnished for the monitoring program.
 5. Within 2 weeks after receipt of each instrument at the site, the Design-Builder shall submit to the Geotechnical Instrumentation Engineer results of each pre-installation acceptance test and test record sheet.
 6. At least 30 days prior to installing each instrument, the Design-Builder shall submit to the MBTA for review, the proposed location, installation schedule and monitoring schedule for that instrument. The Design-Builder shall submit the proposed grout mixes associated with instrumentation installations.
 7. Within 5 days of installing each instrument, the Design-Builder shall submit to the MBTA, the as-built instrument location as specified for individual instruments and its corresponding installation record sheet.
 8. Response Values for changes in measured parameters are to be developed by the Design-Builder, as specified in Section 3.23. When readings indicate that a change has occurred as, the Design-Builder shall initiate the response action(s) specified therein.
 9. The Design-Builder shall submit to the MBTA, raw, reduced and plotted data in accordance with the schedule detailed in Section 3.20. The submittals shall be bound and indexed and shall include:

- a. Raw and reduced data for the week.
 - b. Updated plots of data as specified in Section 3.20. On plots of data versus time, key construction activities and other events that could influence changes in the data shall be shown, as specified in Section 3.20. Threshold Values shall also be shown.
 - c. Plots of the location of the existing and future construction of each relevant retaining structure and/or deep foundation versus time on a plan showing the building footprints and column pile caps. Each heading location shall be labeled by date.
 - d. A statement to indicate whether any Response Value has been reached.
10. The Design-Builder shall submit to the MBTA details of the work performed according to the schedule specified in Section 3.20. The submittal shall include items as described in section 3.20.
 11. Within 5 days of performing a field calibration, submit results of the calibration to the MBTA.
 12. The Design-Builder shall submit to the MBTA, all new data in electronic format via a mutually accessible web connection in accordance with the schedule specified in Section 3.20. All data files shall be compatible with Microsoft Excel spreadsheet file format.

F. Scheduling of Work

1. Install instruments in accordance with the following schedule:
 - a. Observation wells and vibrating wire piezometers shall be installed and formal initial readings agreed on at least 30 days prior to the start of any construction filling.
 - b. Deformation monitoring points (DMPs), Utility Monitoring Points (UMPs) Borros Point Anchors, and Tiltmeters on existing ground and facilities shall be installed and formal initial readings agreed on at least 21 days prior to any excavation or excavation support wall installation operations within 200 feet of the instrument location, except of DMPs installed immediately on support of excavation after its installation.
 - c. Inclinometers in soil and Inclinometer Probe Extensometers shall be installed and formal initial readings agreed on at least 21 days prior to drilled foundation and/or excavation support wall construction within 200 feet of the inclinometer location.
 - d. Inclinometers in controlled density fill shall be installed after controlled density filling is complete.
 - e. Seismographs shall be installed to allow a minimum of seven days of background readings prior to the commencement of any vibration-producing construction activity within 300 feet of the seismograph location.
 - f. Vibrating wire strain gages shall be installed a minimum of five work days before a gaged strut or brace is used in the excavation support system.

Variations in the above schedule require the review of the MBTA.

G. Storage of Instruments

1. All instrumentation materials after receipt at the site and prior to installation shall be stored in an indoor, clean, dry and secure storage space. Instruments shall not be exposed to temperatures outside the manufacturer's stated working temperature range.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Whenever any product is specified by brand name and model number, such specifications shall be deemed to be used for the purpose of establishing a standard of quality and facilitating the description of the product desired. The term "acceptable equivalent" shall be understood to indicate that the "acceptable equivalent" product is the same or better than the product named in the Specifications in function, performance, reliability, quality, and general configuration. This procedure is not to be construed as eliminating from competition other suitable products of equal quality by other manufacturers. The Design-Builder may, in such cases, submit complete comparative data to the MBTA for consideration of another product which shall be equivalent in every respect to that so specified. Substitute products shall not be ordered, delivered to the site, or used in the work unless accepted by the MBTA in writing. The MBTA will be the sole judge of the suitability and equivalency of the substituted product.
- B. Any request from the Design-Builder for consideration of a substitution shall clearly state the nature of the deviation from the product specified.
- C. The Design-Builder shall furnish portable readout units, for use during the Design-Builder's monitoring program. If the Design-Builder requires more than one primary readout unit for each instrument type to achieve the specified data collection schedule, it shall furnish additional readout units to achieve the schedule, at no additional cost to the MBTA. The Design-Builder's Geotechnical Instrumentation Engineer shall be available within 24 hours to take reading in the presence of the MBTA and for verification purposes. Readout units shall be furnished no later than two weeks before commencing installation of the first of each type of instrument. Portable readout units shall be identical to the units used by the Design-Builder.
- D. The Design-Builder shall furnish all installation tools, materials and miscellaneous instrumentation components.
- E. Grout mixes shall be submitted to the MBTA for all grouts associated with instrument installations.
- F. Surface protection shall be flush with the ground surface in paved or other areas. For all instruments except inclinometers, surface protection shall consist of a Morrison Bros. Co. model 418XA roadway box, or acceptable equivalent. Roadway boxes for inclinometers shall either have a diameter adequate to allow attachment of cable support assembly, or shall allow for attachment of an inclinometer casing extension while readings are being taken.
- G. For each instrument type, provide an instruction manual that includes the following:
 - 1. A description of the purpose of the instrument.
 - 2. Theory of operation.
 - 3. Step-by-step procedures for;
 - a. Pre-installation acceptance test when instruments are received on site, to ensure the instruments are functioning correctly prior to installation.
 - b. Calibration of readout units.
 - 4. A list of calibration equipment required, and recommended frequency of calibration.
 - 5. Step-by-step instrument installation procedure including materials, tools, spare parts and any borehole requirements, and post-installation acceptance tests.

6. Maintenance procedures.
7. Step-by-step data collection procedure.
8. Data reduction, processing, and plotting procedures.

H. All graduations shall be in U.S. Customary Units, for example feet, inches, pounds.

2.2 OBSERVATION WELLS

- A. Provide observation wells with slotted pipe, bottom caps and vented top caps. The slotted pipe shall be 5 feet long, 1¼ inch Sch. 80 PVC pipe with 3 rows of 0.01-inch-wide slots on 120° centers, with a slot length to leave 0.25 inch between rows. The riser pipe shall be 1¼ inch Sch. 80 flush-joint PVC pipe.
1. Filter sand shall conform to ASTM C-778-13, Standard Specification for Standard Sand, for 20-30 sand.
 2. Water level indicator shall have a 100-foot-long graduated cable, with graduations at 0.02 foot or smaller intervals. A minimum of one indicator shall be provided for the Design-Builder's monitoring program, and two for the Geotechnical Instrumentation Engineer's monitoring program.
 3. Granular bentonite shall be Enviroplug Medium, as manufactured by Wyo-Ben, Inc., Billings, MT, or Holeplug, as manufactured by Baroid Division, Halliburton, Houston, TX, or acceptable equivalent.

2.3 VIBRATING WIRE PIEZOMETERS

- A. Provide vibrating wire piezometers: model 4500S, as manufactured by Geokon Inc., Lebanon, NH; model PWS as supplied by Roctest Inc., Saint-Lambert, Quebec Canada; or model M-610 as supplied by Geonor Inc., Augusta, NJ, or acceptable equivalent. Piezometers shall have documented long-term stability over a five-year period. Piezometers shall have a range of 50 psi, an over-range rating of twice the rated pressure, ± 0.2% full scale accuracy, and 0.025% full scale resolution, and shall be fitted with a low air entry filter.
1. Piezometers shall be produced with a single continuous cable. In case of extension, provide cable. Cable shall be from the same commercial source as the piezometers, and shall either be 4-conductor, 22 gage, with two shielded twisted pairs, a common drain wire, and a sheath of 0.065-inch-thick pressure-extruded vinyl with an outside diameter of 0.25 inch, or shall be Geonor model P-540. Cable shall be attached to the piezometers through an integral bulkhead seal, consisting of an interior waterstop seal and a cable entry seal. Seals shall be either O-rings or hermetic seals. The seals shall be tested and certified for water-tightness over the specified pressure range of the piezometers.
 2. Provide readout and other terminal units, from the same commercial source as the piezometers. The readout unit shall be capable of reading both the vibrating wire and thermistor reading, shall have a minimum of memory for 6 months of independent readings storage, and shall display readings in engineering units.
 3. Filter sand shall conform to ASTM C-778, Standard Specification for Standard Sand, for 20-40 sand.

4. Granular bentonite shall be Enviroplug Medium, as manufactured by Wyo-Ben, Inc., Billings, MT, or Holeplug, as manufactured by Baroid Division, Halliburton, Houston, TX, or acceptable equivalent.
5. Special grout Type A shall consist of uniform sized fine ground or powdered non-drilling mud grade bentonite, for use in sealing and grouting well casings. A polymer-based thixotropic additive may also be added to the mix if recommended by the manufacturer. Special grout Type A shall have a mixed specific gravity, prior to placement within the instrument borehole, of between 1.03 and 1.10.
6. Cylindrical sounding hammer shall be a steel cylinder with outside diameter 0.3 to 0.5 inch less than the inside diameter of the casing or augers, an inside diameter 0.15 to 0.25 inch larger than the outside diameter of the cable, a length of not less than 2 feet, and a weight of 10 to 20 pounds. When used above the upper piezometer, when two piezometers are installed in the same borehole, sounding hammer shall have two axial holes to ensure that the two piezometer cables are separated by a clear distance of at least 0.75-inch.
7. Provide 2-inch diameter Schedule 80 flush jointed PVC sleeve pipe, for use during installation of vibrating wire piezometers inside the excavation

2.4 DEFORMATION MONITORING POINTS

- A. Deformation monitoring points (DMPs) shall be used to monitor vertical and/or horizontal deformation of various facilities and ground at selected locations shown on the Instrumentation Plan. All DMP's shall be monitored for vertical deformation. Monitoring of horizontal deformation shall be performed where indicated on the instrumentation schedule in the Instrumentation Plan.

The following seven types of DMPs shall be used to monitor deformation:

1. DMP-Type 1 shall consist of a 2-inch long masonry nail with an identification tag. The nail shall be manufactured from hardened, zinc-plated steel. The nail shall have ribbed threads along its shank and a conical point. It shall also have an indent in the center of its head to receive a surveyor's plumb bob. The identification tag shall be 1½ inch diameter × 3/32-inch-thick with a punched number for identification. The masonry nail shall be placed through the central hole in the identification tag and driven into an asphalt-covered surface such that the identification tag lies directly between the asphalt-covered surface and the head of the masonry nail.
2. DMP-Type 2 shall consist of a ¾ inch diameter × 2-inch-long stainless steel socket-head cap bolt, screwed into a ¾ inch diameter × 1½ inch long tamp-in screw anchor. A 4 inch (or longer) bolt may be used at locations where overhanging obstructions prevent the placement of the level rod on the DMP. The longer bolt shall be replaced by a 2-inch-long bolt when readings are not being taken. DMP-Type 2 shall typically be installed into vertical surfaces of buildings and structures. Where removal and patching is not required after construction, the bolts may be installed with epoxy or polyester adhesive in lieu of tamp-in screw anchors. Where the DMP Type 2 is installed in steel column members the Design-Builder may install by drilling and tapping.
3. DMP-Type 3 shall consist of a ¾ inch diameter × 2-inch-long punch marked stainless-steel round head bolt screwed into a ¾ inch diameter × 1½ inch long tamp-in screw anchor (removable installation), or a ¾ inch diameter × 2-inch-long punch marked stainless steel

carriage bolt installed with epoxy or polyester adhesive (permanent installation). DMP-Type 3 shall typically be installed into horizontal concrete and rock surfaces (e.g. sidewalks, granite curbstones). Where the DMP Type 3 is installed in steel column members the Design-Builder may install by drilling and tapping.

4. DMP-Type 4 shall consist of a 5-foot-long, $\frac{3}{4}$ inch diameter steel rod and a surface roadway box. Top of rod shall be rounded and punch marked at its center. DMP-Type 4 shall typically be installed in soil.
5. DMP-Type 5 shall consist of an observable point punch marked on the top horizontal surface of steel sheeting or a soldier pile. The steel surface within 3 inches of the point shall be cleaned by wire brush to permit easy identification of the exact point. The point shall also be clearly identified using fluorescent spray paint adjacent to the point.
6. DMP-Type 6 shall consist of a settlement platform or settlement plates, see Section 4.6 for description.
7. DMP-Type 7 shall consist of settlement cells/sensors as manufactured by Geokon model 4600 or RocTest model SSG or acceptable equivalent.

2.5 BORROS POINTS

- A. Provide Borros anchor, as manufactured by Slope Indicator Co., Mukilteo, WA; Geokon Inc., Lebanon, NH; Geonor Inc., Augusta, NJ; or acceptable equivalent.
 1. Provide $\frac{1}{4}$ inch standard steel pipe, threaded and coupled, ASTM A 53, Grade B. Couplings shall have 45 degree tapered shoulders across the full coupling wall thickness, at both ends.
 2. Provide 1-inch standard steel pipe, threaded and coupled, ASTM A 53, Grade B.
 3. Provide plastic or rubber tubing, to fit and slide in annulus between 1-inch and $\frac{1}{4}$ inch pipes. The radial clearance between the $\frac{1}{4}$ inch pipe and inside of the tubing and between the 1-inch pipe and outside of the tubing shall not be more than 0.07 inch.
 4. Provide 18-inch x 18-inch x $\frac{1}{4}$ inch steel plate with 1.5-inch diameter central hole.
 5. Provide steel pipe clamp to fit 1-inch standard steel pipe. Steel plate and pipe clamp assembly shall be capable of transferring the total weight of the 1-inch standard steel pipe to the soil underlying the steel plate. The assembly shall also be capable of maintaining its position on the 1-inch standard steel pipe.
 6. Provide oakum.
 7. Special grout Type A shall consist of uniform sized fine ground or powdered non-drilling mud grade bentonite, for use in sealing and grouting well casings. A polymer-based thixotropic additive may also be added to the mix if recommended by the manufacturer. Special grout Type A shall have a mixed specific gravity, prior to placement within the instrument borehole, of between 1.03 and 1.10.

2.6 CONVERGENCE GAGES

- A. Provide tape extensometers and carrying cases, as manufactured by RS Technical Instruments Ltd., Maple Ridge, BC, Canada, model 51811510 as manufactured by Slope Indicator Co., Mukilteo, WA, model 1610 as manufactured by Geokon Inc., Lebanon, NH, or acceptable equivalent. Tape length shall be at least 75 feet.
1. Provide anchorage points, from the same commercial source as the tape extensometers, for installation on facilities as shown on the Instrumentation Plan.
 2. Provide calibration frame from the same commercial source as the tape extensometers. Calibration frame shall consist of a 5 ft length of a C6×8.2 steel channel, with a 10 inch × 6 in. × ¼ inch thick steel plate welded to the channel at each end. The channel and the plate shall be made from black A36 steel. All corners shall be rounded. Provide an anchorage point fixed to each plate, with sufficient clearance above the channel to mount the tape extensometer.

2.7 INCLINOMETERS

- A. For probe inclination measurements, provide inclinometer casing, probe, cable, readout unit and accessories, as manufactured by Slope Indicator Co., Mukilteo, WA or Geokon Inc., Lebanon, NH, or acceptable equivalent.
1. Inclinometer casing shall be 2.75 inch O.D. ABS or 2.4 inch O.D. PVC with broached internal keyways, and twist tolerance better than one degree per 10 feet length. Couplings shall be of the telescoping type.
 2. Probe shall be Digitilt Classic Inclinometer System as manufactured by Slope Indicator Co. or model GK-604D as manufactured by Geokon Inc., Lebanon, NH, or acceptable equivalent. Probe shall be biaxial, consisting of two force balance accelerometers mounted at 90°, with a 2-foot wheelbase. Probe shall be supplied in a carrying case.
 3. Cable shall be at least 135 feet long, sheathed with neoprene or polyurethane, with vulcanized rubber or metal markers, and an internal wire rope or kevlar strain core. Minimum cable O.D. shall be 0.4 inch.
 4. Readout unit shall be Digitilt DataMate II as manufactured by Slope Indicator Co. or model CR1000 data logger as manufactured by Campbell Scientific, or data loggers by Geokon Inc., or acceptable equivalent. The time interval between recordings two feet apart in the casing shall be such that the reading stabilizes to within ± 1 unit of display within 8 seconds. Readout unit shall include a battery charger.
 5. Provide accessories, consisting of end caps, tools and materials for attaching couplings, and taking readings.
 6. A minimum of one probe, cable, readout unit and carrying case shall be provided for the Design-Builder's Independent Geotechnical Instrumentation Engineer's monitoring program.
 7. Provide two sets of inclinometer software as supplied by Slope Indicator Co., or Geokon Inc., Lebanon, NH, or acceptable equivalent.

8. Special grout Type B shall include cement, bentonite and water, and shall have approximately the same shear strength and compressibility as the surrounding ground.
9. Surface protection shall have a diameter adequate to allow attachment of cable support assembly, or shall allow for an inclinometer casing extension while readings are being taken. The length of the inclinometer casing extension shall not vary by more than 0.05 inch.
10. In-place inclinometer system as manufactured by Slope Indicator Company, Mukilteo, WA, or by Geokon Inc., Lebanon, NH including IPI IDA-Sensor, wheel assembly gage, extension tubes, placement tubes and fittings, bus cable extensions, data logger, and inclinometer software. Provide one in-place inclinometer system for the Design-Builder's Independent Geotechnical Instrumentation Engineer's monitoring program.
11. Provide a minimum of one in-place inclinometer system readout unit for the Design-Builder's Independent Geotechnical Instrumentation Engineer's monitoring program.

2.8 PROBE EXTENSOMETERS

- A. Provide magnetic extensometer system as supplied by Slope Indicator Co., Mukilteo, WA, or model 1900 magnetic extensometer by Geokon Inc., Lebanon, NH, or acceptable equivalent, amended to conform to the requirements in this section.
 1. Access tube shall be PVC, 1-inch nominal diameter.
 2. Telescoping joints shall be provided at all connections in the access tube to allow for vertical compression.
 3. Magnetic settlement targets shall be pneumatically or mechanically actuated spider magnets, with 6 leaf springs, suitable for installation in a 4.5 to 5.5-inch diameter borehole. The stiffness of the leaf springs shall be such that a force of at least 5 pounds is required to move an 8-inch long leaf spring from its extended position to the longitudinal axis of the target. The extended diameter of the leaf springs shall be at least 9 inches. One datum ring shall be provided for each installation. The profiles of the spider magnet bodies and actuation devices shall be tapered such that there is no possibility of actuation devices hanging up on magnet bodies during retrieval. The actuation devices shall be designed such that there is a clear and reproducible signature to verify that the leaf springs have been released. If pneumatically actuated cutters are used, the connection between the cutter and pneumatic tubing shall sustain a tensile force of not less than 45 pounds.
 4. Reed switch probe and reel shall have at least 100 feet of nylon-coated tape with integral conductors. Tape shall be graduated in feet, tenths, and hundredths of a foot.
 5. Special Grout Type A shall consist of uniform sized ground or powdered non-drilling mud grade bentonite, for use in sealing and grouting well casings. A polymer-based thixotropic additive may also be added to the mix if recommended by the manufacturer. Special grout Type A shall have a mixed specific gravity, prior to placement within the instrument borehole, of between 1.03 and 1.10.

2.9 VIBRATING WIRE STRAIN GAGES

- A. Provide vibrating wire strain gages and cables, model 4000 as manufactured by Geokon Inc., Lebanon, NH, model SM-5A as manufactured by RocTest Inc., Saint-Lambert, Quebec Canada, or model VWSG-E(L) as manufactured by Geonor Inc., Augusta, NJ, or acceptable equivalent. Gages shall have documented long-term stability over a five-year period, and shall be proof tested by submersion in water for 24 hours at 100 lb/in². Strain gages shall have end blocks arranged for arc welding or bolting to steel, with a minimum center-to-center spacing of 3.6 inches, and shall be fitted with a thermistor.
1. Provide readout and other terminal units, from the same commercial source as the strain gages. Terminal units shall be clearly marked with each strain gage number. A minimum of one readout unit shall be provided for the Design-Builder's monitoring program and two for the Geotechnical Instrumentation Engineer's monitoring program.
 2. Provide protective covers for gages.
 3. Provide protection over all exposed gage cables, consisting of steel pipe, channel, angle or flexible steel conduit.

2.10 SEISMOGRAPHS

- A. Provide portable seismographs for monitoring the velocities of ground vibrations resulting from construction activities. Provide model 3000LCP as manufactured by Geosonics of Warrendale, PA or acceptable equivalent. The seismograph shall have the following minimum features: (to be modified later).
1. Seismic range: 0.01 to 8 inches per second with an accuracy of 5% and no more than a 3 db roll off at the low frequency end.
 2. Flat frequency response: 2 to 200 Hertz.
 3. Three component sensor.
 4. Fourth channel for air blast monitoring.
 5. Two power sources: Internal rechargeable battery and charger and 115 volts AC. Battery shall be capable of supplying power to monitor vibrations continuously for up to 24 hours.
 6. Capable of internal dynamic calibration.
 7. Data logging of readings.
 8. Continuous monitoring mode shall be capable of recording peak velocities.
 9. Capability of wirelessly downloading data remotely.

2.11 CRACK MONITORS

- A. Provide calibrated crack monitors as manufactured by RST via Geonor Inc., Augusta, NJ, or Avongard Products USA Ltd. of Los Angeles, CA, or acceptable equivalent.

2.12 TILTMETERS

- A. Provide biaxial tiltmeters, model EL tilt sensor or MEMS tiltmeter 57803102, as manufactured by Slope Indicator Co., Seattle, WA, model 6350 as manufactured by Geokon, Inc., Lebanon, NH, or acceptable equivalent.
1. Provide biaxial tiltmeter brackets from the same commercial source as the tiltmeters.

2. Provide 100 feet of cable from the same commercial source as the tiltmeters. Cable shall be as specified by the manufacturer of the instrument and shall be a shielded cable with a waterproof jacket.
3. Provide readout and other terminal units, from the same commercial source as the tiltmeters.
4. Provide protective boxes, NEMA 4, or equivalent, waterproof and locking, of appropriate size to enclose tiltmeter and allow for connection of readout unit to tiltmeter.

2.13 UTILITY MONITORING POINTS

- A. Provide materials to construct utility monitoring points including: steel pipe flange, 1-inch diameter, ASTM A 403.
 1. Extra strong steel sleeve pipe, threaded and coupled, ASTM A53 Grade B.
 2. Extra strong steel riser pipe, threaded and coupled, ASTM A53 Grade B.
 3. PVC centralizers. Centralizers shall consist of a schedule 40 PVC pipe conforming to ASTM D 1785, sized to provide a tight fit on the riser pipe, and spring-formed to a larger diameter to provide a loose fit in the sleeve pipe.
 4. 18-inch x 18-inch x 1/4-inch. steel plate with 4.25-inch diameter central hole.
 5. Steel pipe clamps and pipe flanges. Steel plate and pipe clamp assembly shall be capable of transferring the total weight of the 3-1/2-inch extra strong pipe to the soil underlying the steel plate. The assembly shall also be capable of maintaining its position on the extra strong steel pipe over time.
 6. Oakum.
 7. Pipe cap with 1/4-inch diameter round head stainless steel bolt set securely in cap.

2.14 DEEP BENCHMARKS

- A. Provide materials to construct deep benchmarks including:
 1. NW Schedule 40 steel casing, ASTM 53.
 2. Schedule 80 steel pipe, ASTM A53.
 3. PVC or nylon centralizers, tight fit on pipe, loose fit in casing.
 4. Bentonite Slurry consisting of a mixture of powdered bentonite and potable water in proportions to yield a thick slurry that can be placed by tremie methods.

2.15 FACTORY CALIBRATION

- A. A factory calibration shall be conducted on all instruments at the manufacturer's facility prior to shipment. Each factory calibration shall include a calibration curve with data points of the applied quantity (e.g. pressure, displacement, force) versus the measured quantity clearly indicated, and a tabulation of the data. Each instrument shall be marked with a unique identification number.

1. Factory calibrations of vibrating wire piezometers shall be made against a pressure gage traceable to the National Institute of Standards and Technology. The accuracy of the pressure gage shall not be less than twice the specified accuracy of the piezometers. Calibrations shall be made to full scale in two complete cycles, recording the reading in 10 equal increments during two loading and two unloading cycles. The thermal factor of each piezometer shall be determined in a precision test chamber, at 0, 10, 20, and 30 degrees C. The calibration record shall include gage factor, thermal factor, and zero reading with corresponding temperature and barometric pressure.
2. Factory calibrations of convergence gages shall be made by attaching the gage to its calibration frame, taking a reading, removing the gage from the frame, repeating the procedure five times, and reporting each reading and the average.
3. Factory calibrations of inclinometers shall include comprehensive calibrations of the force balance accelerometers prior to assembly in the probe. A final calibration shall include measurements made at 10° intervals from -30° to +30° with respect to vertical, and a comprehensive repeatability check over a smaller zone near vertical.
4. Factory calibration of probe extensometers shall be made by verifying that an audible signal is emitted as the probes pass through each magnet. Each magnet shall be supplied with a label or sticker confirming that it has been checked as specified. The tape attached to the probe shall be checked against a standard traceable to the National Institute of Standards and Technology, to an accuracy of ± 0.05 in.
5. Factory calibration of seismograph vibration monitors shall be performed using a shake table and a reference sensor traceable to the National Institute of Standards and Technology. Factory calibrations of overpressure sensors shall be performed using a calibrator traceable to the National Institute of Standards and Technology.
6. Factory calibration of the tiltmeters shall consist of calibrations in a mechanical tilting table within the range of ± 2000 micro-radians, in a minimum of 10 equal increments.

2.16 OPEN STANDPIPE PIEZOMETERS

- A. Provide open standpipe piezometers with slotted pipe, bottom caps and vented top caps. The slotted pipe shall be 1.5 feet long, 1¼ inch Sch. 80 PVC with 3 rows of 0.01-inch-wide slots on 120° centers, with a slot length to leave 0.25 inch between rows. The riser pipe shall be 1¼ inch Sch. 80 flush Joint PVC pipe. The joints shall either have modified pipe threads or O-rings such that they sustain an internal water pressure of 50 lb/sq. inch.
 1. Sand filter shall conform to ASTM C-778-13, Standard Specification for Standard Sand, for 20-30 sand.
 2. Granular bentonite shall be Enviroplug Medium, as manufactured by Wyo-Ben, Inc., Billings, MT, or Holeplug, as manufactured by Baroid Division, Halliburton, Houston, TX, or acceptable equivalent.

PART 3 - EXECUTION

3.1 PRE-INSTALLATION ACCEPTANCE TESTS

- A. When instruments are received at the site, the Design-Builder's instrumentation personnel shall perform pre-installation acceptance tests to ensure that the instruments and readout units are functioning correctly prior to installation. Pre-installation acceptance tests shall include relevant items from the following list:
1. Examine factory calibration curve and tabulated data, to verify completeness.
 2. Examine manufacturer's final quality assurance inspection check list, to verify completeness
 3. Check cable length.
 4. Check tag numbers on instrument and cable.
 5. Check, by comparing with procurement document, that model, dimensions, materials. are correct.
 6. Bend cable back and forth, at point of connection to instrument, while reading the instrument, to verify connection integrity.
 7. Perform resistance and insulation testing, in accordance with criteria provided by the instrument manufacturer, using a gage insulation or circuit tester that applies 2 volts or less for resistance testing and 15 volts or less for insulation testing.
 8. Verify that all components fit together in the correct configuration.
 9. Check all components for signs of damage in transit.
 10. Check that quantities received correspond to quantities ordered.
- B. During pre-installation acceptance testing of each instrument the Design-Builder's instrumentation personnel shall complete a test record sheet. The test record sheet shall include appropriate items from the following list:
1. Project name.
 2. Instrument type and number.
 3. Identification of any testing or readout equipment used during testing.
 4. Personnel responsible for testing.
 5. Date and time of test.
 6. Measurements and observations made during testing, as specified in above, items 1 thru 10.
 7. Test results, pass or fail.

3.2 INSTALLATION - GENERAL

- A. The Design-Builder shall install, monitor, and interpret data from instrumentation to ensure the safety of personnel and the work, at no additional cost to the MBTA. Raw data collected by the Design-Builder from any such additional instrumentation proposed by the Design-Builder's Geotechnical Instrumentation Engineer and approved by the MBTA, shall be collected in the same manner as for the specified instrumentation. Raw, reduced and plotted data shall be made available to the MBTA.
1. Installation procedures for instruments in boreholes shall be such that all steps in the procedure can be quality assured. Volumes of each increment of backfilling with sand and granular bentonite shall be small enough such that no bridging occurs, and the depth to the top of each increment shall be checked after placement.
 2. Grout shall be placed using a tremie method with side discharge ports on the tremie pipe.

3. Prior to installing any instrument through drill casing or augers, all material adhering to the inside of the casing or augers, and all cuttings, shall be removed thoroughly.
4. Whenever withdrawing drill casing or augers during instrument installation in a borehole, care shall be taken to minimize the length of unsupported borehole and the rate of casing or auger withdrawal. Collapse of the borehole shall not be allowed to occur. Backfill material shall not be allowed to build up inside the casing or auger such that the instrument is lifted as the casing or auger is withdrawn. The casing or auger shall be withdrawn without rotation. The casing or auger may be omitted only where it can be shown that instrument installation without the casing or auger will not cause collapse of the borehole or in any way adversely affect instrument installation.
5. The Design-Builder shall notify the MBTA at least 24 hours prior to installing each instrument.
6. Approximate quantities and locations of all instruments shall be shown on the Instrumentation Plan prepared by the Design-Builder's Geotechnical Instrumentation Engineer and approved by the MBTA. Exact locations shall be determined in the field, by the Geotechnical Instrumentation Engineer in cooperation with the Design-Builder's Lead Geotechnical Engineer, to minimize interference to other construction work.
7. The Design-Builder shall extend installed instrumentation and reinstall roadway boxes as necessary as grade changes occur, and revise instrument reference elevations as necessary.
8. As each instrument is installed, an installation record sheet (paper and electronic record) shall be prepared, including appropriate items from the following list:
 - a. Project name.
 - b. Contract name and number.
 - c. Instrument type and number, including readout unit.
 - d. Planned location in horizontal position and elevation.
 - e. Planned orientation.
 - f. Planned lengths and volumes of backfill.
 - g. Personnel responsible for installation.
 - h. Equipment used, including diameter and depth of any drill casing or augers used.
 - i. Date and time of start and completion.
 - j. Spaces on record sheet for necessary measurements or readings required at hold points during installation to ensure that all previous steps have been followed correctly, including instrument readings made during installation.
 - k. A log of subsurface data indicating the elevations of strata changes encountered in the borehole. Strata soil nomenclature shall be based on profiles and boring logs contained in the Geotechnical Data Report.
 - l. Type of backfill used.
 - m. As-built location in horizontal position and elevation.
 - n. As-built orientation.
 - o. As-built lengths and volumes of backfill.
 - p. Result of post-installation acceptance test.
 - q. Weather conditions at the time of installation.
 - r. A space on record sheet for notes, including problems encountered, delays, unusual features of the installation, and details of any events that may have a bearing on instrument behavior.

An instrument that fails the specified post-installation acceptance test shall be replaced by an identical instrument at no cost to the MBTA.

3.3 INSTALLATION OF OBSERVATION WELLS

- A. Observation wells shall be installed at the locations and depths shown on the Design-Builder's approved Instrumentation Plan, in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. Bentonite drilling mud shall not be used. The general installation procedure is as follows.
1. Using a wash boring or rotary drilling method, install HW or larger flush-joint casing to 6 inches below the planned elevation of the bottom of the slotted pipe, taking a split-spoon soil sample at the bottom of the borehole, and wash until the water runs clear. Maximize cutting removal by using the reverse circulation method, with the wash pipe as the intake, its lower end a few inches from the bottom of the borehole.
 2. Pull the casing 6 inches and pour in enough filter sand to fill the borehole below the bottom of the casing. Check the borehole depth.
 3. Lower the slotted pipe, with attached riser pipe, to the top of the sand.
 4. Pull the casing 12 inches and pour sand to fill the borehole below the bottom of the casing. Repeat until the borehole is filled with sand, and the casing is removed, checking the depth of the sand after each pour.
 5. Install granular bentonite plug and surface protection.
 6. Determine as-built location in horizontal position to an accuracy of ± 0.1 foot and in elevation to an accuracy of ± 0.01 foot.
- B. After completion of installation, the as-built location in horizontal position shall be determined to an accuracy of ± 0.1 foot, and in elevation to an accuracy of ± 0.01 foot.

3.4 INSTALLATION OF OPEN STANDPIPE PIEZOMETERS

- A. Open standpipe piezometers shall be installed, one per borehole, at the locations and depths shown on the Design-Builder's approved Instrumentation Plan, in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. Bentonite drilling mud shall not be allowed. The general installation procedure is as follows.
1. Using a wash boring or rotary drilling method install HW or larger flush-joint casing to 1 foot below the planned elevation of the bottom of the piezometer, taking a split-spoon soil sample at the piezometer elevation, and wash until the water runs clear. Maximize cutting removal by using the reverse circulation method, with the wash pipe as the intake, its lower end a few inches from the bottom of the borehole.
 2. Pull the casing 6 inches and pour in enough filter sand to fill the borehole below the bottom of the casing. Check the borehole depth.
 3. Repeat step 2. Lower the porous point, with attached riser pipe, to the top of the sand.
 4. Pull the casing 6 inches and pour sand to fill the borehole below the bottom of the casing. Repeat until the sand and casing are 1 foot above the top of the porous point, checking the depth after each pour.
 5. Pull the casing 6 in and pour granular bentonite very slowly to fill the borehole below the bottom of the casing. Repeat until a 4-foot layer of granular bentonite is in place, checking the depth after each pour using a cylindrical sounding hammer. Do not tamp the granular bentonite.

6. Fill the casing with special grout Type A, using a tremie method with side discharge ports on the tremie pipe. Withdraw all casing, without rotation, and top up the borehole with special grout Type A.
 7. Perform post-installation acceptance test by conducting a falling head permeability test to verify seal integrity.
 8. Install surface protection.
 9. Determine as-built location in horizontal position to an accuracy of ± 0.1 foot and in elevation to an accuracy of ± 0.01 foot.
- B. After completion of installation, the as-built location in horizontal position shall be determined to an accuracy of ± 0.1 foot, and in elevation to an accuracy of ± 0.01 foot.

3.5 INSTALLATION OF VIBRATING WIRE PIEZOMETERS

- A. Vibrating wire piezometers shall be installed, one or two per borehole, at the locations and depths shown on the Design-Builder's approved Instrumentation Plan in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. Bentonite drilling mud shall not be used. The general installation procedure is as follows.
1. Using a wash boring or rotary drilling method, install HW or larger flush-joint casing to 1 foot below the planned elevation of the bottom of the piezometer, taking a split-spoon soil sample at the piezometer elevation, and wash until the water runs clear. Maximize cutting removal by using the reverse circulation method, with the wash pipe as the intake, its lower end a few inches from the bottom of the borehole.
 2. Pull the casing 6 inches and pour in enough filter sand to fill the borehole below the bottom of the casing. Check the borehole depth.
 3. Repeat step 2.
 4. Fully saturate the piezometer filter and cavity between filter and diaphragm with clean water.
 5. While maintaining saturation of the piezometer filter, lower the piezometer, with attached cable, to the top of the filter sand.
 6. Check that the piezometer reading agrees with the water head.
 7. Record the elevation of the diaphragm.
 8. Pull the casing 6 inches and pour sand to fill the borehole below the bottom of the casing. Repeat until the sand and casing are 1 foot above the top of the piezometer, checking the depth after each pour.
 9. Pull the casing 6 inches and pour granular bentonite very slowly to fill the borehole below the bottom of the casing. Repeat until a 4-foot layer of granular bentonite is in place, checking the depth after each pour using a cylindrical sounding hammer. Do not tamp the granular bentonite.

10. Fill the casing with special grout Type A, using a tremie method with side discharge ports on the tremie pipe. Withdraw all casing, without rotation, and top up the borehole with special grout Type A.
 11. Perform post-installation acceptance test by verifying that the piezometer reading agrees with the piezometric head.
 12. Install surface protection.
 13. Determine as-built location in horizontal position to an accuracy of ± 0.1 foot and in elevation to an accuracy of ± 0.01 foot.
- B. Prior to insertion of the piezometer in the borehole, the piezometer and cavity between filter and diaphragm shall be saturated with clean water. Saturation shall be maintained throughout the installation.
 - C. The piezometer shall be lowered to between 24 and 26 feet above its specified installation depth, allowed to achieve thermal equilibrium by waiting for a sufficient time, as stated by the manufacturer, and readings taken of piezometer pressure and temperature, and barometric pressure. Corrections shall be applied in accordance with factory calibration data. The actual water head over the piezometer diaphragm shall be determined by direct depth measurement. The piezometer shall then be lowered to between 4 and 6 feet above its specified installation depth, allowed to achieve thermal equilibrium, and readings taken and corrections made as specified herein. The calibration of the piezometer shall be checked by comparing the actual difference in water head with the difference between the two piezometer readings. If the two values differ by more than 1.0% of the specified range of the piezometer, the piezometer shall be replaced by an identical instrument at no additional cost to the MBTA. If the two values agree to within 1.0 % of the specified range of the piezometer, the piezometer shall be lowered to the specified installation depth and the elevation of the diaphragm shall be recorded.
 - D. Depth to the top of each increment of granular bentonite shall be checked using a cylindrical sounding hammer. The granular bentonite shall not be tamped.
 - E. After completion of installation a post-installation acceptance test shall be performed to verify that the piezometer functions correctly.
 - F. After completion of installation, the as-built location in horizontal position shall be determined to an accuracy of ± 1 foot, and the elevation of the top of the roadway box to an accuracy of ± 0.01 foot. The elevation of the piezometer diaphragm shall also be determined, to an accuracy of ± 0.1 foot.

3.6 INSTALLATION OF DEFORMATION MONITORING POINTS

- A. Deformation monitoring points (DMPs) shall be installed at the locations shown on the Design-Builder's approved Instrumentation Plan, or as directed by the MBTA. Where the DMP is being installed in masonry construction the Design-Builder shall locate the DMP in the grout between masonry units. After installation of a DMP, determine as-built location in horizontal position to an accuracy of ± 0.03 foot, and in elevation to an accuracy of ± 0.01 foot. Deformation Monitoring Points shall be installed in accordance with the manufacturer recommendations and instructions, if available, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.

1. DMP-Type 1 shall be driven with a hammer into asphalt-covered surface. The identification marker shall be installed directly between the asphalt-covered surface and the head of the PK nail.
2. DMP-Type 2 shall be installed in holes drilled into vertical surfaces of building foundations as follows:
 - a. Drill hole in masonry or stone surface.
 - b. Insert tampin screw anchor with conical end first. (The tampin screw anchor consists of threaded steel screw anchor and a lead casing).
 - c. Use setting tool supplied by manufacturer to expand lead sleeve into masonry.
 - d. Cap hole with 5/16-inch diameter x ¾ inch long carriage bolt.
 - e. To take a reading, replace ¾ inch long carriage bolt with 4 ½ inch long (or longer) machined and certified bolt.
3. DMP-Type 3 shall be installed in holes drilled into horizontal concrete and rock surfaces. The monitoring points shall be installed as described for DMP-Type 2, except that the 5/16-inch diameter x ¾ inch long carriage bold shall be punch-marked and kept permanently fixed in the anchor hole with thread-locking compound, and the 4 ½ inch long (or longer) hex bolt is not used.
4. DMP-Type 4 shall be installed by excavating a hole adequate for the roadway box, driving the rod to the required depth, and installing the roadway box. If the rod cannot be driven to the required depth, it shall be withdrawn, and reinstalled by advancing a borehole to the full depth of the rod, and grouting the annulus with cement grout.
5. DMP-Type 5 shall be installed on the top horizontal surface of steel sheeting or a soldier pile. The steel surface within 3 inch of the point shall be cleaned by wire brush to permit easy identification of the exact point. The point shall also be clearly identified using fluorescent spray paint adjacent to the point.

3.7 BORROS POINT ANCHORS

- A. Borros points shall be installed at the locations and depths shown on the Design-Builder's approved Instrumentation Plan or as directed by the MBTA. Borros Point Anchors shall be installed in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.
 1. Using a wash boring or rotary drilling method, install NW or HW flush-joint casing to 1 foot above the depth shown on the Instrumentation Plan. Maximum borehole size shall be 4.5 inches. Wash until the water runs clear.
 2. Assemble Borros anchor, left hand thread, greased garden hose, ¼ inch and 1 inch pipes, with left hand thread greased and hand-tight, and lower to bottom of boring. Grease heavily the outside of all couplings on ¼ inch pipe. At the same time insert a grout tremie pipe to bottom of boring. Drive on 1-inch pipe until Borros anchor is at required depth.
 3. Extend anchor prongs by driving on ¼ inch pipe. Record driving distance, to ensure full extension.
 4. Disconnect the left hand thread and raise the 1 inch pipe 1 foot or a different distance as determined by the Geotechnical Instrumentation Engineer. Relative depths of couplings on ¼

inch and 1 inch pipes shall be planned such that there will be no possibility of them being alongside each other at any time as settlement or heave takes place.

5. Fill the boring with special grout Type A, withdraw the drill casing and tremie pipe, topping up with special grout Type A.
6. Fill top 3 inches of space between ¼ inch and 1 inch pipes with oakum.
7. Place the steel plate over the 1-inch pipe and directly on the soil subgrade. Install the pipe clamp on the 1-inch pipe such that the clamp rests directly on the steel plate.
8. Install surface protection.
9. After completion of installation, determine as-built location in horizontal position to an accuracy of ±0.1 foot, and in elevation to an accuracy of ±0.01 foot.

3.8 INSTALLATION OF CONVERGENCE GAUGES

- A. Convergence gage anchorage points shall be installed at the locations shown on the Design-Builder's approved Instrumentation Plan, or as directed by the Geotechnical Instrumentation Engineer.

3.9 INSTALLATION OF INCLINOMETERS

- A. Inclinator casings shall be installed at the locations and depths shown on the Instrumentation Plan, or as directed by the Geotechnical Instrumentation Engineer. After installation, the bottom 10 feet of inclinometer casing shall be within a stratum suitable for providing base fixity, such as bedrock or glacial till. Inclinator casings shall be installed in accordance with the manufacturer instructions, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.
 1. Prior to drilling, the drill rig shall be plumbed to within one degree of vertical. Using a wash boring or rotary drilling method, install HW or PW flush-joint casing to the specified depth of the bottom cap, plus any additional depth needed to accommodate any required bottom weight. Maximum borehole size shall be 5.5 inches. If drilling in bedrock is required, the boring in bedrock shall be 3.75 inches minimum diameter. Wash until the water runs clear. Maximize cutting removal by using the reverse circulation method, with wash pipe as the intake, its lower end a few inches from the bottom of the borehole.
 2. If the boring extends into bedrock, verify that special grout Type B does not run into the bedrock by using the following method. Add drill casing so that the top is 10 feet above the ground surface. Fill the drill casing with water, and observe the level. If the level remains at the top of the casing for five minutes, proceed with step 3. If the level falls, tremie special grout Type B into the bottom 10 feet of the borehole, redrill, regout and redrill as necessary until, with the water-filled casing 10 feet above the ground surface and the borehole drilled 10 feet into bedrock, water remains at the top of the casing for five minutes.
 3. Install the bottom cap on the inclinometer casing. Verify that the drill casing is free to move. Using a tremie method, fill the drill casing with special grout Type B.

4. Add sufficient weight to the bottom of the inclinometer casing to overcome buoyancy caused by the grout, and lower coupled inclinometer casing throughout the borehole, filling with water, sealing joints to prevent grout ingress. Casing groove orientation shall be maintained throughout installation.
5. When all inclinometer casing is installed, withdraw drill casing without rotation, and top up with special grout Type B.
6. After completion of installation, but before the grout has set, a post-installation acceptance test shall be performed to verify that there is no grout in the inclinometer casing, that groove orientation is correct and that the inclinometer probe tracks correctly in all four orientations. After the grout has set, a check shall again be made to verify that the inclinometer probe tracks correctly in all four orientations.
7. Flush inclinometer casing with clean water. Allow grout to set. Repeat flushing and post-installation acceptance test.
8. Install surface protection.

3.10 INSTALLATION OF IN-PLACE INCLINOMETER (IPI) SENSOR STRING

- A. Install IPI sensor string within acceptably installed inclinometer casing in accordance with the manufacturer's recommendations.
 1. Gage lengths shall be 5 feet from the top of the inclinometer casing to a depth of 50 feet below the top of the casing and 10 feet from a depth of 50 feet below the top of the casing to the bottom of the casing. Provide sufficient IPI sensors for the longest inclinometer casing to be monitored with an IPI.
 2. IPI system shall be installed a minimum of two days prior to the construction of each adjacent slurry wall panel and removed no sooner than two days after the panel is poured.
 3. The IPI data collection shall be closely coordinated with the slurry wall panel construction sequence.

3.11 INSTALLATION OF PROBE EXTENSOMETERS

- A. Probe extensometers shall be installed at the locations and depths shown on the Design-Builder's approved Instrumentation Plan or as directed by the Geotechnical Instrumentation Engineer. After installation, the bottom 10 feet of the access tube shall be within a stratum suitable for providing base fixity, such as bedrock or glacial till. Probe Extensometers shall be installed in accordance with the manufacturer recommendations instructions, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.
 1. Prior to drilling, the drill rig shall be plumbed to within one degree of vertical. Using a wash boring or rotary drilling method, install HW or PW flush-joint casing to the specified depth of the bottom cap, plus any additional depth needed to accommodate any required bottom weight. Maximum borehole size shall be 5.5 inches. If drilling in bedrock is required, the boring in bedrock shall be 3.75 inches minimum diameter. Wash until the water runs clear. Maximize cutting removal by using the reverse circulation method, with the wash pipe as the intake, its lower end a few inches from the bottom of the borehole.

2. Prior to completion of the boring, prefix spider magnets and datum magnets to the access tube, using nylon line to hold the magnet legs in their inward position. Spider magnets shall be held adequately on the access tube so that they do not slide during installation, but are free to slide subsequently. The access tube shall be coated with heavy grease to fill the annular space between each spider magnet and the access tube, and for a distance of 2 inches above and below each magnet location. For a further distance of 12 inches above and below each magnet location, the access tube shall be coated with silicon grease. Spider magnets shall not be installed within 2 feet above or below telescoping joint in the access tube.
3. Fit a pneumatic cutter and tube to each spider magnet, identifying each tube at its upper end. Install the bottom cap on the access tube.
4. The telescoping couplings shall be installed in a two-thirds extended position. No more than one pop rivet shall be used at each end of each telescoping coupling.
5. If the boring extends into bedrock, verify that cement grout does not run into the bedrock by using the following method. Add drill casing so that the top is 10 feet above the ground surface. Fill the drill casing with water, and observe the level. If the level remains at the top of the casing for five minutes, proceed with step 4. If the level falls, tremie cement grout into the bottom 10 feet of the borehole, redrill, regrout and redrill as necessary until, with the water-filled casing 10 feet above the ground surface and the borehole drilled 10 feet into bedrock, water remains at the top of the casing for five minutes.
6. Verify that the drill casing is free to move. Using a tremie method, fill the bottom of the boring with a measured volume of cement grout sufficient to fill the annulus between the bottom 10 feet of access tube and the ground. Fill the remainder of the boring with special grout Type A.
7. Add sufficient weight to the bottom of the access tube to overcome buoyancy caused by the grout, and lower coupled access tube throughout the borehole, filling the access tube with water, and sealing joints in the access tube to prevent grout ingress. Ensure that telescoping couplings are in the fully extended position.
8. When all access tube and magnets are installed, withdraw drill casing without rotation to 2 feet above the lowest spider magnet, release the magnet legs, and retrieve the pneumatic cutter.
9. Repeat step 9 for each spider magnet in turn, topping up with special grout Type A as the installation proceeds, withdrawing all drill casing.
10. During installation, the access tube shall not be rotated, and connections to actuation devices shall not become intertwined. All actuation devices shall be retrieved, to demonstrate that spider magnets have been actuated.
11. After completion of installation, a post-installation acceptance test shall be performed to verify that there is no grout in the access tube, that telescoping couplings are in the two-thirds extended position, that no spider magnet varies from its specified position by more than 9 inches and that no spider magnet is nearer than 24 inches above or below the end of the coupling in the access tube.
12. Flush the access tube with clean water. Fit the top cap to the access tube.
13. Allow grout to set. Repeat flushing and post-installation acceptance test.

14. Install surface protection.
15. After completion of installation the as-built location in horizontal position shall be determined to an accuracy of ± 1 foot and the elevation of the top of the access tube to an accuracy of ± 0.01 foot.

3.12 INSTALLATION OF VIBRATING WIRE STRAIN GAUGES INSTALLATION - GENERAL

- A. Installation of vibrating wire strain gages shall be completed a minimum of 5 work days before a gauged strut or brace is installed in an excavation support system. Gauges shall be installed at the locations shown on the Design-Builder's approved Instrumentation Plan, or as directed by the Geotechnical Instrumentation Engineer. Vibrating wire strain gauges shall be installed in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.
 1. Weld or thread end blocks or posts to member, using a positioning jig. If threaded posts are used, threads shall be covered with a thread locking compound, and a locknut shall be attached to each post.
 2. Stress relieve welded end blocks by lightly tapping with a hammer, or posts by flexing with the fingers several times in all directions. The later procedure shall be repeated after gauge attachment.
 3. Attach the gauge to the end blocks or posts, and set to an initial reading as determined by the Geotechnical Instrumentation Engineer.
 4. Attach coil assembly and cable.
 5. If posts are used, again flex them with the fingers to exercise the gauge as far as possible within its range.
 6. Perform post-installation acceptance test, by reading the gauge, to ensure correct functioning.
 7. Install cover plate over gauge, without reinforcing member. Paint cover plate with white paint.
 8. Coil and protect cable, in preparation for member installation.
- B. After member is installed, route cable to terminal location, install terminal and switch box or datalogger (identify which), and install protection over cable and terminal. Record as-built location in relation to member number and gauge location on member.

3.13 INSTALLATION OF SEISMOGRAPHS

- A. The Design-Builder shall install seismographs where shown on the Design-Builder's approved Instrumentation Plan, or as directed by the Geotechnical Instrumentation Engineer. These locations shall include: (select one or more of the following options: the ground at points between three and six feet from the faces of buildings; the structure of buildings; the floor slab near the closest exterior face of the buildings).

1. Seismographs shall be firmly mounted on the surface slab of concrete or asphalt, firmly set in undisturbed soil, or rigidly attached to the structure of buildings.

3.14 INSTALLATION CRACK MONITORS

- A. Crack monitors shall be installed by the Design-Builder at locations determined by the Design-Builder's Geotechnical Instrumentation Engineer. Crack monitors shall typically be installed in horizontal and vertical surfaces of structures. Installation by the Design-Builder of additional crack monitors shall utilize means and methods that avoid or minimize damage to building materials in general, and in particular, to historic materials. Drilled holes shall be located to avoid historically and architecturally significant design features of the structure.
 1. After completion of installation of additional crack monitors, the Design-Builder shall perform a post-installation acceptance test, by verifying that the monitors are firmly fixed in place.
 2. After completion of installation of additional crack monitors, the Design-Builder shall submit to the Geotechnical Instrumentation Engineer a sketch showing the as-built locations in horizontal position and elevation, measured from permanent physical features in the field, to an accuracy of ± 1 foot.

3.15 INSTALLATION OF TILTMETERS

- A. Tiltmeters shall be securely mounted to interior walls of the structures. The tilt meters shall be installed on the top floor of the buildings, at the locations shown on the Design-Builder's approved Instrumentation Plan or as directed by the Geotechnical Instrumentation Engineer. The bi-axial brackets shall be securely mounted to the structure as directed by the manufacturer. The sensitive axis of the tilt sensor shall be mounted perpendicular to the face of the building.
 1. Tiltmeters shall be connected by cable to terminal units where they can be monitored with the readout box. The terminal units shall be located in areas such that access by the Design-Builder's instrumentation subcontractor will not interfere with the Building Owner or occupants.
 2. After tiltmeter installation, perform post-installation acceptance by reading the tiltmeter to ensure correct functioning.
 3. The threshold limits and signal functions on the readout box shall be set as directed by the Geotechnical Instrumentation Engineer.
 4. After the tiltmeter is installed, record as-built location.

3.16 INSTALLATION OF UTILITY MONITORING POINTS

- A. Utility monitoring points shall be installed at the locations and depths shown on the Design-Builder's approved Instrumentation Plan, or as directed by the Geotechnical Instrumentation Engineer. Utility monitoring points shall be installed in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.

1. The location and top of the utility in plan shall be determined using vacuum excavation methods. The Design-Builder shall be responsible for any damage to the utility during installation of the utility monitoring point.
2. Vacuum excavation methods shall be used to locate the top of the utility. Approach the top of the utility very slowly, to avoid risk of damage.
3. Install the sleeve pipe to the top of the utility.
4. Attach the steel flange to a length of riser pipe within the sleeve pipe, with centralizers every 10 feet, until the flange rests on top of the utility. Record the total length of flange and riser pipe to an accuracy of ± 0.01 foot.
5. Raise the sleeve pipe a distance of 1 foot keeping it in place as necessary by supporting the top.
6. Attach the pipe cap to the top of the riser pipe.
7. Fill the top 3 inches of space between the riser pipe and sleeve pipe with oakum.
8. Place the steel plate over the sleeve pipe and directly on the soil subgrade. Install the pipe clamp on the sleeve pipe such that the clamp rests directly on the steel plate.
9. Install surface protection.
10. After completion of installation, the as-built location in elevation shall be determined to an accuracy of ± 0.01 foot.

3.17 INSTALLATION OF DEEP BENCHMARKS

- A. Deep benchmarks shall be installed at the locations and depths shown on the Design-Builder's approved Instrumentation Plan, or as directed by the Geotechnical Instrumentation Engineer. Deep benchmarks shall be installed in accordance with the manufacturer recommendations and instructions, and as directed by the Geotechnical Instrumentation Engineer. The general installation procedure is as follows.
 1. Prior to drilling, the drill rig shall be plumbed to within one degree of vertical.
 2. The boring shall be drilled and permanently cased from the ground surface to a minimum one foot into bedrock.
 3. Core minimum of 10 feet of bedrock below the bottom of the permanent casing using an NX-sized core barrel.
 4. Add casing so that the top of the casing is 10 feet above ground surface. Fill the casing with water and observe the level. If the level remains within one foot of the top of the casing for five minutes, proceed with next step. If the level drops more than one foot below the top of the casing, tremie grout the bottom 10 feet of the borehole. Allow the grout to setup then drill out the bottom 10 feet. Repeat the process until water drops less than one foot from the top of the casing.

5. Tremie grout the bottom 10 feet of the borehole.
6. Lower the 1-½ inch steel pipe into the casing.
7. The length of the 1-½ inch pipe shall be adjusted as required so that the final location of the round head reference screw fitted to the steel cap is approximately four inches below ground surface.
8. A steel pipe cap fitted with a stainless steel round head reference screw shall be attached to the 1-½ inch pipe by welding.
9. Install the protective casing at the ground surface. The bottom of the protective casing shall extend to a minimum depth of 30 inches below the ground surface. The protective casing shall be secured in concrete.
10. The annulus between the permanent casing and the protective casing shall be filled (for corrosion protection) with bentonite slurry.

3.18 FIELD CALIBRATION AND MAINTENANCE

- A. The Design-Builder's instrumentation personnel shall conduct regular field calibrations and maintenance of readout units used for the Design-Builder's monitoring program, and regular maintenance of field terminals and accessible instrument components, following the guidelines included in the manufacturers' instruction manuals, and as detailed in the reviewed submittal. Regular field calibrations of readout units shall be made on a frequency not exceeding three months. Maintenance shall include both instruments installed by the Design-Builder and existing instruments installed by others. The Design-Builder shall conduct regular calibration and maintenance of readout units.
 1. On each day during which convergence gage readings are to be made, the Design-Builder's instrumentation personnel shall, before any readings are made, verify that the convergence gage is in calibration by attaching the gage to its calibration frame and verifying that the reading has not varied by more than ± 0.005 inch. from all previous such values.
 2. On each day during which inclinometer readings are to be made, the Design-Builder's instrumentation personnel shall, before any readings are made, verify inclinometer repeatability by lowering the probe to a stable depth in one selected inclinometer casing, at a depth where verticality of the casing is within 0.5% of vertical, waiting for temperature stabilization, taking a reading on both axes, repeating after rotating the probe 180 degrees, and determining the algebraic differences for both the A- and B-axes. The standard deviation of this A-axis difference and all the previous such A-axis differences shall not be greater than 0.0002 foot over a 2-foot interval. The standard deviation of this B-axis difference and all such B-axis differences shall not be greater than 0.0006 foot over a 2-foot interval. If no installed inclinometer casing satisfies the specified criteria for verticality and stability, the Design-Builder's instrumentation personnel shall construct a test length of inclinometer casing that satisfies these criteria, and shall use the test length for field calibration.
 3. Prior to their use during the Work of this Contract, seismographs shall be calibrated by the manufacturer, on a shake table. Shake table calibrations shall also be performed at least once a year. A certificate of calibration shall be submitted to the Geotechnical Instrumentation Engineer within 5 work days of performing each calibration.

3.19 DATA COLLECTION

- A. The Design-Builder's independent instrumentation subcontractor and surveyors shall collect data for the Design-Builder's monitoring program, following the guidelines included in the manufacturers' instruction manuals, and as detailed in the reviewed submittal. Data collection shall include both instruments installed by the Design-Builder and existing instruments installed by others.
- B. Immediately after taking a reading, the reading shall be compared with the previous reading of that instrument. When a reading indicates that a threshold or limiting value has been exceeded as specified in Section 3.23, the Design-Builder shall initiate the response action(s) specified therein.
- C. The Design-Builder's Instrumentation subcontractor and surveyors shall meet with the Geotechnical Instrumentation Engineer at least once each week to examine data, resolve any incompatibilities, and to discuss any issues associated with the Design-Builder's monitoring programs.
- D. No instrument will be accepted or paid for until satisfactory formal initial readings are obtained, as specified herein. Formal initial readings shall be agreed upon between the Design-Builder and the Geotechnical Instrumentation Engineer by taking readings and agreeing on their consistency.
- E. Data shall be recorded on field electronic and manual data records, which shall include at least the following:
 - 1. Project name.
 - 2. Contract name and number.
 - 3. Instrument type.
 - 4. Date and time.
 - 5. Observer.
 - 6. Readout unit number.
 - 7. Instrument number.
 - 8. Readings.
 - 9. Remarks.
 - 10. Visual observations.
 - 11. Other casual data including weather, temperature, and construction activities.
- F. Data shall be recorded in U.S. Customary Units, for example feet, inches, pounds.
- G. Instrumentation shall be monitored in accordance with the Monitoring Schedules in Table 1 of this Specification. The Geotechnical Instrumentation Engineer may at any time instruct the Design-Builder to collect data supplementary to the frequencies given in Table 1.
- H. The Design-Builder shall collect data, in addition to the monitoring frequencies given in Table 1, and the supplementary readings directed by the Geotechnical Instrumentation Engineer, to ensure the safety of personnel and the work, at no additional cost to the MBTA. The Design-Builder's Geotechnical Instrumentation Engineer may propose alternative reading frequencies in their instrumentation plan, for approval by the Design-Builder's Lead Geotechnical Engineer.
- I. The Design-Builder shall provide access to the instrumentation and the Data Acquisition systems for the Geotechnical Instrumentation Engineer to observe and complete verification readings.
- J. A formal initial observation well or open standpipe piezometer reading shall consist of the average of three readings with the water level indicator. The indicator shall be removed from the riser pipe between these three readings. Each reading other than the formal initial reading shall be a single reading with the water level indicator. Reading accuracy shall be ± 0.05 foot.

Table 1: Monitoring Schedule of Manual Readings

INSTRUMENT	SCHEDULE
All instruments	(1) Minimum of three readings prior to formal initial reading with additional readings as necessary to verify that changes resulting from the installation process have ceased. (2) Formal initial reading. (3) Weekly until any construction of the associated facility. (4) One reading immediately prior to start of construction of the associated facility. Thereafter, the reading frequency shall follow the schedule given below.
Observation Wells and Piezometers	Daily during dewatering or excavation within 200 feet of observation well location. Weekly after dewatering has stopped or excavation is backfilled, until equilibrium is reached. Thereafter, monthly until the completion of contract.
Deformation Monitoring Points	One daily reading or every five (5) vertical feet of excavation within 200 horizontal feet of the DMP location, or weekly, whichever is more frequent, until excavation has been backfilled or permanently braced by the completed structure. Thereafter, monthly until completion of contract. Readings shall be taken daily if threshold values in section 3.23 are exceeded and until the readings have stabilized to the satisfaction of the Geotechnical Instrumentation Engineer.
Vibrating Wire Strain Gages	Daily from brace installation until brace removal.
Inclinometers/Extensometers	Twice a day or one reading every five (5) vertical feet of excavation within 200 horizontal feet of the inclinometer location, or weekly, whichever is more frequent, until excavation has been backfilled or permanently braced by the completed structure. Thereafter, monthly until completion of contract. Readings shall be taken daily if values in section 3.23 are exceeded and until the readings have stabilized to the satisfaction of the Geotechnical Instrumentation Engineer.
Seismographs	Continuously with a strip chart recording during vibration-producing construction activities within 300 feet of seismograph location.
Utility Monitoring Points	Same Reading Schedule as Deformation Monitoring Points and Borros Points
Convergence Gages	Twice a day during construction activity within 150 ft of the building limits. Weekly when construction is completed. Thereafter, monthly until end of project.
Crack Monitors	Twice a day during construction activity within 150 ft of the building limits. Weekly when construction nearby is completed. Thereafter, monthly until end of project or until the readings have stabilized to the satisfaction of the Geotechnical Instrumentation Engineer.
Tiltmeters	Twice a day when excavating/constructing within 150 ft of the building limits. Weekly when construction nearby is completed. Thereafter, monthly until end of project.

- A. A formal initial vibrating wire piezometer reading shall consist of the average of three readings. Each reading other than the formal initial reading shall be a single reading. Readings shall be corrected for

changes in barometric pressure, as determined in accordance with data provided by the Geotechnical Instrumentation Engineer.

- B. A formal initial set of readings on a deformation monitoring point (DMP) of Borros Point shall consist of the average of two survey measurements of elevation or horizontal offset with two independent set-ups. Each reading other than the formal initial reading shall consist of a single set of survey measurements. All elevation readings shall be referenced to a deep benchmark. Reading accuracy shall be ± 0.01 foot. Reading accuracy for horizontal position shall be ± 0.03 foot.
- C. A formal initial convergence gage reading shall consist of the average of three readings with the gage attached to the anchorage points. The gage shall be removed from the anchorage points between each of these three readings, and shall be un-tensioned and re-tensioned. Each reading other than the formal initial reading shall consist of the average of two readings, with removal and un-tensioning as specified herein. A previous or subsequent convergence gauge reading shall be a single reading. Reading repeatability shall be ± 0.005 inch.
- D. An inclinometer reading is defined as a set of readings at 2 foot intervals throughout the casing, and a second set at 180 degrees to the first set. A formal initial inclinometer reading shall consist of the average of three readings as defined above, involving six complete traverses along the casing. Each reading other than the formal initial reading shall be a single reading. Check-sums (sum of two readings at the same depth but 180 degrees apart) shall be examined in the field. Except where obvious imperfections in the casing have affected the check-sums, the standard deviation of A- and B-axis check-sums over a 2-foot interval shall not exceed 0.0003 foot and 0.0005 foot, respectively.
- E. A formal initial probe extensometer reading shall be selected from three sets of readings with the probe alongside each magnetic settlement target, starting from the bottom upwards, so that the reed switch closes as it enters the bottom of the magnetic field. The probe shall be removed from the access tube between each of these three sets of readings. A formal initial probe extensometer reading shall also consist of two reading of the elevation of the top of the access tube, using surveying methods referenced to a deep benchmark, using two independent set-ups, to an accuracy of ± 0.01 foot. Each reading other than the formal initial reading shall be a single set of readings with the probe, starting from the bottom upwards. Reading accuracy shall be ± 0.01 foot.
- F. A formal initial set of vibrating wire strain gage readings shall consist of three readings of strain and temperature at each of the following four times:
 - 1. Within two days prior to installing the structural member and after no part of it has been exposed to direct sunlight for a minimum period of two hours.
 - 2. Immediately before lifting the structural member for installation in the excavation.
 - 3. With the member in place in the excavation and ready for prestressing.
 - 4. Immediately after prestressing.
- G. Each reading other than the formal initial reading shall consist of a single reading of strain and temperature. Such readings shall be taken after no part of the structural member has been exposed to direct sunlight for a minimum period of two hours, to minimize extraneous effects caused by non-uniform temperature.
- H. Formal initial background seismograph readings shall be taken prior to the beginning of blasting, pile-driving or other vibration-producing construction activity. Initial readings shall consist of a minimum of 7 days of continuous monitoring of peak particle velocities, which shall be printed to a strip chart. During this period, particle velocities shall be read with a minimum sensitivity of 0.002 inch/second.

- I. Prior to the beginning of blasting, pile-driving or other vibration-producing construction activity, determine peak particle velocity and corresponding frequencies produced by single hammer blows or blasts or other vibration-producing activities to establish the maximum energy which can be used without surpassing acceptable vibration levels in nearby structures.
- J. A formal initial crack monitor reading shall consist of the average of three readings. Each reading other than the formal initial reading shall be a single reading. Reading accuracy shall be ± 0.02 inch.
- K. Tiltmeter readings shall be made by connecting the portable readout unit to the terminal unit, and reading the measurements. A formal initial tiltmeter reading shall consist of the average of three readings of tilt.

3.20 DATA REDUCTION, PROCESSING, PLOTTING AND REPORTING

- A. The Design-Builder shall provide data to the Geotechnical Instrumentation Engineer from the Design-Builder's Monitoring Program in accordance with the following schedule:
 - 1. All manual data, in the form of daily electronic data reports, except survey data, shall be provided no later than 16:00 on the day following the day on which the data are collected.
 - 2. Survey data shall be provided no later than 24 hours after the time specified in item 1 above.
 - 3. The Design-Builder's Geotechnical Instrumentation Engineer shall provide an electronic data summary reports and summary plots within one week of collecting data, for data that the Geotechnical Instrumentation Engineer anticipates are affected by construction activities.
- B. The Design-Builder's Geotechnical Instrumentation Engineer and surveyors shall reduce, process, plot and report data for the Design-Builder's monitoring program, following the guidelines included in the manufacturers' instruction manuals, as detailed in the reviewed submittal, and in the reviewed format. All data shall be submitted to the Design-Builder's Lead Geotechnical Engineer in accordance with Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements".
- C. Raw, reduced and plotted data resulting from the Design-Builder's monitoring program shall be submitted to the Design-Builder's Lead Geotechnical Engineer in accordance with submittal, and in the reviewed format. All data shall be submitted to the Design-Builder's Lead Geotechnical Engineer in accordance with Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements".
- D. When data resulting from the Design-Builder's or Geotechnical Instrumentation Engineer's monitoring program indicate that threshold or limiting values have been exceeded as provided in the Design-Builder's Instrumentation Plan, the Design-Builder shall notify the MBTA and initiate the response action(s) provided in the Instrumentation Plan.
- E. The Design-Builder shall submit, to the Geotechnical Instrumentation Engineer, descriptions of the work performed according to the following schedule: daily during active tunneling operations otherwise, weekly. Descriptions of work performed are to include:
 - 1. A description of groundwater control and temporary pressure relief operations, including pump locations, times and duration of operations, and estimated quantity of flow from dewatering operations as well as metered quantities of flow from each well.

2. A summary of support system and other relevant construction activities, including location, time and narrative indicating any excavation or construction activities, amount of soil excavated per unit excavated depth, underpinning progress, piles installation and obstructions removal, slurry wall installation, pile driving, installation and prestressing of support elements.
 3. A summary of excavation or filling activities, including location plan and description of where excavation has occurred with plots of the elevation of the bottom of the excavation or top of the fill vs. station together with plots of the previous three reports.
 4. A description of any construction activities other than excavation support system, excavation, and filling, including any surcharge caused by temporary construction loads.
 5. A report of any unusual events that may have affected the instrumentation readings, including any remedial or precautionary measures that were implemented in response to geotechnical instrumentation or other data during the period covered by the report. The report is to include when, where, and why the measures were implemented. The report is to include a description of any future remedial or precautionary measures that are planned in response to existing geotechnical instrumentation.
- F. Each week the Design-Builder shall also submit to the Geotechnical Instrumentation Engineer a cross section, at each inclinometer/probe extensometer location, using a vertical scale of 1 inch = 20 feet, showing the key construction activities and other events that could influence changes in the data.
- G. If the Geotechnical Instrumentation Engineer determines that data resulting from the monitoring program indicate that a threshold or limiting value has been exceeded as provided in the Design-Builder's Instrumentation Plan, the Design-Builder and MBTA shall be notified immediately.
- H. Readings shall be taken daily by the Design-Builder if values threshold or limiting values are exceeded and until the readings have stabilized to the satisfaction of the MBTA.
- I. All plots shall conform to the following guidelines:
1. Choose scales so that observations fill the space available, but do not use exaggerated scales that would magnify minor changes to make them appear alarmingly large.
 2. Plots shall be slightly darker than the underlying grid so that when copied both are visible but the plots stand out. Data points shall be visible.
 3. Plot elevations and depths on the vertical axis.
 4. Plots shall be self-explanatory. Show project name, contract name and number, the type of instrument, the scale and units of measurement, and the time of measurement. Use U.S. Customary Units, for example feet, inches, pounds.
 5. Sketches shall be provided to show the locations of the instruments relative to the construction activity and the geology.
 6. For each instrument, maintain consistency of scales so that plots can be compared.
 7. On plots of data versus time, show key construction activities and other events that could influence changes in the data. These key construction and other events shall include weather, elevation of the bottom of the excavation or top of the fill at the same station as the instrument,

tunnel excavation support system construction, groundwater control and temporary pressure relief operations with pump locations and estimated quantities of flow, and surcharge caused by temporary construction loads. On plots of data versus time, Threshold Values shall also be shown.

8. Use symbols to distinguish between different instruments or different times.
9. All plots shall show the full name of the person responsible for their preparation.
- J. Plots of observation well data shall show groundwater table elevation versus time.
- K. Plots of vibrating wire piezometer data shall show piezometric elevation versus time. Vibrating wire piezometer data shall be corrected for changes in barometric pressure, and referenced to the barometric pressure at the time of the initial reading. A plot of barometric pressure shall be included on the same axes.
- L. Plots of deformation monitoring point and Borros point data shall show absolute vertical or horizontal deformation versus time.
- M. Plots of convergence gage and crack monitor data shall show change with respect to the initial reading, versus time.
- N. Plots of inclinometer data shall be "cumulative change" data, showing absolute horizontal deformation versus depth. Multiple plots shall be on the same sheet to provide a time history, each labeled with the date. When requested by the MBTA, additional plots shall be prepared to show horizontal shear deformation across a given depth interval versus time.
- O. Plots of probe extensometer data shall show "cumulative change" data, showing absolute vertical deformation versus depth, and also absolute vertical deformation versus time. The lower datum ring magnet shall be used as a datum for determination of vertical deformation. Each plot shall be on an 8-½ inch x 11-inch sheet.
- P. Plots of vibrating wire strain gage data shall show axial load, bending moment, and maximum stress at each cross section (composite of data from four gages at the cross section), versus time, and shall show location of the maximum stress. Plots of strain gage data shall also show temperature versus time.
- Q. The Design-Builder's Geotechnical Instrumentation Engineer shall provide the MBTA with the results of daily vibration monitoring, one work day after the readings are taken. Upon completion of the construction operations for those locations requiring vibration monitoring, the daily submittals shall be synthesized into a final report prepared by the Design-Builder's Geotechnical Instrumentation Engineer. Each report shall include the time-histories of all seismograph readings.
- R. Plots of tiltmeter data shall show change with respect to initial reading degree of tilt versus time.

3.21 DAMAGE TO INSTRUMENTATION

- A. The Design-Builder shall protect all instruments and appurtenant fixtures, leads, connections, and other components of instrumentation systems from damage due to construction operations, weather, traffic, and vandalism.

If an instrument is damaged, including an existing instrument installed by others, the Design-Builder's instrumentation personnel shall repair or replace the damaged instrument at no additional cost to the MBTA. The MBTA will be the sole judge of whether repair or replacement is required. The MBTA may impose a work stoppage in the vicinity of the damaged instrument until it is again operational, at no additional cost to the MBTA.

3.22 DISCLOSURE OF DATA

- A. The Design-Builder shall not disclose any instrumentation data to third parties and shall not publish data without prior acceptance and written consent of the MBTA.

The Design-Builder transmits the instrumentation data collected by the Design-Builder to the MBTA. Any data relevant to the MBTA that is collected by the Design-Builder shall be transmitted to the MBTA by the MBTA within 24 hours of receiving the data from the Design-Builder.

3.23 INTERPRETATION OF DATA AND RESPONSE VALUES

- A. The Design-Builder shall make its own interpretations of the data resulting from the monitoring programs. The Design-Builder shall develop Threshold and Limiting Values for the geotechnical instruments based on their specific use and provide the values and basis of the values in the Instrumentation Plan.
- B. If the Threshold Value is reached the Design-Builder shall:
1. Immediately notify the MBTA.
 2. Meet with the MBTA to discuss response action(s).
 3. Provide the MBTA with an up-to-date report within 24 hours of obtaining a reading indicating that the Threshold Value has been reached. The report shall include raw, reduced and plotted data for all instruments for which the Threshold Value has been reached, as well as on any other instruments requested by the MBTA. The report shall contain the same information as specified for the weekly submittal. The Design-Builder shall subsequently provide a daily report as specified in this sub-article, until all instrument readings fall below the specified.
- C. Upon notification by the Design-Builder, the MBTA will notify the Building Owner if a threshold value relevant to the building or structures is reached and will report to those parties the results of the meeting with the Design-Builder to discuss implementation of a response action.
- D. If the Threshold Value is reached, the Design-Builder may also be required to initiate one or more of the following response actions, as directed by the MBTA.
1. Increase instrument monitoring frequencies.
 2. Install and monitor additional instruments.
 3. Modify construction procedures.
 4. Implement the reviewed plan of action, in the event the Threshold Value is reached, so that the Limiting Value is not exceeded.

- E. The Design-Builder shall take all necessary steps so that the Limiting Value is not exceeded. Design-Builder may be directed to suspend activities in the affected area with the exception of those actions necessary to avoid exceeding the Limiting Value.
- F. If the Limiting Value is reached, the Design-Builder shall:
 - 1. Immediately notify the MBTA.
 - 2. Meet with the MBTA to discuss response action(s).
 - 3. Implement the reviewed plan of action, in the event the Limiting Value is reached.
- G. Upon notification by the Design-Builder, the MBTA will notify the Building Owner if a limiting value relevant to the building or MBTA structures is reached and will report to those parties the results of the meeting with the Design-Builder to discuss implementation of a response action.
- H. The MBTA will also interpret data resulting from both the Design-Builder's and MBTA's monitoring programs, and make interpretations available to the Design-Builder as soon as practicable. This does not relieve the Design-Builder from the requirement to make its own interpretation, notify the MBTA, and take steps to protect persons and property. The Design-Builder shall not wait for or rely on receipt of the MBTA's interpretation to identify when threshold or limiting values have been exceeded, or to begin preparations for response actions.
- I. The MBTA is not responsible for guaranteeing the safety of the work based on data from the Design-Builder's monitoring program.

3.24 DISPOSITION OF INSTRUMENTS

- 1. Remove salvageable instruments only when directed by the MBTA.
- 2. All portable readout units, used for both the Design-Builder's and MBTA's monitoring programs, except for seismographs, shall become the property of the MBTA.
- 3. All salvaged instruments shall become the property of the MBTA.
- 4. Boreholes for the instruments shall be grouted as directed by the MBTA.
- 5. All surfaces affected by installation of instruments shall be restored to their original condition prior to completion of the Work. This shall include instruments installed both by the Design-Builder as well as instruments installed by others and monitored by the Design-Builder.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02052

MAINTENANCE OF TRAFFIC THROUGH WORK AREAS

GENERAL

1.1 DESCRIPTION OF WORK

A. All practices and traffic control devices shall conform to the relevant provisions of Section 850 of the Massachusetts Department of Transportation (hereinafter called State) Standard Specifications for Highways & Bridges (latest edition) and the Manual on Uniform Traffic Control Devices (MUTCD), including latest amendments and addenda.

B. Work Included: The work under this section includes the following items:

Furnishing all Engineering, materials, labor, and equipment required for traffic management and maintenance on the municipal roadways within the limits of construction under this contract.

Furnish adequate notice to police and fire departments, public transportation authorities, and school departments/districts of the proposed traffic maintenance plan including, but not limited to, detours, lane closures, and alternate routes.

Furnish, erect and maintain traffic control devices, as required by the traffic maintenance Approved Plan. The Design-Builder shall provide traffic control devices including lights, markings, barricades, warning signs, and all other safety precautions necessary to protect streets, sidewalks, access to adjoining property, and the traveling public within the area of the construction. Reference is made to traffic management Approved Plan drawings for guidelines for typical traffic control devices and their placements. These do not necessarily include all possible warning devices, control devices, or police details which may be required by the project.

Remove, replace, and/or reposition all traffic control devices, as necessary.

C. Related Work:

Section 01570 – VOLUME 2 TECHNICAL PROVISIONS EXHIBIT 2I “ADDITIONAL PROJECT REQUIREMENTS”

Section 02296 - TRAFFIC DECKING

Section 02298 - TEMPORARY PEDESTRIAN FACILITIES

1.2 JOB CONDITIONS

A. The Design-Builder shall notify the MBTA, state, local, and/or jurisdictional agencies well in advance of commencing construction. The Design-Builder shall arrange all detours, partial road closures, and alternate traffic patterns. The Design-Builder shall inform emergency departments on the daily status of project roadways.

B. The Design-Builder shall arrange for the services of uniformed police officers, as required to protect and facilitate the flow of vehicular and pedestrian traffic through the construction work zone.

C. During winter months, the Design-Builder shall be responsible for snow removal and prevention of icing conditions within active construction work zones, and shall assist local or state agencies in clearing roads used as detour routes to facilitate uninterrupted movement of traffic.

1.3 SUBMITTALS

- A. Submit copies of the Traffic Management Plan and a list of certified flaggers to the MBTA prior to start of site preparation work.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All devices required under this Section shall meet the quality standards set forth in the Quality Standards of Work Zone Traffic Control Devices compiled by the American Traffic Safety Services Association (ATSSA). Any devices that, in the judgment of the MBTA, are unsatisfactory in appearance, and/or performance shall be removed and immediately replaced by acceptable devices. The work to be done under these items shall conform to the relevant provisions of Section 850 of the State Standard Specifications and the following:

2.2 ROADWAY FLAGGER

- A. The Design-Builder shall provide the number of flaggers required in either the appropriate Traffic Control Plan (TCP) template (see MassDOT's website at (<http://www.massdot.state.ma.us/>) or that the MBTA deems necessary for the direction and control of traffic within the site. A flagger shall be used as directed by the MBTA in accordance with 701CMR 7.00, this section, and the TCP. Any flagger determined by the MBTA to be ineffective in controlling traffic may be removed at the discretion of the MBTA. If a flagger is directed to be removed, the Design-Builder shall immediately comply with the directive from the MBTA and shall suspend operations as necessary until a qualified replacement can be provided. Such a suspension of operations shall not be considered as a basis for a claim or an extension of time. Flaggers used during the performance of the Work shall be at least eighteen (18) years of age.
- B. Flaggers used during the performance of the Work shall possess a current certificate of satisfactory completion from a Department-approved flagger training program within the previous two (2) years. Prior to the start of work, the Design-Builder shall provide to the MBTA a written list of certified flaggers to be used, including the most recent date of certification or re-certification for each person listed. All flaggers shall carry their approved flagging training program certification card with them while performing flagging duties. Flagger certifications shall remain valid for the duration of the project or the flagger shall be removed from the project.
- C. Flaggers used during the performance of the Work shall have completed a First Aid training course according to the standards and guidelines of the American Heart Association or the American Red Cross. Flaggers shall carry their First Aid certification cards with them while performing flagging duties.
- D. Each flagger shall be equipped with the following high visibility clothing, signaling, and safety devices:

1. A white protective hard hat with a minimum level of reflectivity per the requirements of ANSI, Type I, Class E&G;
2. A clean, unfaded, untoned lime/yellow reflective safety vest and safety pants meeting the requirements of ANSI 107 Class 3 with the words "Traffic Control" on the front and rear panels in minimum two (2) inch (50 millimeter) high letters;
3. A twenty-four (24) inch "STOP / SLOW" traffic paddle conforming to the requirements of Part 6E.03 of the Manual on Uniform Traffic Control Devices (MUTCD), a weighted, reflectorized red flag, flagger station advance warning signage, and two-way radios capable of providing clear communication within the work zone between flaggers, the Design-Builder, and the MBTA. The traffic paddle shall be mounted on a pole of sufficient length to be seven (7) feet above the ground as measured from the bottom of the paddle.
4. A working flashlight with a minimum of 15,000 candlepower and a six (6) inch red attachable wand, a whistle with an attached lanyard, and a First Aid kit that complies with the requirements of ANSI Z308.1.
5. An industrial/safety type portable air horn that complies with the requirements of the U.S. Coast Guard.

2.3 SAFETY CONTROLS AND SIGNING FOR CONSTRUCTION OPERATIONS

- A. All signs and safety controls including but not limited to signs, cones, drums, barricades, pavement markings, lighting, and attenuators shall conform to the relevant provisions of the 2009 Manual on Uniform Traffic Control Devices and the MassDOT Standard Specifications, all as amended.
- B. All signs, barricades, and drums shall have reflective sheeting, in accordance with Subsection M9.30.0 of Division III, Materials of the State Standard Specifications.
- C. The Design-Builder shall use sandbags or provide other suitable means to weigh down Portable Breakaway Barricades Type III, to minimize the disturbance of barricades by vandals.
- D. Warning and directional signs used on the project shall be furnished, erected, and maintained throughout the construction period by the Design-Builder.
- E. Traffic control devices not conforming in type, composition, and size to the standards specified herein shall not be used under this contract.
- F. All erected signs not consistent with the use of the roadway shall be removed or covered each day by the Design-Builder.

2.4 TEMPORARY CONCRETE BARRIER

- A. Temporary Concrete Barriers shall conform to Section 629 of the State Standard Specifications for Highways and Bridges.
- B. The Design-Builder shall furnish, set up, move, maintain, and remove Temporary Concrete Barriers, when positive traffic barriers are needed for traffic control and safety in construction zones.
- C. Each run or bay of Temporary Concrete Barrier units shall be installed and fastened together to form a continuous chain, in accordance with the requirements of the state or local agencies having jurisdiction.

2.5 PORTABLE BREAKAWAY BARRICADE TYPE III

- A. Portable Breakaway Barricades, Type III shall be a 4-foot unit and conform to the latest edition of the State Construction Standards and any additional requirements of this specification.
- B. Reflectorized sheeting shall conform to Subsection M9.30.0. of Division III, Materials of the State Standard Specifications. Alternating 6 inch wide stripes shall be orange and white and shall slope downward at 45 degrees toward the end by which traffic is to pass. Pipe shall be Polyvinyl Chloride (PVC) pressure rated SDR 26 conforming to ASTM D2241. Fittings may be PVC conforming to ASTM D2665 or Acrylonitrile Butadiene Styrene (ABS) conforming to ASTM D2661 Drainage Waste and Vent.
- C. The Design-Builder shall furnish, set up, move, maintain (in good and serviceable condition), and remove Portable Breakaway Barricades Type III, as required by the performance of this work or as may be required by jurisdictional authorities, at no additional cost to the MBTA.

2.6 PORTABLE BARRIER FENCE

- A. Construction of Portable Barrier Fences shall be as shown on the plans. The Design-Builder shall include the necessary signs, reflectors, and all incidental equipment in order to provide the portable barrier fence, complete in place.

2.7 REFLECTORIZED DRUMS WITH OR WITHOUT WARNING LIGHTS

- A. Reflectorized drums shall conform to Subsection M9.30.0 of Division III, Materials of the State Standard Specification and shall be placed as shown on the construction drawings and as directed by the MBTA. Other drum-type products providing equivalent target value and stability, and accepted by the State, may be used.
- B. Drums shall be used in the protection of driveways, utility structures, and pedestrian control and safety throughout the construction period.
- C. Warning lights shall conform to the MUTCD Subsection 6F-83 for Type A or Type C. Drums shall be maintained in a satisfactory manner including the removal of dirt or road film that may cause a reduction in reflective efficiency. Type A, Low Intensity Flashing Warning Lights, mounted on drums, shall be used to continually warn drivers that they are approaching or proceeding in a hazardous area. Type C, Steady-Burn Lights, placed in a series on drums, shall be used to delineate the proper vehicle path through construction areas (which require changing patterns of traffic movement).
- D. The Design-Builder shall furnish, set up, move, maintain (in good and serviceable condition), and remove reflectorized drums with or without warning lights as required by the performance of his work or as directed by jurisdictional authorities, at no additional cost to the MBTA.

2.8 SPECIAL LIGHTING UNITS-FLASHING ARROW BOARDS AND PORTABLE CHANGEABLE MESSAGE SIGNS

- A. Flashing Arrow Board shall be as specified in Subsection 850.45 of the State Standard Specifications as amended.

- B. Flashing Arrow Board shall consist of a black background panel meeting the requirements of the MUTCD Subsection 6F-81, Table VI-3 for Type C and shall contain at least 15 No. 4412A (or equal) amber lights with approximately 8000 initial maximum candlepower each. Each Special Lighting Unit shall automatically provide for a minimum of 50% dimming from their rated lamp voltage at night. The flashing rate of the lamps shall not be less than 25 not more than 40 flashes per minute. The arrow panels shall have the capability of the following mode selection: (1) left or right flashing or sequential arrows; (2) left or right sequential chevrons; (3) double flashing arrows; (4) flashing caution and (5) alternating diamond caution.
- C. Minimum mounting height of Flashing Arrow Board shall be seven feet above the roadway to the bottom of the panel, except on vehicle-mounted panels.
- D. Portable Changeable Message Sign shall be as specified in Subsection 850.33 of the State Standard Specifications as amended. It shall consist of furnishing, positioning, repositioning, operating, maintaining, and removing a portable message sign as shown on the drawings and/or directed by the MBTA. All messages displayed shall be approved by the MBTA prior to being displayed.

2.9 TEMPORARY PAVEMENT MARKINGS

- A. Paints, tapes, and glass beads used for temporary pavement markings shall conform to Subsections M7.01.07, M7.01.10, M7.01.11, M7.01.14, M7.01.15 and M7.01.16 of Division III, Materials of the State Standard Specifications. Other material, which will provide satisfactory durability and reflectivity, and are accepted by the MassDOT, maybe used. The reflectivity of temporary pavement markings shall be equal to or better than the MassDOT minimum requirements for a period of 90 days. The colors of the marking materials shall be white, yellow, or black.

2.10 TEMPORARY IMPACT ATTENUATOR

- A. The attenuator shall be designed to safely accommodate a design speed of 40 miles per hour or other such greater additional speed as the manufacturer recommends.
- B. Before installation, the Design-Builder shall provide the MBTA with copies of the Manufacturers documents indicating satisfactory testing in accordance with NCHRP 350 and its subsequent revisions, and of the approval by the FHWA for the use and location of the attenuator as intended.

A. The attenuators shall be capable of redirecting an impacting vehicle. Anchoring of the units to the roadway shall be recommended by the manufacturer for the specific field conditions encountered. The Design-Builder is fully responsible for the design of the attenuator anchoring system.

2.11 TEMPORARY ILLUMINATION

- A. Temporary Illumination shall be as specified in Subsection 850.35 of the State Standard Specifications as amended. The work shall consist of illumination of the work areas and lane drops on a temporary basis as directed by the MBTA.

PART 3 - EXECUTION

3.1 PERFORMANCE

- A. The Design-Builder shall furnish, erect, and maintain suitable barriers, barricades, signs, markings, drums, and all other traffic control devices necessary to protect all roadways, which are partially obstructed or closed to vehicular or pedestrian traffic, as a result of this project.
- B. The MBTA reserves the right to suspend work, if the Design-Builder fails to provide such adequate traffic control devices to control and protect both vehicular and pedestrian traffic.
- C. The Design-Builder shall completely backfill all trenches at the end of each work day and/or when work is suspended for indefinite periods.
- D. The Design-Builder shall be responsible, at his own expense, for all damage to the work, pedestrians or public/private property due to his failure to place or maintain adequate warning or directional signs or other traffic control devices.
- E. The Design-Builder shall furnish, supply, maintain and remove temporary white and/or yellow reflectorized and/or black non-reflectorized pavement markings, as required by the performance of his work or as directed by jurisdictional authorities, at no additional cost to the MBTA. For the purpose of this specification, temporary markings shall mean an effective marking for a 90-day period.
- F. The Design-Builder shall remove existing pavement markings as required by the performance of his work or as directed by jurisdictional authorities, at no additional cost to the MBTA. Pavement marking removal methods used by the Design-Builder shall not cause damage to the pavement or cause significant change in its texture. Any damage to the pavement or surfacing caused by pavement marking removal shall be satisfactorily repaired by the Design-Builder, at no additional cost to the MBTA.
- G. Where required by the project, the Design-Builder shall provide all necessary temporary pavement markings, and/or temporary raised pavement markers following the completion of each day's operation or prior to opening the roadway to traffic. The Design-Builder will be responsible for making all necessary arrangements for this work, as required by the performance of his work.
- H. The Design-Builder shall be responsible for transporting and relocating any or all signs, barriers, barricades, or other safety devices as specified herein, as required or directed during the project.
- I. If the impact attenuators are moved on a daily basis to allow access to the work area, such daily moving shall be considered incidental to the work and for the Design-Builder's convenience.
- J. Upon project completion, the attenuator will become the property of the Design-Builder and will be removed from the project area.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02060

EROSION AND SEDIMENTATION CONTROL

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies (1) furnishing and applying water and calcium chloride for dust control, (2) furnishing, maintaining, and eventually removing erosion control barriers for the control of erosion and sedimentation on the site and adjacent to the site, (3) the installation, maintenance, and eventual removal of the catch basin protection (filter media skirt with knit polyesyster mesh), and (4) other incidental work related to erosion and sedimentation control.

The Design-Builder shall design, layout and install all erosion and sediment controls and provide dust control at all work sites. All work shall be in accordance with MassDOT Standard Specifications, Construction Standard Details and the Project Development and Design Guide. The work must also be in accordance with MADEP Stormwater Management Standards, Erosion and Sediment Control Guidelines and the Conditions of all permits.

The Design-Builder may elect to substitute different materials or methods other than those specified herein. In that instance, it shall be the Design-Builder's responsibility to demonstrate to the MBTA that the proposed design is equal to or greater than these specifications and will comply with all permit and regulatory requirements.

- B. Dust control operations shall meet the requirements of the Commonwealth of Massachusetts Department of Environmental Protection "310 CMR 7.09: Air Pollution Control Regulations."
- C. Erosion control barrier shall consist of staked straw bales and silt fence. Straw bale barriers and filter fabric silt sacks shall be as detailed on the Approved Drawings.
- D. Related work:
1. Volume 2 Technical Provisions Exhibit 21 "Additional Project Requirements".
 2. Section 02100 SITE PREPARATION
 3. Section 02196 GEOTEXTILE MATERIALS
 4. Section 02250 STORMWATER POLLUTION PREVENTION
 5. Section 02270 SLOPE PROTECTION
 6. Section 02282 HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 7. Section 02300 EARTHWORK
 8. Section 02369 DRILLED MINI-PILES
 9. Section 02400 DRAINAGE AND SEWER SYSTEMS
 10. Section 02632 STORMWATER BYPASS PUMPING SYSTEMS

1.2 SUBMITTALS

- A. Submit product information for calcium chloride, silt fence fabric, filter fabric silt socks, and straw bales.

1.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

- A. The silt fence fabric shall be furnished with suitable wrapping for protection against moisture and extended ultraviolet exposure prior to placement.
- B. Each roll of fabric shall be labeled or tagged to provide product identification sufficient for field identification, as well as inventory and quality control purposes.
- C. Each roll of fabric shall be stored in a manner that will protect them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover.
- D. Straw bales shall be stored in a manner that will protect them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover.

1.4 JOB CONDITIONS

- A. Confine construction operations to the limits of work indicated on the Approved Drawings. The Design-Builder shall be responsible for protection of slopes at 2:1 or shallower during the construction period and also during any extended maintenance period. For slopes greater than 2:1, erosion control mats as specified in Section 02270 Slope Protection are required. Where clearing and grubbing, and regrading of such existing slopes is required, provide suitable means for erosion control. Re-grade slopes as necessary.

1.5 QUALITY CONTROL

- A. Erosion control mats shall be installed in accordance with the manufacturer's recommendations. Where manufacturer's recommendations conflict with details shown on the Drawings, the more stringent, in the opinion of the MBTA, shall apply.

PART 2 - PRODUCTS

2.1 MATERIALS AND EQUIPMENT

- A. Calcium Chloride shall conform to the requirements of AASHTO-M144, Type I or Type II. Use mechanical spreader or other approved equipment.
- B. Straw bales shall be individually banded and staked into the ground:
 - 1. Straw bales shall consist of straw for outdoor use be banded with string or nylon cord (minimum two bands per bale) and shall be staked into the ground.
 - 2. Stakes for straw bales shall be standard 2 inch by 2 inch wood stakes or approved equal.
- C. Single compost filter tube tamped in place to ensure good contact with soil. It is not necessary to trench the tubes into the existing grade.
 - 1. The tubes for the compost filters shall be jute mesh or approved biodegradable material.
 - 2. Filter tubes should be 12-inches (minimum) in diameter with an effective height of 9.5 inches.

- D. Silt fence shall consist of a self-supported or wire supported geotextile silt fence with support posts:
1. Fibers used in the manufacture of geotextiles, and the threads used in joining geotextiles by sewing, shall consist of long chain synthetic polymers composed of at least 85% by weight polyolefins or polyesters.
 2. Both the geotextile and threads shall be resistant to chemical attack, mildew, and rot.
 3. Geotextiles for silt fences shall conform to the following physical requirements in accordance with the acceptance criteria required by ASTM D4759. Values shown are minimum average roll values. Strength values are in the weaker principal direction.
 - a. Tensile Grab Strength: ASTM D4632; 90 pounds minimum.
 - b. Elongation at 50% Minimum Tensile Strength: ASTM D4632; 50% maximum for self-supported fences.
 - c. Permittivity: ASTM D4491; 0.010 per second minimum.
 - d. Apparent Opening Size (AOS): ASTM D4751; 0.84 millimeters maximum.
 - e. Ultraviolet Degradation: ASTM D4759; at 500 hours exposure, 70% strength retained for all cases.
 4. Posts for Silt Fence: Either wood, or synthetic posts may be used. Posts shall have a minimum length of 30" plus burial depth and be of sufficient strength to resist damage during installation and to support applied loads.
 5. Wire Support: 12-gauge wire supports at 6-inch maximum spacing each way shall be used when geotextile fabric is not strong enough to support applied loads. Provide hog supports.
 6. Prefabricated fence systems may be used provided they meet all of the above material requirements.

PART 3 - EXECUTION

3.1 DUST CONTROL

- A. Leave existing pavement and/or ground covering in place until the last possible moment prior to final earth excavation for purposes of dust control.
- B. Calcium chloride and water shall be properly applied as required and/or where directed by the MBTA and distributed uniformly at the rate required or ordered. Method and equipment used to distribute the material shall be satisfactory to the MBTA.
- C. The Design-Builder is responsible for keeping dust down at all times, including non-working hours, weekends, and holidays. Sprinkle or treat, with dust suppressors, the soil at the site, and other areas disturbed by construction operations. No dry power brooming is permitted. Instead use vacuuming, wet mopping, wet sweeping, or wet power brooming. Air blowing is permitted only for cleaning nonparticulate debris, such as steel reinforcing bars. No sandblasting is permitted unless dust therefrom is confined. Only wet cutting of concrete blocks, concrete, and asphalt is permitted.

- D. Stop all earthwork when, as determined by the MBTA, dust control procedures have not proved effective in controlling dust. Resumption of work may only begin when site conditions have improved or constructions procedures are modified to the satisfaction of the MBTA.

3.2 TEMPORARY EROSION CONTROL

- A. Method of stripping vegetation shall be such as to minimize erosion. Fills shall be placed and compacted in such a manner that soil sliding and erosion is minimized. Grading shall be done in such a manner as not to divert water onto the property adjoining the MBTA's right-of-way or construction site without expressed written permission of the land owner and the local Conservation Commission. If the Design-Builder fails to employ adequate and acceptable erosion control techniques during construction, the MBTA may order a suspension of the work until implementation of satisfactory techniques are agreed upon and demonstrated, and the Design-Builder shall have no claim for damages or time extension resulting from such delays.
- B. Staked straw bale siltation barriers shall be installed at the following locations:
 - 1. Toe of embankment construction.
 - 2. Toe of abutments/retaining walls and temporary earthwork stockpiles.
 - 3. Across construction ditches prior to entry into any drainage system or waterway.
 - 4. Other locations shown on the Approved Drawings, as dictated by the Order of Conditions or as designated by the MBTA.
 - 5. Toes of temporary earthwork stockpile.
- C. Abut straw bales to form a continuous barrier. Straw bales shall be entrenched 4". Secure bales in place with two stakes per bale.
- D. Silt fence construction shall be adequate to handle the stress from sediment loading. Geotextile fabric at the bottom of the fence shall be buried a minimum of 6 inches in a trench so that no flow can pass under the barrier. Trench shall be backfilled and the soil compacted over the geotextile fabric. Fence height shall be as shown on the Approved Drawings, but in no case shall exceed 30 inches above ground surface. Geotextile fabric shall be spliced together only at a support post with a minimum 6-inch overlap. Posts shall be installed no more than six feet on center and angled slightly toward the embankment or anticipated source of runoff. Where an 18 inch depth is not possible, the post shall be adequately secured to prevent overturning of the fence due to sediment or wind loading.
- E. Sediment controls shall be in place prior to any soil disturbing activities including, but not limited to earthwork, clearing and grubbing, dewatering and excavation.
- F. Any disturbed soils shall be stabilized, either permanently or temporarily, within 2 weeks of disturbance or when directed by the MBTA.

3.3 MAINTENANCE AND CLEANUP

- A. Maintain the integrity of erosion control barriers as long as they are necessary to contain sediment runoff. Promptly repair or replace ineffective barriers.
- B. Inspect all barriers immediately after each rainfall and at least daily during prolonged rainfall. Any deficiencies shall be immediately corrected. Make a daily review of the location of barriers in areas where

construction activities have changed the natural contour and drainage runoff to ensure that the barriers are properly located for effectiveness. Where deficiencies exist, additional barriers shall be installed as directed by the MBTA.

- C. Sediment deposits behind or in the vicinity of erosion control barriers shall either be removed when the deposit reaches approximately one-half of the height of the barrier or a second barrier shall be installed as directed by the MBTA. Sediment shall be removed and disposed of periodically from behind the straw bales and within the silt sacks. Disposal shall be offsite and in accordance with all applicable regulations. In no case shall the accumulated sediment be allowed to rise above the mid height of the bale. All remaining sediment shall be disposed of in an approved manner at the completion of the work.
- D. Erosion control barriers shall remain in place until the MBTA directs that they be removed. Upon removal, remove and dispose of any excess silt accumulations, dress the area to blend in with the existing lines and grades, and vegetate all bare areas in accordance with MBTA Standards.
- E. Erosion control barriers will remain the property of the Design-Builder, may be re-used at other locations provided the materials meet these specifications requirements, and shall be removed and disposed of at the completion of the Project unless directed otherwise by the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02080

ASBESTOS REMOVAL

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies all labor, materials, equipment, services, employee training and testing, permits, waste transportation and disposal (at an approved landfill) required for the removal of all asbestos-containing materials (ACMs) at the MBTA Green Line Extension project. All work shall be performed in accordance with these Specifications; USEPA, OSHA, and Commonwealth of Massachusetts Department of Environmental Protection (MassDEP) and the Massachusetts Division of Labor Standards (DLS) regulations; and all other applicable federal, state and local regulations. Whenever there is a conflict or overlap of the above references, the most stringent provisions are applicable. See Paragraph 1.17 of this Section for Special Considerations.
- B. The DESIGN-BUILDER shall provide all labor, materials and services to perform all the work specified in this Section, including but not limited to the following:
1. Install a temporary power distribution and lighting network. The DESIGN-BUILDER shall provide connection from the local power utility lines and provide an auxiliary generator where needed. The DESIGN-BUILDER shall provide ground-fault interrupt panel boards and installations where needed.
 2. Provide water or make arrangements to use existing water utilities.
 3. Isolate each work area with air-tight barriers, erect temporary staging, containment barriers, Decontamination Facilities (DFs) and waste transfer chambers as required to perform the Work.
 4. Install HEPA-filtered negative air units to exhaust the work area. The DESIGN-BUILDER shall arrange for HEPA units to exhaust directly outside the containment area.
 5. Remove all ACMs indicated in the Project documents, Specifications or on the drawings, and other ACMs as otherwise found at the site during the project.
 6. Perform all other selective demolition as required herein or as is otherwise needed to locate, identify and remove hidden or inaccessible suspect ACM at the Site.
 7. Package and label all asbestos waste for disposal and transport waste to an EPA-approved landfill in accordance with all applicable federal, state and local regulations.
 8. Thoroughly clean each work area and obtain final visual inspection and approval from the CONSULTANT.
 9. Perform all other work noted in the Specifications, directed by CONSULTANT, or as otherwise necessary to remove all dust, debris, ACM, suspect ACMs including potential suspect ACMs that may also include buried debris that is uncovered during the course of the work.
- C. It is the intent of this Specification that the DESIGN-BUILDER remove all ACMs from the entire MBTA Green Line Extension project wherever and in whatever form it exists. All means and methods intended by the DESIGN-BUILDER to accomplish the work are subject to the review and acceptance of the CONSULTANT. The DESIGN-BUILDER shall prepare and submit a detailed work plan for the mobilization of qualified personnel and equipment in the event that ACMs are suspected or encountered.

The work plan shall be acceptable to the AUTHORITY and the CONSULTANT. No additional compensation will be made if the conditions found vary from that indicated in the Specifications, except where provided for in this Section.

- D. The following is a summary of the work items to be performed under the Contract: The Asbestos Abatement DESIGN-BUILDER is required to remove all ACMs (and specified non-ACMs) from any structures that are being removed as part of the project. Nothing in this Section may be interpreted as limiting the scope of work otherwise required by this contract and related documents. Neither the CONSULTANT nor MBTA will be responsible for errors or omissions and/or charges for extra work arising from any bidders' failure to become familiar with the existing conditions of the Site, requirements of the Work and the results to be produced. By submitting a Bid, the Bidder further agrees that the descriptions contained herein and on project documents are adequate and that the bidder will produce the required results (i.e., remove all ACM identified at the Site). By submitting a bid, a bidder agrees and warrants that he is familiar with and will perform all the work required in the Specifications.
- E. If the DESIGN-BUILDER discovers any suspect building components, the DESIGN-BUILDER shall stop all work impacting the suspect materials and notify the CONSULTANT. The CONSULTANT will sample the suspect material and submit them for analysis to a laboratory accredited under the National Institute of Standards and Technology (NIST) "National Voluntary Laboratory Accreditation Program (NVLAP)."
- F. After all indicated ACMs have been removed, perform any exploratory demolition of building components and equipment as directed by the CONSULTANT to confirm that all asbestos materials have been identified and removed. All ACM identified as a result of this exploratory process shall be properly removed and disposed in accordance with this Section.
- G. The DESIGN-BUILDER shall not adversely impact the integrity of structures scheduled to remain during the asbestos abatement process including but not limited to structural supports, etc.
- H. The following is an outline of work requirements and sequencing that provides a minimum level of detail for the overall abatement scope/sequence, and is expected to be adhered to by the DESIGN-BUILDER, except where otherwise stated in the DESIGN-BUILDER's Work Plan. The projected sequence of work in the main asbestos work area(s) that would be acceptable to the CONSULTANT and AUTHORITY is as follows:
1. Work Area Preparation and Pre-Cleaning
Decontamination units and negative air units will be installed as needed to support the Work. Water sources will be identified and utilized or off-site sources of water will be utilized. Electrical power distribution will be provided as needed including transformers and power panels. Walkways shall be maintained clear of debris at all times.
 2. Scaffolding/Staging
During work area preparation and as needed throughout the project, OSHA approved ladders, trench protection and scaffolding/staging shall be installed where needed to perform the Work.
 3. Gross Asbestos Removal
Asbestos and debris on pipes, pipe chases, etc. throughout the work area will be adequately wetted, removed and properly packaged in MassDEP-approved containers (including bulk loads where applicable) and disposed as asbestos waste (as a minimum). Waste packages will be properly labeled for asbestos waste and marked with generator labels.

4. Decontamination and Wash Down/Fine Cleaning

All surfaces shall be cleaned using water, controlled pressure washing, sponges, rags, tools, etc. needed to remove all traces of visible debris, controlling the use of the water as practical. Controlled usage of water includes containment of the water, avoidance of water streaming/splashing. The DESIGN-BUILDER shall assure that all ACM and/or potential ACM is maintained adequately wetted throughout the removal and disposal process.

5. Final Visual Inspection and Air Clearance

The CONSULTANT or CONSULTANT's representative will perform a final visual inspection of the work area(s). The DESIGN-BUILDER shall re-clean the work area(s) as needed until no visible debris remains. Once the area has been accepted by the CONSULTANT, final air clearance testing shall be performed.

1.2 RELATED WORK

A. Other specification sections that relate to the work include but are not limited to the following:

1. Section 01060 – PERMITS AND REGULATORY REQUIREMENTS
2. Section 01560 – TEMPORARY CONTROLS
3. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
4. Section 02091 – REMOVAL OF CONTAMINATED FIXTURES
5. Section 02092 – PCB BULK PRODUCT WASTE ABATEMENT
6. Section 02221 – DEMOLITION
7. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS

1.3 AUTHORITY TO STOP WORK

A. The CONSULTANT has the AUTHORITY to stop the abatement work at any time the CONSULTANT determines that conditions are not in accordance with the Specifications and applicable regulations. The stoppage of work shall continue until conditions have been corrected and corrective steps have been taken to the satisfaction of the CONSULTANT. Standby time required to resolve violations and Specification interpretations or contractual obligations shall be at the DESIGN-BUILDER's expense.

1.4 DEFINITIONS

- A. The following terms are defined in the specific context of asbestos removal as addressed by this Section:
1. Abatement: Any activity which has as its principal purpose the removal, enclosure or encapsulation of asbestos.
 2. Accessible: Any item (including ACM) or surface that can be reached by hand, provided sufficient ladders, lifts, safety lines, shoring, scaffolding and/or staging are installed to reach such item/surface, without performing any demolition of existing structures/items to reach such item/surface.
 3. ACGIH: American Conference of Governmental Industrial Hygienists
 4. AIHA: American Industrial Hygiene Association

5. Airlock: A mechanism consisting of doors and/or curtains that control air flow patterns in doorway such that the air flows only towards the inside of the enclosure to which the decontamination system is attached.
6. Air Monitoring: The process of measuring the fiber content of a known volume of air collected during a specific period of time. The procedure normally utilized for asbestos monitoring follow the NIOSH Method 7400 with analysis by Phase Contrast Microscopy and/or the Transmission Electron Microscopy method.
7. Amended Water: Water to which a wetting agent has been added.
8. Asbestos Project Monitor: The MADLS-certified professional contracted or employed by the AUTHORITY to supervise and conduct air sampling and monitor asbestos abatement activities.
9. Asbestos: The asbestos form varieties of chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.
10. Asbestos Containing Material (ACM): Any material containing one percent (1%) or more asbestos.
11. Asbestos-Contaminated Objects/Surfaces: Shall mean any objects/surfaces that may be contaminated by asbestos or ACM or water.
12. Asbestos Containing Waste: ACM or asbestos-contaminated objects requiring disposal as asbestos.
13. Certified Industrial Hygienist (CIH): An industrial hygienist certified in Comprehensive Practice by the American Board of Industrial Hygiene.
14. Class I asbestos work: Activities involving the removal of thermal system insulation, surfacing insulation and Presumed ACMs (PACM).
15. Class II asbestos work: Activities involving the removal of ACM that is not thermal system insulation or surfacing material. This includes, but is not limited to the removal of asbestos-containing wallboard, floor tile and sheeting, roofing and siding shingles, and construction mastics.
16. Clean Room: An uncontaminated area or room which is a part of the worker decontamination enclosure system with provisions for storage of worker's street clothes and clean protective equipment.
17. Competent Person: In addition to the definition in Title 29 CFR, Part 1926.32(f), an individual who is capable of identifying existing asbestos hazards in the workplace and selecting the appropriate control strategy for asbestos exposure, and who has the AUTHORITY to take corrective measures to eliminate them. In addition, for Class I and II work, this individual must be trained in a training course which meets the criteria of USEPA's Model Accreditation Plan (Title 40 CFR, Part 763, Subpart E, Appendix C) for Project Designer or Supervisor, or its equivalent.
18. CONSULTANT: Authorized representatives who are under contract with the AUTHORITY to provide asbestos abatement consulting or monitoring services.
19. Curtained Doorway: A device to allow ingress or egress from one room to another while permitting minimal air movement between the rooms, typically constructed by placing two overlapping sheets of plastic over an existing or temporarily framed doorway, securing each along the top of the doorway, securing the vertical edge of one sheet along one vertical side of the doorway and securing the vertical edge of the other sheet along the opposite vertical side of the doorway. Other effective designs are permissible.

20. Decontamination Enclosure System: A series of connected rooms separated from the work area and from each other by airlocks and used for the decontamination of workers and equipment.
21. Demolition: The wrecking or taking out of any load-supporting structural member of a facility together with any related handling operations.
22. Disposal Bag: 6-mil thickness leak-tight plastic bags used for transporting asbestos waste from work and to disposal site. Each bag shall be labeled in accordance with USEPA's NESHAPS, OSHA and USDOT regulations.
23. Encapsulation: The application of a coating or liquid sealant to ACMs to reduce the tendency of the material to release fibers.
24. Enclosure: The construction of an air-tight, impermeable, permanent barrier around ACMs or equipment containing ACM debris.
25. Fixed Items: Equipment, mechanical systems, or other objects which cannot be removed from the work area without cutting/demolition,
26. Friable Asbestos-Containing Material: Material that contains one percent or more asbestos, which when dry, may be crumbled, pulverized, or reduced to powder by hand pressure. The term includes non-friable ACM that becomes damaged to the extent it may be crumbled, pulverized, or reduced to powder by hand pressure.
27. HEPA Filtered Exhaust Units or Fans: A fan equipped with a High Efficiency Particulate Air (HEPA) filter, greater than 99.97 percent efficient by 0.3 micron (μm) DOP test, and complying with ANSI Z9.2 (1979), Local Exhaust Ventilation. It shall be used to create a negative pressure in a work area (reduced with respect to surrounding areas) to prevent the escape of asbestos fibers. It shall also be used to reduce and control the airborne concentration of asbestos fibers.
28. HEPA Filter Vacuum Collection Equipment (or vacuum cleaner): High efficiency particulate air (absolute)-filtered vacuum collection equipment with a filter system capable of collecting and retaining asbestos fibers. Filters shall be of 99.97% efficiency for retaining fibers of 0.3 μm or larger.
29. High-Efficiency Filter: A filter which removes from air 99.97% or more of monodisperse dioctyl phthalate (DOP) particles have a mean particle diameter of 0.3 μm .
30. Industrial Hygienist: A professional qualified by education, training and experience to anticipate, recognize, evaluate and develop controls for occupational health hazards.
31. Isolation Barriers: The construction of partitions, the placement of solid materials, and the plasticizing of apertures to seal off the workplace from surrounding areas and to contain asbestos fibers in the work area.
32. Log: An official record of all activities that occurred during the project and it shall identify the building, agent, DESIGN-BUILDER, workers, and other pertinent information.
33. Negative Pressure Respirator: A respirator in which the air pressure inside the respiratory-inlet covering is positive during exhalation in relation to the air pressure of the outside atmosphere and negative during inhalation in relation to the air pressure of the outside atmosphere.
34. Negative Initial Exposure Assessment: A demonstration by the DESIGN-BUILDER that employee exposure during an operation is expected to be consistently below the Permissible Exposure Limit (PEL).
35. Negative Pressure: Air pressure lower than surrounding areas, generally caused by exhausting air from a sealed space (work area).
36. Permissible Exposure Limit (PEL): An exposure limit that is published and enforced by OSHA as a legal standard.

37. Personal Monitoring: Sampling of the asbestos fiber concentrations within the breathing zone of an employee.
38. Project Designer: An individual who has successfully completed the training requirements for an abatement Project Designer established by Title 40 CFR, MADLS as an Asbestos Abatement Project Designer.
39. Protect Fixed Items: Shall mean to cover with solid enclosures and/or 6-mil thickness polyethylene sheeting, and secure by taping or gluing water and airtight.
40. Protection Factor: The ratio of the ambient concentration of an airborne substance to the concentration of the substance inside the respirator at the breathing zone of the wearer. The protection factor is a measure of the degree of protection provided by a respirator to the wearer.
41. Regulated Area: An area established by the DESIGN-BUILDER to demarcate areas where Class I and II asbestos work is conducted, and any adjoining area where debris and waste from such asbestos work accumulate; and a work area within which airborne concentrations of asbestos exceed, or there is a reasonable possibility they may exceed the PEL.
42. Seal, or Block and Seal: Preparing a space or area such that there is no air movement or passage to and from the area. "Isolation barrier" shall mean the system of seals or other items which prevent air movement to and from any work area.
43. Surface barriers, Protective Coverings or Polyethylene: The plasticizing of walls, floors, and fixed objects within the work area to prevent contamination during subsequent abatement activities.
44. Time Weighted Average (TWA): The average concentration of a contaminant in air during a specific time period.
45. Visible Emissions: Any emissions containing particulate asbestos material that are visually detectable without the aid of instruments. This does not include condensed uncombined water vapor.
46. Wet Cleaning: The process of eliminating asbestos contamination from building surfaces and objects by using cloths, mops, or other cleaning utensils which have been dampened with amended water or diluted removal encapsulant and afterwards thoroughly decontaminated or disposed as asbestos contaminated waste.
47. Work Area: The area where asbestos related work or removal operations are performed which is defined and/or isolated to prevent the spread of asbestos dust, fibers or debris, and entry by unauthorized personnel. Work area is a Regulated Area as defined by Title 29 CFR, Part 1926.1101. A work area is considered a contaminated space between the time preparation begins and the time the area is certified clean.

1.5 SUBMITTALS

- A. The DESIGN-BUILDER shall submit to the CONSULTANT the following listed items within 30 days after notice to proceed.
 1. Name and experience of proposed Supervisors and Foremen (Submittal #1).
 2. Summary of workforce by disciplines, and a notarized statement documenting that all proposed workers, by name, have received all required medical exams and have been properly trained in asbestos removal work, respirator use, and appropriate MADLS, USEPA & OSHA standards (Submittal #2).
 3. Copies of all current training certifications (including original and refresher), MA DLS licenses, fit test clearances and medical clearances to wear a respirator. The DESIGN-BUILDER shall

submit to the Consultant, copies of requested records for new site workers whose certifications have not previously been reviewed.

4. Notarized Certification: Submit notarized certification signed by an officer of the abatement contracting firm that exposure measurements, medical surveillance, and worker training records are being kept in conformance with OSHA, EPA, MA DEP and MA DLS requirements (Submittal #3).
5. Plan of Action & Standard Operating Procedures: Submit a detailed site-specific plan of the procedures proposed for use in complying with the requirements of this Specification. Include in the plan the specific location and layout of decontamination areas and negative air units; location of lighting and power outlets; distribution of amended water; the sequencing of asbestos work; detailed schedules by dates, shift times, and work activities during that shift; the interface of trades involved in the performance of work; methods to be used to assure the safety of occupants and visitors to the Site, and a detailed description of the methods to be employed to control pollution. The Plan shall also include/address the following.
 - a. Proper protective clothing and respiratory protection prior to entering the work space from the outside.
 - b. Safe work practices in the work place, including provisions for inter-room communications; exclusion of eating, drinking, smoking, and application of cosmetics; or use of procedures or equipment that would in any way reduce the effectiveness of respiratory protection or other engineering controls.
 - c. Proper exit practices from the work space to the outside through the showering and decontamination facilities.
 - d. Preventing a fiber release episode.
 - e. Packing, labeling, loading, transporting, and disposing of contaminated material in a way that minimizes or prevents exposure and contamination.
 - f. Emergency evacuation of personnel, for medical or safety (fire and smoke) so that exposure will be minimized.
 - g. Safety from accidents in the work space, especially from electrical shocks, slippery surfaces, and entanglements in loose hoses and equipment.
 - h. Provisions for effective supervision, and OSHA-specified personnel air monitoring for exposure during the work.
 - i. Project sequencing.
 - j. Waste segregation, minimization, decontamination packaging and disposal.
 - k. Any other items as noted in this Specification or as required by the CONSULTANT to be addressed upon submittal review.
1. Provide the following information for exposure controls (Submittal #4):
 1. Number of negative air machines required and the calculations necessary to determine the number of machines for each work area.
 2. Description of projected airflow within each work area and methods required to provide adequate air flow in all portions of the work area.
 3. Pressure differential across work area enclosures anticipated.
 4. Description of methods of testing for correct airflow and pressure differentials.
 5. Manufacturer's product data on the machines to be used.

6. Location of the machines in the work space.
 7. Method of supplying adequate power to the machines.
 8. Description of work practices to reduce worker exposure to airborne fibers.
 9. Manufacturer's product data on equipment used to monitor pressure differential between inside and outside of work area.
- m. Contingency Plan: Submit a contingency plan for emergencies including fire, accident, power failure, negative air system failure, supplied air system failure, or any other event that may require modifications or abridgment of decontamination or work area isolation procedures. Include in plan specific procedures for decontamination or work area isolation. Note that nothing in this Specification should impede safe exiting or providing adequate medical attention in the event of an emergency. Include telephone number and locations of emergency services including but not limited to fire, ambulance, doctor, hospital, police, power company, telephone company (Submittal #5).
 - n. Summary of other proposed materials and equipment (manufacturer, catalog number or model, and description) and method of application or use, including but not limited to wetting agents, personal protective equipment, and test samples of all proposed materials for performing the work (Submittal #6).
 - o. A plan describing the method for exposure monitoring to document compliance with OSHA Asbestos Standard, including frequency of monitoring, equipment and calibration methods, and name of analysis laboratory (Submittal #7).
 - p. All required permits, certifications and licenses (Submittal #8).
 - q. Copies of the completed USEPA, State, and local asbestos removal pre-abatement notification forms (Submittal #9).
 - r. Copies of all proposed daily inspection and record logs, including work area entry data, respirator inspections and maintenance, HEPA-exhaust inspections and maintenance, and other work applicable activities (Submittal #10).
 - s. Name, location, and applicable licenses, operating permits and insurance certificate for primary and secondary landfill for disposal of asbestos-containing or asbestos-contaminated waste. Name and applicable federal and state permits and insurance certificate for transporter of asbestos waste materials. (Submittal #11).
 - t. Respiratory Protection Program: Submit level of respiratory protection intended for each operation required by the Project (Submittal #12).
 - u. Historic Airborne Fiber Data: Submit airborne asbestos fiber count data from an independent air monitoring firm to substantiate selection of respiratory protection proposed. Data submitted shall include at least the following for each procedure required by the work: (Submittal #13)
 1. Name of Testing Laboratory (Must be a Massachusetts State-Certified Lab)
 2. Dates of measurements
 3. Operations monitored
 4. Sampling and analytical methods used and evidence of their accuracy.
 5. Number, duration, and results of samples taken.
 - v. Resume Information: Submit resume and information on training for individual monitoring the operation of supplied air respiratory systems. Submit training certifications where applicable (Submittal #14).

- B. No asbestos removal work activities shall commence until these items are reviewed and accepted by the CONSULTANT. Submittal data shall be in sufficient detail to enable the CONSULTANT to identify the particular product or equipment and to form an opinion as to its conformity to the Specifications. Each submittal item shall be identified with a cover page and/or transmittal sheet containing the listed submittal number. The CONSULTANT may reject the entire submittal package if not submitted in the same order presented above.

- C. The DESIGN-BUILDER shall submit to the CONSULTANT the following items prior to individual workers being allowed to work on the project:
 - 1. Submit copies of the training certificates and current MADLS certificate for each worker.
 - 2. Report from Medical Examination: Submit a copy of Physician's Written Opinion for medical examination conducted within last 12 months as part of compliance with OSHA medical surveillance requirements for each worker who is to enter the work area.
 - 3. Current (within 12 months) respirator fit test record for each employee anticipated to conduct work on the project.

- D. During Abatement Activities:
 - 1. Submit weekly job progress reports detailing abatement activities. Include review of progress with respect to previously established milestones and schedules, major problems and action taken, injury reports, equipment breakdown, and bulk material and air sampling results conducted by DESIGN-BUILDER.
 - 2. Submit each week copies of all transport manifests, trip tickets, and disposal receipts for all asbestos waste materials removed from the work area during the abatement process.
 - 3. Submit each week daily copies of worksite entry logbooks with information on worker and visitor access.
 - 4. Submit each week logs documenting filter changes on respirators, HEPA vacuums, negative pressure ventilation units, and other engineering controls.
 - 5. Submit each week results of air sampling data collected during the course of the abatement including OSHA compliance air monitoring results.
 - 6. Post outside or immediately adjacent to the clean room of the worker decontamination enclosure, a list containing names, addresses, and telephone numbers of the DESIGN-BUILDER, the AUTHORITY, the Asbestos Abatement Project Monitor, the General Superintendent, the testing laboratory, and any other personnel who may be required to assist during abatement activities.

1.6 PROJECT COORDINATION - ASBESTOS ABATEMENT

- A. Minimum administrative and supervisory requirements necessary for coordination of work on the Project include but are not necessarily limited to the following:
 - 1. Administrative and supervisory personnel.
 - 2. Special reports.
 - 3. Contingency Plan.
 - 4. Notifications to other entities at job site.

- B. Administrative and Supervisory Personnel:
 - 1. General Superintendent: Provide a full-time General Superintendent who is experienced in administration and supervision of asbestos abatement projects including work practices, protective

measures for site and personnel, disposal procedures, etc. This person shall generally remain outside the work area, except for daily checks on the quality and progress of work, and be available to the AUTHORITY and the CONSULTANT at all times while work is in progress.

This person is the Competent Person as required by OSHA in Title 29 CFR, Part 1926.1101 for the DESIGN-BUILDER and is the DESIGN-BUILDER's representative responsible for compliance with all applicable federal, state and local regulations, particularly those relating to ACMs. This person must have completed a course at an USEPA Training Center or equivalent certificate course in asbestos abatement procedures, have had a minimum of four (4) years on-the-job training and meet any additional requirements set forth in Title 29 CFR, Part 1926.1101 for a Competent Person.

2. Provide a full-time non-working supervisor/foreman for each work area who is experienced in the supervision of asbestos abatement projects including work practices, protective measures for site and personnel, disposal procedures, etc. This person shall remain inside the work area at all times while work is in progress. This person must have completed a course at an USEPA Training Center or equivalent certificate course in asbestos abatement procedures, have a minimum of two years on-the-job training and meet any additional requirements set forth in Title 29 CFR, Part 1926.1101 for a competent person. This person must also be certified by the Commonwealth of Massachusetts as an Asbestos Abatement Supervisor as required by MADLS regulations located at 453 CMR 6.00.

C. Special Reports: Except as otherwise indicated, submit special reports directly to the CONSULTANT within one day of occurrence requiring special report, with copy to others affected by occurrence.

1. Reporting Unusual Events: When an event of unusual and significant nature occurs at site (examples: failure of negative pressure system, rupture of critical barriers), prepare and submit a special report listing chain of events, persons participating, response by DESIGN-BUILDER's personnel, evaluation of results or effects, and similar pertinent information. When such events are known or predictable in advance, advise the CONSULTANT in advance at earliest possible date.
2. Reporting Accidents: Prepare and submit reports of any accidents, at site and anywhere else work is in progress. Record and document data and actions; comply with industry standards. For this purpose, an accident is defined to include events where personal injury is sustained, or property loss of substance is sustained, or where the event posed a significant threat of loss or personal injury.

D. Contingency Plan:

1. Contingency Plan: Prepare and submit for approval a contingency plan for emergencies including fire, accident, power failure, negative air system failure, supplied air system failure, or any other event that may require modification or abridgment of decontamination or work area isolation procedures. Include in plan specific procedures for decontamination or work area isolation. Note that nothing in this Specification should impede safe exiting or providing adequate medical attention in the event of an emergency.
2. Post outside or immediately adjacent to the clean room of decontamination facility telephone numbers and locations of emergency services including but not limited to fire, ambulance, doctor, hospital, police, power company, telephone company.

E. Notifications to other entities at job site: Notify other entities at the job site of the nature of the asbestos abatement activities, location of ACMs, requirements relative to asbestos set forth in these Specifications and applicable regulations.

- F. Prior to the start of work, the DESIGN-BUILDER will prepare and submit a detailed removal plan to the CONSULTANT for review and approval. This plan must comply with all applicable Federal, State, and local regulations.

1.7 SCHEDULES AND REPORTS

- A. Coordination: Coordinate both the listing and timing of reports and activities required by provisions of this section and other sections, so as to provide consistency and logical coordination between the reports. Maintain coordination and correlation between separate reports by updating at weekly or shorter time intervals. Make appropriate distribution of each report and updated report to all parties involved in the work including the CONSULTANT. In particular provide close coordination of the progress schedule, listing of subcontractor's schedule of submittals, progress reports, and payment requests.
- B. Schedules: Provide proposed detailed schedule including work dates, work shift times, number of employees, dates of start and completion including dates of preparation, removals and final inspection dates. Submit schedule with Plan of Action.
- C. Daily Log: Maintain within the Decontamination Facility a daily log documenting the dates and time of but not limited to, the following items:
 - 1. Visitations; authorized and unauthorized attempts.
 - 2. Personnel, by name and Social Security Number, entering and leaving the work area.
 - 3. Special or unusual events, i.e., Barrier breaching, Equipment failures.
 - 4. Air monitoring tests and test results as required by OSHA.
 - 5. Inspection of work area preparation prior to start of removal and daily thereafter.
 - 6. Removal of any polyethylene barriers.
 - 7. DESIGN-BUILDERS inspections prior to encapsulation.
 - 8. Removal of waste materials from work area.
 - 9. Decontamination of equipment (list items).
 - 10. Final inspection/final air test analysis results.

Provide two copies of this log at final closeout of project for use by the CONSULTANT.

1.8 PRE-CONSTRUCTION CONFERENCE & MEETINGS

- A. Prior to start of any work, the DESIGN-BUILDER shall meet at project site with the CONSULTANT, AUTHORITY, and other entities concerned with asbestos abatement work. The Consultant will record discussions and agreements and furnish copy to each participant as required by the AUTHORITY.
- B. For specific coordination and pre-installation meetings for each element of work, and other regular project meetings for other purposes, the CONSULTANT will hold general progress meetings as required. Each entity then involved in planning, coordination or performance of work is required to be represented properly at each meeting.

1.9 GENERAL APPLICABILITY OF CODES, REGULATIONS AND STANDARDS

- A. Except to the extent that more explicit or more stringent requirements are written directly into the Contract Documents, all applicable codes, regulations, and standards have the same force and effect (and

are made part of the contract documents by reference) as if copied directly into the contract documents, or as if published copies are bound within.

- B. The DESIGN-BUILDER shall assume full responsibility and liability for the compliance with all applicable Federal, State, and local regulations pertaining to work practices and the protection of workers, visitors to the site, and persons occupying areas adjacent to the site. The DESIGN-BUILDER shall hold the CONSULTANT and its representatives harmless for failure to comply with any applicable work, hauling, disposal, safety, health or other regulation on the part of himself, his employees, or his subcontractors.

- C. Federal Requirements: Which govern asbestos abatement work or hauling and disposal of asbestos waste materials include the following:
 - 1. U.S. Department of Labor, Occupational Safety and Health Administration, (OSHA) including but not limited to:
 - a. Asbestos 29 CFR 1926.1101.
 - b. Respiratory Protection Standard, 29 CFR 1910.134.
 - c. Safety and Health Regulations for Construction, 29 CFR 1926.
 - d. Hazard Communication, 29 CFR 1910.1200
 - e. Specifications for Accident Prevention Signs and Tags, 29 CFR 1910.145
 - f. Asbestos General Standard 29 CFR 1910.1101
 - 2. U.S. Environmental Protection Agency (EPA) including but not limited to:
 - a. National Emission Standard for Hazardous Air Pollutants (NESHAPs) 40 CFR, Part 61, Subpart M
 - b. Asbestos Worker Protection Rule (40 CFR Part 763, Subpart G)
 - c. Hazardous Waste Regulations (Resource Conservation & Recovery Act) 40 CFR 260-265
 - 3. U.S. Department of Transportation, 49 CFR 172 - 173:

- D. State Requirements: Which govern asbestos abatement work or hauling and disposal of asbestos waste materials include the following:
 - 1. Massachusetts Division of Occupational Safety Regulations for the Removal, Containment or Encapsulation of Asbestos 453 CMR 6.00.
 - 2. Massachusetts Department of Environmental Protection:
 - a. Air Pollution Control Regulations, 310 CMR 7.00
 - b. Solid Waste Regulations, 310 CMR 18.000, 310 CMR 19.000
 - c. Sewer Use Regulations, 314 CMR 7.00
 - 3. Massachusetts Water Resources Authority
 - a. Discharge permitting requirements, 360 CMR 10.000

- E. Local Requirements: Abide by all local requirements which govern asbestos abatement work or hauling and disposal of asbestos waste materials.
 - 1. City of Boston Department of Health, 1.05 CMR, Section 440.353
 - 2. City of Boston Fire Department, Fire Prevention Code, Article 1, Section 1.05 and Article XX, Section 20.03

- F. Reference Guidelines: Which govern asbestos abatement work or hauling and disposal of asbestos waste materials include the following:
1. American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018
(212) 354-3300
 - a. Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Publication Z9.2-79
 - b. Practices for Respiratory Protection, ANSI Publication Z288.2-80

1.10 NOTIFICATIONS, PERMITS, AND LICENSES

- A. Once the DESIGN-BUILDER has been selected to perform an asbestos abatement, and a project schedule has been determined, external notifications must be filed. Copies of all notifications must be to the attention of the Engineer.
- B. The DESIGN-BUILDER is responsible for all required notifications of asbestos abatement work prior to the start of the abatement work. MADEP requires notification 10 working days prior to commencement of work involving the removal of any amount of asbestos.
- C. The DESIGN-BUILDER is responsible for the proper notification that must be made using MADEP's "Asbestos Notification Form ANF-001" (also known as BWP AQ-04). Submission of the form satisfies the notification requirements of both MADEP and DLS regulations.
- D. To submit an Asbestos Notification Form ANF-001, do one of the following:
1. File the ANF-001 online via MassDEP's website.
 2. Select "New User" and complete the required steps.
 3. For paper filers, when the ANF-001 is completely filled out, and the appropriate decal is affixed to the form (see Question #6 below), use regular, certified or U.S. Postal Service Express mail to send the form to:

Commonwealth of Massachusetts
Asbestos Program
P.O. Box 120087
 4. Use a private delivery or overnight service and send the ANF-001 to the following address:
Asbestos Notification, 8th Floor, MADEP, One Winter Street, Boston, MA 02108
- E. If the site project is planned for demolition or construction of a building, the DESIGN-BUILDER must notify MADEP. Notifications must be made using MADEP's "BWP AQ 06 Notification Prior to Construction or Demolition." The Construction/Demolition Notification Form and Instructions are available on MADEP's website at www.mass.gov/dep. To submit a Construction/Demolition Notification AQ-06 Form, the DESIGN-BUILDER must do one of the following:
1. File the AQ-06 online via MADEP's website. If you have not already done so, register online with eDEP at <https://edep.dep.mass.gov/DEPLogin.aspx>. Select "New User" and complete the required steps.
 2. For paper filers, when the AQ-06 is completely filled out, and the appropriate decal is affixed to the form (see Question #6 below), use regular, certified or U.S. Postal Service Express mail to send the form to:

Commonwealth of Massachusetts
Asbestos Program
P.O. Box 120087
Boston, MA 02112-0087

3. Use a private delivery or overnight service and send the AQ-06 to the following address:
Asbestos Notification, 8th Floor, Massachusetts DEP, One Winter Street, Boston, MA 02108.

- F. The DESIGN-BUILDER is responsible to confirm with local MADEP regional office, that construction and demolition notification fees might not apply for the Green Line Extension Project. For jobs that are exempt from the notification fee an EXEMPT decal must be obtained from the MADEP regional office and affixed to the notification form. For fee-exempt construction/demolition jobs, EXEMPT notification decals may be picked up (free of charge) at the reception area of MADEP's One Winter Street Boston Office or at any regional MADEP office. Each notification decal contains a unique number that is used to track the notification. Forms without decals will not be accepted.

- G. After the AQ-06 is received it will be reviewed by MADEP. The DESIGN-BUILDER will be contacted only in case of deficiencies in the submitted notification form, in which case the construction/demolition operation may not start.

- H. If MADEP informs the DESIGN-BUILDER of deficiencies in the notification form, the DESIGN-BUILDER will have 30 calendar days from the date of being informed of the deficiencies in which to respond.

- I. If necessary, the DESIGN-BUILDER may make revisions to the construction or demolition by doing either of the following:
 1. File the notification revision online via eDEP (you can do this even if the original notification was a paper copy).
 2. For paper filers, on a copy of the original notification form, write "REVISION" under the notification fee decal, and on the form indicate the revisions being made to the original notification. Mail a copy of the revised form to:

Commonwealth of Massachusetts
Asbestos Program
P.O. Box 120087
Boston, MA 02112-0087

- J. If the DESIGN-BUILDER needs an emergency waiver from the 10 working day notification requirement for abatement of previously unidentified ACM, the DESIGN-BUILDER shall contact the appropriate MADEP regional office to determine if an emergency is warranted, and to receive an emergency waiver number. If MADEP issues an emergency waiver, the construction/demolition operation may proceed. A Construction/Demolition Form and fee must still be submitted to MADEP as noted earlier. The AQ-06 form should be submitted within one working day of the beginning of the construction or demolition operation that received the emergency waiver.

- K. The DESIGN-BUILDER is responsible to notify all local agencies that state such requirements prior to the start of construction.

- L. For All Emergency Asbestos Responses:

Emergency asbestos responses may be arranged in response to unexpected incidents and uncontrolled events. Notification procedures are slightly different when there will be less than a 10 day advance notification period between the request and the abatement.

In the event of an emergency asbestos response, the DESIGN-BUILDER shall notify the AUTHORITY and CONSULTANT of emergency condition. The DESIGN-BUILDER shall provide AUTHORITY or CONSULTANT with the following information:

1. Building name, address, and specific location for the abatement
2. Nature of the emergency and reason for waiver
3. Type and quantity of asbestos to be remove
4. Name of the asbestos abatement DESIGN-BUILDER
5. Name of the environmental CONSULTANT
6. Names of any other DESIGN-BUILDERS performing work at this site.
7. BWPAQ06 Construction / Demolition notification number pertinent to work at this site, if applicable
8. Desired start date of the project

M. The AUTHORITY will contact the MADEP by phone to request an Emergency Waiver:

1. If an Emergency Waiver Number is issued, it will be communicated to the DESIGN-BUILDER along with the name of the Inspector who issued it. (During weekends and late night periods, the DEP on-call representative may be notified via the Massachusetts State Police.
2. The abatement DESIGN-BUILDER will notify DLS and provide them with the DEP Waiver number, and request a DLS Emergency Waiver number.
3. The DESIGN-BUILDER will fill out Form ANF-001, fax it to both the DEP and DLS, and then mail hard copies with the required fees.
4. The DESIGN-BUILDER will be responsible to also notify all appropriate local agencies as required.

N. Licenses: Maintain current licenses as required by applicable state or local jurisdictions for the removal, transporting, disposal or other regulated activity relative to the work of this Contract.

O. Posting and Filing of Regulations: Maintain two (2) copies of applicable federal, state and local regulations above. Post one copy of each at the job site and keep one copy of each regulation file in DESIGN-BUILDER's office.

1.11 AVAILABILITY OF TRAINED PERSONNEL

A. There shall be a sufficient number of trained, licensed and qualified workers, foremen and superintendents to accomplish the work within the required schedule, which may require work to be performed 24 hours a day, seven days a week. No untrained, unlicensed, unqualified, or non-approved person shall be employed to speed up completion of the abatement work.

1.12 RESPIRATORY PROTECTION

A. The DESIGN-BUILDER shall supply workers and supervisory personnel with NIOSH approved protective respirators and HEPA/filters. Appropriate respirator selection shall be determined by the

daily personnel samples being taken and strictly follow the guidelines set forth in the OSHA respiratory program, Title 29 CFR, Part 1910.134, Title 29 CFR, Part 1926.1101 and the Massachusetts DLS Regulations, 453 CMR 6.00. The respirators shall be sanitized and maintained according to the manufacturer's recommendations. Disposable respirators shall not be considered acceptable in any circumstance. The DESIGN-BUILDER shall maintain on site a sufficient supply of disposable HEPA/filters to allow workers and supervisory personnel to change contaminated filters. The DESIGN-BUILDER is solely responsible for means and methods used and for compliance with applicable regulations.

- B. The DESIGN-BUILDER is responsible to instruct and train each worker involved in asbestos abatement or maintenance and repair of friable ACMs in proper respiratory use and require that each worker always wear a respirator, properly fitted on the face in the work area from the start of any operation which may cause airborne asbestos fibers until the work area is completely decontaminated. The DESIGN-BUILDER is responsible to mandate proper respiratory protection appropriate for the fiber level encountered in the work place as required. The DESIGN-BUILDER is responsible to assess any additional respiratory protection requirements for other toxic or oxygen-deficient situations encountered.
- C. Except to the extent that more stringent requirements are written directly into the Contract Documents, the following regulations and standards have the same force and effect. Where there is a conflict in requirements set forth in these regulations and standards, meet the more stringent requirement.
 - 1. OSHA: U.S. Department of Labor Occupational Safety and Health Administration, Safety and Health Standards Title 29 CFR, Part 1926.1101.
 - 2. CGA: Compressed Gas Association, Inc., New York, Pamphlet G-7, "Compressed Air for Human Respiration", and Specification G-7.1 "Commodity Specification for Air".
 - 3. ANSI: American National Standard Practices for Respiratory Protection, ANSI Z88.2-1992.
 - 4. NIOSH: National Institute for Occupational Safety and Health.
 - 5. MSHA: Mine Safety and Health Administration.
- D. Initial Exposure Assessment
 - 1. The DESIGN-BUILDER shall ensure that a "competent person" conduct an exposure assessment immediately before, or at the initiation of work to determine expected exposures during the work. For Class I asbestos work, until the DESIGN-BUILDER conducts exposure monitoring and documents that workers on the job will not be exposed in excess of the PEL, or otherwise makes a negative exposure assessment, the DESIGN-BUILDER shall assume that workers are exposed in excess of the PEL or excursion limit.
 - 2. The DESIGN-BUILDER may demonstrate that worker exposures will be below the PEL (Negative Exposure Assessment) by practices which conforms to the following:
 - a. Objective data which demonstrates that the material containing asbestos cannot release airborne fibers in concentrations exceeding the TWA and excursion limit, or
 - b. The DESIGN-BUILDER has monitored prior asbestos projects for the PEL and excursion limit within one year of this project and the data was obtained during work operations and conditions which "closely resembles" the processes, type of material, control methods, work practices as that on this project and that the operations were conducted by workers whose training and experience are no more extensive than that of the workers who will work on this project; and this data shows that for the conditions present on this project, there is a high degree of certainty that worker exposures will not exceed the TWA and excursion limit; or

- c. The results of initial exposure monitoring of this project for 8-hour TWA and 30-minute short-term exposures of each employee covering operations which are most likely to take place during the entire course of this project result in exposures below the PEL.
- E. The DESIGN-BUILDER shall provide the appropriate respirator to all workers (and ensure that the employee uses the respirator provided) in accordance with the requirements of Title 29 CFR, Part 1926.1101 (h)(3) and Title 29 CFR, Part 1910.134 (d)(3)(i)(A). Respiratory protection as specified herein shall be worn at all times, including preparation of the work areas, loading and unloading of waste containers in the work area or at the transport truck, cleaning of work areas, and performance of glove bag removal work.
- F. Facial hairs, such as beards, long sideburns, and mustaches, which could interfere with the seal of air purifying type respirators, shall not be allowed.
- G. Respiratory protection maintenance and decontamination procedures shall meet the following requirements:
 - 1. Respiratory protection shall be inspected and decontaminated on a daily shift basis in accordance with OSHA Title 29 CFR, Part 1910. 134(b).
 - 2. Respiratory protection shall be the last piece of worker protection equipment to be removed. Workers must wear respirators in the shower when going through decontamination procedures as stated herein.
 - 4. Airline respirators with HEPA-filtered disconnect shall be disconnected in the equipment room and worn into the shower. Powered air-purifying respirator (PAPR) face pieces shall be worn into the shower. Filter/power pack assemblies shall be decontaminated in accordance with manufacturer's recommendations.
 - 5. Respirators shall be stored in a dry place and in such a manner that the face piece and exhalation valves are not distorted.
 - 6. Organic solvents shall not be used for washing of respirators.
 - 7. Whenever respirator design permits, workers shall perform a positive and negative air pressure fit test each time a respirator is worn. PAPRs shall be tested for adequate flow (using the methods specified by the manufacturer) every four (4) hours of use and each time the worker enters or exits the work area. Written logs of these tests shall be maintained by the DESIGN-BUILDER.
 - 8. The DESIGN-BUILDER shall furnish to the CONSULTANT written documentation that each worker is medically approved to wear respirators and has been properly trained in their use, inspection, care, maintenance, and fitting testing pursuant to the DESIGN-BUILDER's written Respirator Plan and applicable regulations.
- H. Air Purifying Respirators:
 - 1. Negative Pressure - Half or Full Face Mask: Supply a sufficient quantity of respirator filters approved for asbestos, so that workers can change filters during the workday. Require that respirators be wet-rinsed, and filters discarded, each time a worker leaves the work area. Require that new filters be installed each time a worker re-enters the work area. Store respirators and filters at the job site in the changing room and protect totally from exposure to asbestos prior to their use.
 - 2. Powered Air Purifying - Half or Full Face Mask: Supply a sufficient quantity of high efficiency respirator filters approved for asbestos so that workers can change filters at any time that flow through the face piece decreases to the level at which the manufacturer recommends filter replacement. Require that HEPA elements in filter cartridges be protected from wetting during

showering. Require entire exterior housing of respirator including blower unit, filter cartridges, hoses, battery pack, face mask, belt, and cords to be washed with a rag or towel each time a worker leaves the work area. Caution should be used to avoid shorting battery pack during washing. Provide an extra battery pack for each respirator so that one can be charging while one is in use.

3. Initial Fitting: Provide initial fitting of respiratory protection during an approved respiratory protection training course. Fit types of respirator to be actually worn by each individual. Allow an individual to use only those respirators for which he has been trained and fit.
4. Upon Each Wearing: Require that each time an air-purifying respirator is put on, it be checked for fit with a positive and negative pressure fit test in accordance with the manufacturer's instructions or ANSI Z88.2 (1992).

I. Type "C" Respirator:

1. Air Systems Monitor: Continuously monitor the air system operation including compressor operation, filter system operation, backup air capacity and all warning and monitoring devices at all times that system is in operation. Assign an individual trained, by manufacturer of the equipment in use or by a Certified Industrial Hygienist, in the operation and maintenance of the system to provide this monitoring. Assign no other duties to this individual which will take this person away from monitoring the air system.
2. The Compressed Air System for Type "C" Respirators (if utilized) shall be high pressure, with a compressor capacity to satisfy the respirator manufacturer's recommendations. The receiver shall have sufficient capacity to allow a 30 minute escape time for the respirator wearers in the event of compressor failure or malfunction. The Compressed Air System shall have compressor failure alarm, high temperature alarm, carbon monoxide alarm, and suitable in-line air purifying adsorbent beds and filters to assure Grade "F" Breathing Air. (See Part 2 -Materials)
3. Where Type "C" Respirators are used, they shall be worn with a belt to minimize possibility of dislodging face mask when hose is snagged in the work area.
4. The DESIGN-BUILDER shall provide at all times a minimum of six spare hoses for the CONSULTANT and authorized visitors and inspectors to connect to their assigned Type "C" Respirator without having to wait for removal of workers from the work area to obtain a hose connection.

1.13 TEMPORARY FACILITIES

- A. The DESIGN-BUILDER shall provide water and electric service sufficient to perform and complete the work of this Specification. Use qualified tradesmen for installation of temporary services and facilities. Locate temporary services and facilities where they will serve the entire project adequately and result in minimum interference with the performance of the work. Relocate, modify and extend services and facilities as required during the course of work so as to accommodate the entire work of the project.
- B. Scaffolding: Provide all scaffolding, ladders and/or staging, etc. as necessary to accomplish the work of this contract. Scaffolding may be of suspension type; or standing type such as metal tube and coupler, tubular welded frame, pole or outrigger type or cantilever type. The type, erection and use of all scaffolding shall comply with all applicable OSHA provisions.
 1. Equip rungs of all metal ladders, etc. with an abrasive non-slip surface.
 2. Provide a nonskid surface on all scaffold surfaces subject to foot traffic.
 3. During the erection and/or moving of scaffolding, care must be exercised so that the contaminated debris on the floor and other surfaces is not disturbed.

4. At the completion of abatement work, clean all construction aids within the work area.
- C. Water Service: All water shall be supplied by the DESIGN-BUILDER. Sufficient water shall be brought on site by the DESIGN-BUILDER or the DESIGN-BUILDER shall make arrangements to use a nearby fire hydrant. Sufficient hot water for all workers shall be supplied by DESIGN-BUILDER at a minimum temperature of 100° F.
1. Temporary Water Service Connection: All connections to the water system shall include backflow protection. Valves shall be temperature and pressure rated for operation of the temperatures and pressures encountered. After completion of use, connections and fittings shall be removed without damage or alteration to existing water piping and equipment.
 2. Water Hoses: Employ heavy-duty abrasion-resistant hoses with a pressure rating greater than the maximum pressure of the water distribution system to provide water into each work area and to each decontamination unit. Provide temporary water heating equipment, branch piping, showers, shut-off nozzles and equipment. Maintain hose connections and outlet valves in leak-proof condition.
 3. Hot Water Heater: Provide UL rated 40 - 80 gallon electric hot water heater to supply hot water for the decontamination unit shower. Activate from 30 amp circuit breaker located within the decontamination unit subpanel. Provide with relief valve compatible with water heater operation; provide piping from relief valve down to drip pan on floor with type L copper. Drip pans shall consist of a 12" x 12" x 6" deep pan, made of 19 gauge galvanized steel, with handles. Wiring of the hot water heater shall be in compliance with NEC, Massachusetts modifications to the NEC, and UL standards.
- D. Electrical Service: Comply with applicable NEC, Massachusetts modifications to the NEC, and UL standard and governing regulations for materials and layout of temporary electric service. Provide a weatherproof, grounded temporary electric power service and distribution system of sufficient size, capacity, and power characteristics to accommodate performance of work during the construction period. Install temporary lighting adequate to provide sufficient illumination for safe work and traffic conditions in every area of work and acceptable to CONSULTANT.
1. Temporary Power: Provide service to decontamination unit sub-panel with minimum 60 amp, 2 pole circuit breaker or fused disconnect connected to the main distribution panel. Sub-panel and disconnect shall be sized and equipped to accommodate all electrical equipment required for completion of the work.
 2. Provide electrical outlets (and extension cords) in the clean room, equipment room, and at locations inside and outside the work area as required by the CONSULTANT for the exclusive use of the CONSULTANT for air monitoring purposes. Since the Regulations will require between 35-50 or more PCM air samples for final clearance purposes for a work area, the outlets and cords must be in sufficient numbers and locations to allow these samples to be taken simultaneously.
- E. Temporary Lighting: Provide sufficient temporary lighting to ensure proper workmanship everywhere; by combined use of daylight and portable plug-in task lighting. Protect lamps with guard cages or tempered glass enclosures, where fixtures are exposed to breakage by construction operations. Provide exterior fixtures where fixtures are exposed to the weather or moisture.
- F. Sanitary Facilities: Provide one self-contained chemical toilet for each ten workers (as a minimum). Toilets shall be located outside the asbestos abatement work areas.
- G. Temporary Heating: Provide temporary heat where indicated or needed for performance of the work. Provide temporary heating units that have been tested and labeled by UL, FM or another recognized

trade association related to the fuel being consumed. Use Type MUH Unit heaters from Qmark or other heating units approved by MBTA Safety Department. No open fires or burning will be allowed.

- H. Fire Extinguishers: Comply with the applicable recommendation of NFPA Standard 10 "Standard For Portable Fire Extinguishers." Locate fire extinguishers where they are most convenient and effective for their intended purpose, but provide no less than one extinguisher in the corner of each work area, one in each Equipment Room, and one outside each work area in the Clean Room.

1.14 DECONTAMINATION FACILITIES (DF)

- A. For Class I work involving less than 25 linear feet or 10 square feet of thermal or surfacing ACM and PACM, and for Class II asbestos work operations where exposures exceed a PEL, or where there is no negative exposure assessment produced before the project, the DESIGN-BUILDER shall provide the following:

1. An equipment room or area adjacent to the regulated area for the decontamination of workers and their equipment which is contaminated with asbestos which shall consist of an area covered by an impermeable drop cloth on the floor or horizontal working surface.
2. The area must be of sufficient size as to accommodate cleaning of equipment and removing personal protective equipment without spreading contamination beyond the area.
3. Work clothing must be cleaned with a HEPA vacuum before it is removed.
4. All equipment and surfaces of containers filled with ACM must be cleaned prior to removing them from the equipment room or work area.
5. The DESIGN-BUILDER shall ensure that all workers enter and exit through the equipment room or area.
6. Provide an air lock leading into the equipment room or area that is physically and visually separated from the equipment room or area.

- B. For Class I work involving more than 25 linear feet or 10 square feet of thermal or surfacing ACM and PACM, the DESIGN-BUILDER shall establish a decontamination area that is adjacent and connected to the regulated area for the decontamination of workers. The decontamination area shall consist of an equipment room, shower area and clean room in series. The DESIGN-BUILDER shall ensure that workers enter and exit the regulated area through the decontamination area. The DESIGN-BUILDER shall provide the following:

1. Equipment Room (Dirty Room): Provide Equipment Room with airlocks to the work area and Shower Room, large enough for all workers to remove and dispose of contaminated protective clothing, and for storage of contaminated DESIGN-BUILDER equipment.
2. Shower Room: Provide a completely watertight operational shower to be used for transit by cleanly dressed workers heading for the work area from the Changing Room, or for showering by workers headed out of the work area after undressing in the Equipment Room. The shower room facilities and size shall be adequate to allow decontamination and thorough washing of all the workers and visitors within the 30 minute escape time allowed under air compressor failure (if Type C Supplied Air Respirators are used).
 - a. Construct room by providing a shower pan and 2 shower walls in a configuration that will cause water running down walls to drip into pan. Install a freely draining wooden floor in shower pan at elevation of top of pan.
 - b. Provide shower head and controls.

- c. Provide temporary extensions of existing hot and cold water and drainage, as necessary for a complete and operable shower.
 - d. Provide a soap dish and a continuously adequate supply of soap and maintain in sanitary condition.
 - e. Arrange so that water from showering does not splash into the Changing or Equipment Rooms.
 - f. Arrange water shut off and drain pump operation controls so that a single individual can shower without assistance from either inside or outside of the work area.
 - g. Provide flexible hose shower head.
 - h. Pump waste water to drain or to storage for use in amended water. If pumped to drain, provide 20 μm and 5 μm waste water filters in line to drain approved by the CONSULTANT or waste water storage. Change filters daily or more often if necessary. Locate filters inside shower unit so that water lost during filter changes is caught by shower pan.
3. Clean Room (Changing Room): Provide a room that is physically and visually separated from the rest of the building for the purpose of changing into protective clothing. Locate so that access to work area from Clean Room is through Shower Room.
- a. Require workers to remove all street clothes in this room, dress in clean disposable coveralls, and don respiratory protection equipment. Do not allow asbestos contaminated items to enter this room. Require workers to enter this room either from outside the structure dressed in street clothes, or naked from the showers.
 - b. Maintain floor of changing room dry and clean at all times. Do not allow overflow water from shower to wet floor in changing room.
 - c. Damp wipe all surfaces twice after each shift change with a disinfectant solution.
 - d. Provide a continuously adequate supply of disposable bath towels.
 - e. Provide posted information for all emergency phone numbers and procedures.
- C. Construction: Decontamination facilities shall be located in areas acceptable to the CONSULTANT and as shown on the DESIGN-BUILDER's approved Work Plan. Construction shall have load-bearing capabilities if required to support workers overhead. DF shall be fully lined utilizing two layers of 6-mil thickness opaque polyethylene sheeting at a minimum. The entire floor of the DF shall be covered with two (2) layers of 6-mil thickness polyethylene sheeting turned up 12" - 16" on the wall layers. The upper layer of floor polyethylene sheeting shall be replaced as wear necessitates (or as determined by the CONSULTANT). The floor of the DF Shower Room shall be sealed and maintained watertight at all times. Leaks shall be immediately cleaned up and then the cause repaired to the satisfaction of the CONSULTANT. The interior surfaces of the walls, floor, and ceiling shall then be covered with an additional two layers of 6-mil thickness polyethylene sheeting sealed water and airtight with duct tape at all overlapping seams.
- D. Air Locks: Shall be constructed by placing three overlapping sheets of plastic over a framed doorway, securing each along the top of the doorway. The first and third sheets shall be secured on one side of the doorway and the middle sheet shall be secured on the other side of the doorway. The distance between doorways must allow enough space for one doorway to be closed before the next doorway is opened (i.e., approximately three (3) feet).
- E. Provide heating and HEPA-filtered exhaust ventilation for all decontamination systems so that air flow will be from the clean outside towards the contaminated workspace.

- F. Cleaning: The decontamination facility shall be cleaned using a HEPA-filtered vacuum at least once every shift, or more frequently if needed to prevent residue accumulation.
- G. Prohibitions: Smoking, drinking, or eating shall not be permitted in the work area, Shower Room or Equipment Room. Personal equipment such as radios or flashlights shall not be permitted in the work area, Shower Room or Equipment Room unless they can be washed in the shower.
- H. The DESIGN-BUILDER shall post or have available the following items in each clean room of the worker decontamination facility.
 - 1. A copy of the USEPA NESHAPs regulations, Title 40 CFR, Part 61 Subparts A and M; and a copy of OSHA Asbestos Regulations, Title 29 CFR, Part 1926.1101;
 - 2. A copy of the MADLS Regulations for Asbestos, 453 CMR 6.00.
 - 3. A list of telephone numbers for local hospital, location of hospital and/or emergency squad, local fire department, and the name and telephone number of the CONSULTANT.
 - 4. A copy of the asbestos abatement Specifications and Drawings.
 - 5. A copy of the respirator protection program which conforms to the requirements of Title 29 CFR, Part 1910.134(b).
 - 6. A listing of all employees, by name, social security number and Massachusetts Asbestos Abatement Worker or Supervisor/Foreperson Certification Number working on the Project.
 - 7. A legible copy of each assigned employee's Massachusetts Certification.
 - 8. A daily sign in/out log which identifies persons by name and Massachusetts Asbestos Certification Number, who are/were at the site, and the length of the time each spent at the site.
- I. A solid, hinged door with a single cylinder dead-bolt lock shall be installed at the outside entrance to each decontamination facility. Provide a shutter which opens on make-up air inflow and seals on air flow cessation. This door shall be closed and locked whenever the work area is unattended. Two sets of keys for the lock shall be distributed to the CONSULTANT.
- J. Ensure that barriers and plastic linings are effectively sealed and taped at all times, and that the Shower Room floor is watertight. Repair damaged barriers, and remedy defects immediately upon discovery. Visually inspect the facility at the beginning of each work period. The CONSULTANT shall also be allowed to use smoke generators to test effectiveness of barriers, flow of air through the DF, and HEPA-exhaust systems.
- K. Maintain emergency and fire exits from the work areas, or establish alternative exits satisfactory to local fire officials and the CONSULTANT. Exits shall be checked daily for exterior blockages or impediments to exiting.
- L. Warning signs as required in Title 29 CFR, Part 1926.1101 shall be posted on the entrance to all work areas
- M. Equipment and Waste DF - Where space allows, provide a separate DF consisting of a serial arrangement of rooms, Holding area, and Wash Room for removal of equipment and material from the work area. Do not allow personnel to enter or exit work area through Equipment DF. Equipment and Waste DF shall be constructed as described above.

1.15 PERSONNEL PROTECTION AND DECONTAMINATION

A. Protective Clothing

1. Coveralls: Provide disposable full-body coveralls and disposable head covers, and require that they be worn by all workers in the work area. Provide a sufficient number for all required changes, for all workers in the work area.
2. Boots: Provide work boots with non-skid soles, and where required by OSHA, foot protection, for all workers. Provide boots at no cost to workers. Do not allow boots to be removed from the work area for any reason, after being contaminated with asbestos containing material. Dispose of boots as asbestos contaminated waste at the end of the work or seal in 6-mil polyethylene bags (with labels) for transportation to another work area.
3. Goggles: Provide eye protection (goggles) as required by OSHA for all workers involved in scraping, spraying, or any other activity which may potentially cause eye injury. Goggles are not required if full face respiratory protection is used.
4. Gloves: Provide work gloves to all workers and require that they be worn at all times in the work area. Do not remove gloves from work area and dispose of as asbestos-contaminated waste at the end of the work.
5. Hard Hats: Provide hard hats to all workers and authorized visitors and require that they be worn at all times in the work area. Hard hats shall be worn over the hood of the coveralls.
6. Additional Protective Equipment: Respirators, disposable coveralls, head covers, and footwear covers shall be provided by the DESIGN-BUILDER for the CONSULTANT, and other authorized visitors who may inspect the job site.

B. Each Time Work Area is Entered: Remove all street clothes in the Changing Room of the Personnel decontamination unit and put on new disposable coverall, new head cover, and a clean respirator. Proceed through Shower Room to Equipment Room and put on work boots.

C. Decontamination Procedures: Require all workers to adhere to current regulations and the project Health and Safety Plan. An overview is provided below of personal decontamination procedures to be followed whenever workers leave the designated work area:

1. When exiting area, remove disposable coveralls, disposable head covers, and disposable footwear covers or boots in the Equipment Room.
2. If wearing breathing protection, keep respirators on while proceeding to the mandatory showering step. Showering will be done with respirator still in place, according to respirator-specific procedures. Care must be taken to follow reasonable procedures in removing the respirator to avoid releasing asbestos fibers while showering. The following general procedures are required at a minimum:
 - a. Type "C" Supplied Air: Thoroughly wash body, including hair and face, and all pieces of respirator. While holding breath, remove respirator and hold it away from face before starting to breath. Carefully wash face piece of respirator inside and out.
 - b. PAPR: Thoroughly wash body, including hair and face, while holding blower unit above head to keep canisters dry. Wash all parts of the respirator except the blower unit and battery pack. Shut down unit in a specified sequence and then thoroughly wash blower unit and hoses. Carefully wash battery pack with wet rag. Be extremely cautious of getting water in battery pack as this will short out and destroy battery.
 - c. Air Purifying-Negative Pressure Respirators: Thoroughly wet body and hair as thoroughly as possible without wetting the respirator filter. Hold breath while wetting face, respirator

and filter and removing respirator. Dispose of wet filters from air purifying respirator. Carefully wash face piece of respirator inside and out.

- D. Within Work Area: Require that workers NOT eat, drink, smoke, chew gum or tobacco, apply cosmetics or use toilet facilities (either existing or temporary) in the work area.
- E. Post written procedures in work place and train all personnel on the procedures for the evacuation of the injured and the handling of potential fires. Provide aid to a seriously injured worker without delay for decontamination. Make provisions to minimize exposure of rescue workers and to minimize spreading of contamination during evacuations and fire procedures.
- F. The DESIGN-BUILDER shall instruct all employees and workers in the proper care of their personally issued respiratory equipment, including daily maintenance, sanitizing procedures, etc.
- G. All respiratory equipment shall be inspected by DESIGN-BUILDER's project supervisory personnel at the beginning of each work period, including breaks and lunch periods. Written records of these inspections shall be maintained for review by the CONSULTANT.

1.16 EXPOSURE CONTROLS AND HEPA-FILTERED EXHAUST VENTILATION

- A. The DESIGN-BUILDER shall install inside each work area portable HEPA-filtered exhaust units to maintain the area, including the Decontamination (and Waste Transfer) Facilities, under negative air pressure, and to reduce and control airborne asbestos fiber concentrations. Exhaust systems shall be operated twenty-four hours per day at all times from the time DESIGN-BUILDER takes control of the Site and during preparation, removal, and cleanup tasks as specified herein; and until acceptable final air clearance is obtained for the work area. In all cases, the units shall exhaust directly to the outside of the containment area.
- B. Each exhaust unit shall be serviced by a dedicated minimum 115V-20A circuit with overload device.
- C. The exhaust system must be capable of providing: 1) at least four (4) full air changes per hour in each work area; 2) an inward velocity through any openings, including the decontamination facilities, of at least 200 feet per minute (fpm); and 3) a static negative air pressure inside the area of a minimum of - 0.02 inches of the water column.
- D. Determine number of units needed by dividing the ventilation requirement cubic feet per minute (CFM) above by capacity of exhaust unit(s) used. Capacity of a unit for purposes of this Section is the capacity, in CFM with fully loaded filters, (pressure differential which causes loaded filter warning light to come on) in the machines labeled operating characteristics. Add a minimum of one (1) additional unit as a backup in case of equipment failure or machine shutdown for filter changing.
- E. All exhaust air shall pass through HEPA-filters before being discharged directly to the exterior of a building. The DESIGN-BUILDER shall securely install (and seal with caulking) a solid window or door insert with cutouts sized for the exhaust air duct from each HEPA-exhaust unit. The exterior exhaust discharge point shall be at least 40 feet from a receptor such as an air intake port, louvers, or entrances to the building or an adjoining building.
- F. Locate exhaust unit(s) so that makeup air enters work area primarily through decontamination facilities and traverses work area as much as possible. This may be accomplished by positioning the exhaust unit(s) at a maximum distance from the worker access opening or other makeup air sources.

- G. If there are multiple sealed areas or partition walls within a work area, the exhaust systems shall be arranged so that air flows from the least to most contaminated area, and to prevent spaces from having poor or dead air movement.
- H. Provide supplemental make-up air inlets where required for proper air flow through the work space in locations approved by the CONSULTANT. Additional make-up air shall be delivered through horizontal shutters which open on make-up air inflow and seal on air flow cessation, or is delivered through a HEPA-filtered supply fan system.
- I. Testing the System: Test the negative pressure system before any asbestos-containing material is wetted or removed. After the work area has been prepared, the decontamination facility set up, and the exhaust unit(s) installed, start the unit(s) one at a time. Demonstrate operation and testing of negative pressure system to the CONSULTANT. Demonstrating and testing the operation of the negative pressure system will include, but not be limited to, the following:
1. Plastic barriers and sheeting move lightly in toward work area.
 2. Curtain of decontamination units move lightly in toward work area.
 3. There is a noticeable movement of air through the decontamination unit. Use smoke tube to demonstrate air movement from Clean Room to Shower Room, from Shower Room to Equipment Room, and from Equipment Room to work area.
 4. Use a differential pressure meter or manometer to demonstrate a pressure difference of at least -0.02 (-0.04 desirable) inches of water across every barrier separating the work area from the balance of the building or outside.
 5. The CONSULTANT may use smoke generators to confirm that air flowing through all open areas is directed into the decontamination facilities and isolation barrier, and good air turnover conditions exist within the work area. If deficient air flows are reported to the DESIGN-BUILDER, the DESIGN-BUILDER shall cease work and promptly correct the deficiency.
- J. Use of System During Abatement Operations:
1. Start exhaust units before beginning work (before any asbestos-containing material is disturbed). After abatement work has begun, run units continuously to maintain a constant negative pressure until final air clearance of the work area is complete. Do not turn off units at the end of the work shift or when abatement operations temporarily stop.
 2. Start abatement work at a location farthest from the exhaust units and proceed toward them. If an electric power failure occurs, immediately stop all abatement work and do not resume until power is restored and exhaust units are operating again.
 3. At completion of abatement work, allow exhaust units to run to remove airborne fibers that may have been generated during abatement work and cleanup and to purge the work area with clean makeup air. The units may be required to run for a longer time after decontamination, if dry or only partially wetted asbestos material was encountered during any abatement work.
- K. On loss of negative air pressure or electric power, all work activities in an area shall stop immediately and shall not resume until power is restored and the HEPA-exhaust systems are operating again. When power failure or loss of negative pressure lasts, or is expected to last, longer than one hour, then the following shall occur:
1. The make-up air inlets in the decontamination facilities shall be sealed airtight.
 2. The decontamination facilities shall be sealed airtight after the evacuation of all personnel from the work area.

3. All adjacent areas shall be monitored for asbestos fiber concentration upon discovery of, and subsequently throughout, the power failure.
- L. Monitoring: Continuously monitor and record pressure differential between the work area and the building outside the work area with a monitoring device incorporating a continuous recorder. Meter shall be equipped with a warning buzzer which will sound if pressure differential drops below -0.02" of water. The monitor will be located at a point acceptable to the CONSULTANT. On a weekly basis, submit printout from pressure differential monitoring equipment. Mark printouts with location, date and start of time for each day.

1.17 SPECIAL CONSIDERATIONS

- A. Selective demolition or exploration may be needed to properly access and remove all the ACM at the site. All such work is part of the Work of Section 02080 and related sections identified in 1.2 "Related Work" above.
- B. The DESIGN-BUILDER is responsible for the integrity and safety of all structural elements to remain during the project wherever their work involves accessing, disturbing, or otherwise has the potential to affect in any way interior/exterior structures. DESIGN-BUILDER is responsible for submitting all scaffolding plans.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. General
 1. Deliver all materials in the original packages, containers, or bundles bearing the name of the manufacturer and the brand name where applicable.
 2. Store all materials subject to damage off the ground, away from wet or damp surfaces, and under cover sufficient enough to prevent damage or contamination. Replacement materials shall be stored outside of the work area until abatement is completed.
 3. Damaged, deteriorating, or previously used materials shall not be used and shall be removed from the worksite and disposed of properly.

2.2 MATERIALS, TOOLS, AND EQUIPMENT

- A. Negative Air Machines: Supply the required number of asbestos air filtration units to the Site in accordance with these specifications. Each unit shall include the following:
 1. Cabinet: Constructed of steel or other durable materials able to withstand damage from rough handling and transportation. The width of the cabinet should be less than 30 inches to fit through standard-size doorways. Cabinet shall be factory sealed to prevent asbestos-containing dust from being released during use, transport, or maintenance. Access to and replacement of all air filters shall be from intake end. Unit shall be mounted on casters or wheels.
 2. Fans: Rate capacity of fan according to useable air-moving capacity under actual operating conditions. Use centrifugal-type fan.
 3. HEPA Filters: The final filter shall be the HEPA type. The filter media (folded into closely pleated panels) must be completely sealed on all edges with a structurally rigid frame.

- a. A continuous rubber gasket shall be located between the filter and the filter housing to form a tight seal.
 - b. Each filter shall be individually tested and certified by the manufacturer to have an efficiency of not less than 99.97% when challenged with 0.3 μm dioctylphthalate (DOP) particles. Testing shall be in accordance with Military Standard Number 282 and Army Instructions Manual 136-300-175A. Each filter shall bear a UL586 label to indicate ability to perform under specified conditions.
 - c. Each filter shall be marked with: the name of the manufacturer, serial number, air flow rating, efficiency and resistance, and the direction of test air flow.
4. Pre-filters: which protect the final filter by removing the larger particles, are required to prolong the operating life of the HEPA filter. Two stages of pre-filtration are required. The first-stage pre-filter shall be a low-efficiency type (e.g., for particles 10 μm and larger). The second-stage (or intermediate) filter shall have efficiency (e.g., effective for particles down to 5 μm). Pre-filters and intermediate filters shall be installed either on or in the intake grid of the unit and held in place with special housings or clamps. Pre-filters shall be checked for accumulation at least twice per shift, and shall be changed as frequently as conditions require, especially during asbestos removal or during times of dust creation.
 5. Instrumentation: Each unit shall be equipped with a Magnahelic gauge or manometer to measure the pressure drop across filters and indicate when filters have become loaded and need to be changed. A table indicating the useable air-handling capacity for various static pressure reading on the Magnahelic gauge shall be affixed near the gauge for reference or the Magnahelic reading indicating at what point the filters should be changed, noting CFM air delivery at the point. Provide units equipped with an elapsed time meter to show the total accumulated hours of operation.
 6. Safety and Warning Devices: The unit shall have an electrical (or mechanical) lockout to prevent fan from operating without a HEPA filter or with a filter installed backwards. Units shall be equipped with automatic shutdown system to stop fan in the event of a major rupture in the HEPA filter or blocked air discharge. Warning lights and audible alarms are required to indicate normal operation, too high a pressure drop across the filters (i.e., filter overloading), and too low of a pressure drop (i.e., major rupture is HEPA filter or obstructed discharge).
 7. Flexible metal hoses (ducts) of sufficient length must be provided to allow the units to discharge outside of buildings (where possible).
 8. Electrical components shall be approved by the National Electrical Manufacturers Association (NEMA) and Underwriter's Laboratories (UL). Each unit shall be equipped with overload protection sized for the equipment. The motor, fan, fan housing, and cabinet shall be grounded.
- B. Respirator Protection Equipment:
1. Air Purifying Respirators:
 - a. Respirator Bodies: Provide half face or full face type respirators. Equip full face respirators with a nose cup or other anti-fogging device as would be appropriate for use in air temperatures less than 32° F.
 - b. Filter Cartridges: Provide, at a minimum, HEPA type filters labeled with NIOSH and MSHA Certification for "Radionuclides, Radon Daughters, Dust, Fumes, Mists including Asbestos-Containing Ducts and Mists" and color coded in accordance with ANSI Z228.2 (1992). In addition, a chemical cartridge section may be added, if required, for solvents, etc., in use. In this case, provide cartridges that have each section of the combination canister labeled with the appropriate color code and NIOSH/MSHA Certification.

- c. Non-permitted respirators: Do not use any single-use, disposable or quarter face respirators.
2. Supplied Air Respirator Systems:
- a. Provide equipment capable of producing air of the quality and volume required by the reference standards applied to the job site conditions and crew size. Comply with provisions of this specification. If more stringent than the governing standard.
 - b. Face piece and hose: Provide a pressure-demand full face piece supplied air respirator incorporating an auxiliary self-contained breathing apparatus (SCBA) which automatically maintains an uninterrupted air supply in pressure demand mode with a positive pressure face piece. Respirator assembly, including hose, shall be NIOSH/MSHA approved. Provide hose approved by respirator manufacturer. Provide sufficient number of hoses for all workers and authorized visitors including regulatory inspectors and CONSULTANT's Representatives.
 - c. Backup air supply: Provide a reservoir of compressed air located outside the work area which will automatically maintain a continuous uninterruptable source of air automatically available to each connected face piece and hose assembly in the event of compressor shut-down, contamination of air delivered by compressor, power loss or other failure. Provide sufficient capacity in the back-up air supply to allow a minimum escape time of one-half hour times the number of connections available to the work area. Air requirement at each connection is the air requirement of the respirators in use plus the air requirement of an average sized adult male engaged in moderately strenuous activity.
 - d. Warning device: Provide a warning device that will operate independently of the power supply. Locate so that alarm is clearly audible above the noise level produced by equipment and work procedures in use, in all parts of the work area and to the compressor. Connect alarm to warn of:
 - 1. Compressor shut down or other fault requiring use of backup air supply.
 - 2. Carbon Monoxide (CO) levels in excess of 5 parts per million (ppm).
 - e. Carbon Monoxide (CO) Monitor: Continuously monitor and record on a strip chart recorder Carbon Monoxide (CO) levels. Place monitors in the air lines between compressor and back-up air supply and between backup air supply and workers. Connect monitors so that they also sound an alarm as specified under "Warning Devices".
 - f. Compressor Shut Down: Interconnect monitors, alarms and compressor so that compressor is automatically shut down and the alarms sounded if any of the following occur:
 - 1. Carbon monoxide (CO) concentrations exceed 5 ppm in the air line between the filter bank and backup air supply,
 - 2. Compressor temperature exceeds normal operating range.
 - g. Compressor Motor: Provide a compressor driven by an electric motor. Do not use a gas or diesel engines to drive compressor. Insure that electrical supply to be provided at the work site is adequate to energize motor.
 - h. Compressor Location: Locate compressor outside of work area in location that will not impede access to the work area, and that will not cause a nuisance by virtue of noise or fumes to the surrounding area.
 - i. Air Intake: Locate air intake remotely from any source of automobile exhaust or any exhaust from motors, or buildings.
 - j. After Cooler: Provide an after cooler at entry to filter system which is capable of reducing temperatures to outside ambient air temperatures.

- k. Self-Contained Breath Apparatus (SCBA): Configure system to permit the recharging of 1/2 hour 2260 PSI SCBA cylinders.
 - l. Air Quality For Supplied Air Respiratory Systems: Provide air used for breathing in Type "C" supplied air respiratory systems that meets or exceeds standards set for C.G.A. type 1 (gaseous Air) Grade H or CSA Z1801.1 whichever presents the most stringent quality standard.
- C. Wetting Materials: For wetting prior to disturbance of ACMs use amended water. The material must be odorless, non-flammable, non-toxic, non-irritating, and non-carcinogenic. It shall be applied as a mist using a low pressure sprayer recommended by the manufacturer. Use a mixture of surfactant and water which results in wetting of the asbestos containing material and retardation of fiber release during disturbance of the material equal to or greater than that provided by the use of one ounce of a surfactant consisting of 50% polyoxyethylene ester and 50% polyoxyethylene ether mixed with five gallons of water.
- D. Lock-Down Encapsulant: Provide penetrating or lock-down type encapsulants specifically designed for the use intended (as permitted). The material shall not contain organic solvents and be non-flammable, non-toxic, non-irritating, and non-carcinogenic.
- E. Polyethylene Sheeting: Provide flame resistant polyethylene film that conforms to requirements set forth by the National Fire Protection Association Standard 701, Small Scale Fire Test for Flame-resistant Textiles and Films. Provide largest size possible to minimize seams, 6.0 mils thick, frosted or black as required by CONSULTANT.
- F. Duct Tape: Provide duct tape in 2" or 3" widths as indicated, with an adhesive which is formulated to aggressively stick to sheet polyethylene.
- G. Spray Cement: Provide spray adhesive in aerosol cans which is specifically formulated to stick tenaciously to sheet polyethylene.
- H. Waste Containers: For asbestos waste, provide 6 mil thick leak-tight polyethylene bags labeled with required USEPA, USDOT, OSHA labels. If the waste material contains sharp edges or may otherwise puncture polyethylene bags, provide drums or other closed containers for storage, transportation, and disposal.
- I. Fans and Leaf Blowers: Provide two leaf blowers and one 20" diameter fan per 10,000 cubic feet of work area volume to be used for aggressive sampling techniques for clearance air testing.
- J. Filters: Provide cascaded filter units on drain lines from showers or any other water source carrying asbestos contaminated water from the work area. Provide units with disposable filter elements as indicated below. Connect so that discharged water passes primary filter and output of primary filter passes through secondary filter.
- 1. Primary Filter - Pass particles 20 microns and smaller
 - 2. Secondary Filter - Pass particles 5 microns and smaller.
- K. Sump Pump: Provide totally submersible waterproof sump pump with integral float switch. Provide unit sized to pump 2 times the flow capacity of all showers or hoses supplying water to the sump, through the filters specified herein when they are loaded to the extent that replacement is required. Provide unit capable of pumping debris, sand, plaster or other materials washed off during decontamination procedures without damage to mechanism of pump. Adjust float switch so that a minimum of 3" remains between top of liquid and top of sump pan.

- L. Warning Signs and Labels shall comply with Title 29 CFR, Parts 1926.1101 and 1926.62, and all other federal, state, or local codes and regulations.
- M. Ladders or Scaffolds shall be OSHA-approved, and be of sufficient dimensions and quantities so that all work surfaces can be easily and safely accessed by the CONSULTANT, workers, and other inspectors. Scaffold joints and ends shall be sealed with tape to prevent incursion of asbestos fibers.
- N. Hand Power Tools shall be equipped with HEPA-filtered local exhaust ventilation if used to drill, cut into, or otherwise disturb ACM.
- O. Pressure-Differential Recorder: provide air pressure sensing devices equipped with recorders for continuous monitoring of work area pressure differential. Provide sufficient quantities of chart paper and maintain devices until completion of work.
- P. Two Way Radios: provide Supervisor and all work area Foremen with compatible two-way radios. Provide three compatible two-way radios for the exclusive use of the CONSULTANT.
- Q. Lumber and Plywood: all lumber and plywood used for temporary barriers and Decontamination Facilities shall be new and of fire retardant grade to comply with the requirement for a flame spread of 25 or less with no evidence of significant progressive combustion when tested for thirty minutes duration under the Standard Test Method for surface burning characteristics of building materials (ASTM E-84, NFPA 255, UL 723 and AWPA C-20 and C-27). Lumber shall have minimum dimensions of 2" x 4" or as specified. Tongue and groove plywood shall be minimum 3/4 inch thickness, other plywood shall be minimum 1/2 inch thickness.
- R. Vacuum Cleaning Equipment shall be industrial type designed for such use, equipped with High Efficiency Particulate Air (HEPA) filters. Separate dedicated vacuum cleaners shall be used for asbestos work and shall be clearly labeled as to their intended use. No other method will be permitted. Vacuuming equipment shall be Model GA72 or GA73 as manufactured by NILFISK of America, Inc.; Model CMP-1500-P as manufactured by Car-Mon Products, Inc.; equipment manufactured by J. D. Brophy, Inc. or approved equal. The equipment shall be properly operated at all times and shall contain no air leaks. The CONSULTANT will inspect all vacuuming equipment prior to its use, and may request verification of the efficiency of the filtration. Each vacuum cleaner shall be emptied and thoroughly cleaned (inside the work area) at the conclusion of the project, or each use.

PART 3 – EXECUTION

3.1 PRE-ASBESTOS ABATEMENT PREPARATIONS

- A. The DESIGN-BUILDER shall prepare each work area as part of mobilization and as described in this section. Preparation work shall be performed according to the following general sequence of steps and procedures to ensure that proper containment and protection systems are installed prior to any work that could disturb ACMs and generate airborne asbestos fibers:
 1. Erect decontamination facilities and install HEPA exhaust units.
 2. Erect any required barriers, coverings, or access platforms/scaffolding; post access restriction signs; seal all openings into the work area; install any temporary access openings; and install polyethylene sheeting on all containment floors and walls.
 3. Provide temporary power and lighting as required for work areas.

4. Obtain CONSULTANT's written approval of all preparation work before starting pre-cleaning or removal of asbestos materials.
5. Clean and remove any non-fixed items to storage areas designated by the CONSULTANT. Items that cannot be cleaned to the satisfaction of the CONSULTANT shall be disposed of as asbestos waste.
6. Carefully clean all surfaces in the work area which may be contaminated with any dust or debris by using a vacuum equipped with a HEPA-filter.
7. Misting of the area shall be conducted throughout all stages of pre-cleaning and general removal to minimize the generation of airborne fibers.

3.2 ISOLATION OF WORK AREAS

- A. The DESIGN-BUILDER shall isolate each work area for the duration of work by completely closing and sealing all openings and doorways into the work area. Critical isolation/sealing shall be accomplished by using two (2) layers of 6-mil thickness plastic sheeting taped securely in place, or by caulking, including temporary construction as noted in Paragraph C below. The work area shall be protected and sealed airtight to the extent possible, and be subject to the inspection of the CONSULTANT.
- B. Emergency and fire exits shall be maintained, or alternative exits shall be established in accordance with applicable codes and regulations. Exits shall be checked daily against blockages or impediments to exiting. Entrances which shall not be used by workers shall be locked against unauthorized entry. Arrange exit door so that it is secure from outside the work area but permits exiting from the work area. Mark outline of door on Primary and Critical Barriers with luminescent paint at least 1" wide. Hang a razor knife on a string beside outline. Arrange Critical and Primary barriers so that they can be easily cut with one pass of razor knife. Paint words "EMERGENCY EXIT" inside outline with luminescent paint in letters at least one foot high and 2" thick. Provide lighted EXIT sign at each exit. Provide battery-operated emergency lighting that switches on automatically in the event of a power failure. Paint arrows on walls and floor with luminescent paint to direct workers to nearest emergency exit.
- C. Isolation Partitions and Barriers Open doorways etc. shall be sealed airtight with temporary structural partitions as follows:
 1. Erect wood or metal studs, 16" off center, and then cover the opening with 1/2" plywood sheeting (or equivalent) on work area side only.
 2. Cover the work side of this partition with a double layer of plastic sheeting with joints staggered and sealed with tape partition at floor, walls, ceiling, and all joints shall be caulked airtight.
- D. Construct rigid enclosures and install Decontamination Facilities as required.
- E. Provide temporary power and lighting to work areas, and ensure safe installation of temporary power sources and equipment per applicable electrical code requirements and OSHA requirements for temporary lighting in the environmental normal to asbestos abatement work areas.
- F. Seal all seams, joints, covers or casings with tape, and enclose fixed objects or equipment with a minimum of two layers of 6-mil plastic sheeting secured and sealed airtight with duct tape.
- G. Cover walls with two (2) layers of 6-mil thickness polyethylene sheeting. Use strapping to secure 6-mil thickness polyethylene sheeting to walls where needed. Joints in plastic sheets shall be taped and glued in a manner to prohibit air movement, and to prevent passage of water or other liquids. Any floor drains or other openings shall be sealed individually with two (2) layers of 6-mil sheeting and tape. Pits,

sumps, and other openings shall be covered with plywood sheathing secured so as to prevent a tripping hazard and then covered with two (2) layers of 6-mil thickness polyethylene sheeting.

- H. Install work area HEPA-filtered exhaust systems as previously specified.
- I. Warning Signs: The DESIGN-BUILDER shall post warning signs in English meeting the requirements of OSHA Title 29 CFR, Part 1926.1101 at the outside doorway to the decontamination facility which shall be the only non-emergency entrance into the work area. The CONSULTANT may also request that the DESIGN-BUILDER post additional warning signs around the work area or at other potential entrances or exposure points. Warning signs shall be readily visible to any person attempting to enter the work area.
- J. Access Restrictions: The DESIGN-BUILDER shall restrict access to work areas to persons who have previously been identified to the CONSULTANT; or persons who have legal jurisdiction over the work. The DESIGN-BUILDER's Supervisor shall at all times monitor the entrance to the decontamination facility to prevent unauthorized people from entering, and to maintain a written log of all people entering the work area.

3.3 APPROVAL OF PREPARATION WORK

- A. After each asbestos removal work area has been prepared as specified above, the DESIGN-BUILDER shall request a formal site inspection by the CONSULTANT. No pre-cleaning, removal, demolition, or other disturbance of ACMs, dust, or debris shall occur until the CONSULTANT has inspected and accepted the site preparation work.

3.4 ASBESTOS REMOVAL UNDER GENERAL CONTAINMENT PROCEDURES

- A. This section covers the removal of ACMs where conducted inside of a removal area which has been isolated and protected with polyethylene coverings, and has a HEPA-exhaust system and 3-room decontamination facility.
- B. Amended water (wetting agent), mixed and carefully applied using an airless sprayer as specified by the manufacturer, shall continuously be used to control the release of asbestos fibers from the friable material prior to and during removal. The amended water shall be applied in sufficient quantity to fully penetrate and saturate the friable material before it is removed. Where necessary, wetting shall commence up to 24 hours before removal work to ensure effectiveness.
- C. Removal:
 - 1. No asbestos removal work shall begin until the work area has been prepared to the satisfaction of the CONSULTANT as summarized in preceding Sections. Removal workers shall wear respirators and protective clothing as previously described throughout all removal, cleanup, and waste handling operations.
 - 2. Small test patches of asbestos material shall be wetted, and then removed and examined to determine degree of saturation prior to removing the bulk of the material. The DESIGN-BUILDER may use removal encapsulants instead of amended water; applied per manufacturer's and federal guidelines. Use of high rpm power equipment pressure washers or hydro-blasters for removal of asbestos materials is not acceptable. Hoses used for wash-down shall be limited to a certain size and pounds per square inch (psi) as specified herein.
 - 3. After large areas of the asbestos material have been fully wetted and tested, the asbestos shall be carefully removed in small sections by hand using scrapers or other suitable tools.

4. As the material is removed, it shall be promptly wetted and packed into impermeable, labeled 6-mil thickness polyethylene disposal bags and/or appropriate disposable drums. When each bag is full, the packaged material shall be sprayed with amended water, sealed, and transported to a temporary storage area inside of the work area. Accumulations of standing or free water shall not be allowed to collect on the work area floor.
 5. If the asbestos material is located on surfaces higher than 15 feet above the floor, the DESIGN-BUILDER shall provide fully-enclosed, dust-free chutes (with maximum incline of 60 degrees from horizontal), or scaffolding for waste containers to prevent dropping material down to the floor during removal.
 6. The DESIGN-BUILDER shall repeatedly mist the work area and spray the friable material to prevent it from drying out. Metal shovels shall not be used to pick up or move waste on a floor.
 7. Once the majority of the asbestos is removed, the DESIGN-BUILDER shall scrub the substrate surface and then thoroughly wash all surfaces to remove all remaining material.
 8. The DESIGN-BUILDER shall not be permitted to seal substrate surfaces from which asbestos material was removed with lockdown encapsulants.
 9. The DESIGN-BUILDER shall minimize contamination of the work floor, the exterior of disposal containers, and all other surfaces within the work area. At the end of each shift, all surfaces shall be cleaned of all materials and then HEPA-vacuumed or wet mopped and all debris packaged in 6-mil polyethylene bags.
 10. The decontamination facility shall be wet cleaned twice per shift using wet cleaning methods upon completion of any waste removal.
 11. Excessive water accumulation or flooding in the work area shall require work to stop until the water is collected and disposed of properly.
- E. After all indicated asbestos materials have been removed, perform exploratory demolition of components and equipment as directed by the CONSULTANT to confirm that all accessible asbestos materials have been identified and removed.

3.5 ASBESTOS REMOVAL USING GLOVEBAG ENCLOSURE

- A. This Section pertains to the removal of asbestos pipe and pipe fitting insulation using the glovebag technique in areas where appropriate.
- B. The DESIGN-BUILDER shall provide and utilize the following materials and equipment for this work: amended water, duct tape, plastic sheeting and waste bags, minimum of half mask passive respiratory protection, disposable coveralls, warning signs, HEPA-filtered vacuum cleaner, utility knife (retractable blade), tin snips as required for aluminum jacket, wire cutters (as required for wire reinforcing), industrial stapler (Bostitch or equivalent), nylon brush, and airless sprayer (equipped with + 3 LF of maximum 3/16" I.D. flexible tubing at end of wand for insertion into glove bag), chisels, etc.
- C. Precautions:
 1. Install critical isolation barriers and decontamination facility as specified herein. Establish negative air pressure within work area as specified herein. Provide one layer of 6-mil thickness fire retardant polyethylene sheeting on floor and fixed items (polyethylene sheeting on walls is not required).
 2. Provide supplementary lighting as required.

3. DESIGN-BUILDER shall provide a crew of two (2) or more well trained persons for each glove bag removal project. One member of the crew shall be dedicated to ensuring that the glove bag is secured to the component.

D. Preparation:

1. Pipe, Small Duct, and other Covered Components: Place necessary tools in bag. Wrap bag on pipe, seal with staples and tape leaving enough sealed space above pipe to allow easy access. Secure bag to pipe to support weight of stripped insulation and water (additional support for the bag may be provided by a chair or ladder, or by suspension).
2. Insert HEPA-vacuum nozzle and flexible tubing of wetting agent sprayer into hole location provided; seal airtight with duct tape.
3. Smoke Test: CONSULTANT shall inject smoke via a small hole and slowly squeeze bag. Repair leaks and holes as required.

E. Removal Procedure:

1. During removal, periodically wet the inside surfaces of bag and any waste for better visibility and fiber control. Use cold water to prevent fogging.
2. During removal, periodically use HEPA-vacuum to compensate for any leaks and to reduce airborne fiber levels.
3. Cut the insulation sharply for neat sealing of exposed insulation. Leave 4" minimum margin at the bag seal point for safety.
4. After removal and brushing, wash down all surfaces to below the levels where the bag will be sealed, and saturate the waste. Look for residue in folds, on the back side of pipe, etc.
5. Gather tools in a glove hand and pull the glove inside out. Seal the arm with + 6" tape and cut through the middle of the tape. Bend and re-tape the ends. Save the "bagged" tools for the next bag operation or clean by placing in pail of water.
6. Collapse the bag with the HEPA-vacuum. With vacuum still applied, seal the bag just above the glove level. Remove the nozzle and tubing. Place a 6-mil thickness waste bag over the glove bag and then carefully remove the glove bag from the component and immediately seal it in the waste bag. Check the component for loose waste and vacuum as required.
7. If no additional removal is planned, the glove-enclosed tools shall be immersed in a pail of water, opened and cleaned. (Rags and/or sponges can be used to clean other tools, but cannot be salvaged.) The water and other debris shall be disposed of as asbestos waste.

3.6 REMOVAL AND DISPOSAL OF ASBESTOS ROOFING AND FLASHING MATERIALS

- A. This paragraph specifies the removal, handling, and disposal of asbestos-containing asphaltic and felt built-up roofing, flashing, tar, and other roofing products. The term roofing materials, as used in this Section, refers to all ACM roofing, flashing, tar etc. products found at the site.
- B. Removal of roofing materials will be in a manner that minimizes overall destruction of the roofing components and ensures that no visible emission of asbestos or other dusts occurs. Roofing materials cannot be drilled, sawed, or mechanically abraded in any fashion.
- C. Once removed from the substrate, roofing materials will be immediately prepared for transportation to the approved landfill. The DESIGN-BUILDER shall remove no more roofing material than can be

transported from the site by the end of daily operations. Stockpiling or roofing materials on site is not permitted.

- D. Roofing materials will be handled in accordance with the following:
 - 1. Roofing materials will be maintained in a wet condition during all handling/removal procedures.
 - 2. Large roofing material components will be placed into approved dumpsters or transport vehicles immediately upon removal from the building.
 - 3. All roofing material debris or rubble (items small enough to be placed into standard asbestos disposal bags) will be bagged and labeled for disposal as asbestos waste.
- E. Transportation and disposal of roofing materials will be as specified in this Section, 310 CMR 18.00-19.00, other applicable regulations, and the following:
 - 1. DESIGN-BUILDER shall provide the following types of waste dumpsters:
 - a. Fully enclosed units for all roofing material that is bagged or wrapped and labeled for disposal as asbestos waste.
 - b. Fully enclosed or covered open-top units for large, unwrapped sections of roofing material.
 - 2. All roofing material that is bagged or wrapped and labeled as asbestos waste will be disposed of at a landfill approved for disposal of asbestos waste. Large, unwrapped sections of roofing material may be transported to an approved landfill and disposed of as general demolition debris, provided the landfill will accept such waste. All open-top dumpsters into which roofing material has been placed will be removed from the work site by the end of the daily operations and transported to the approved landfill site.
- F. DESIGN-BUILDER shall clean-up any remaining debris/residue to the point of no visible debris, as required by CONSULTANT.

3.7 REMOVAL OF PIPE AND PIPE FITTING INSULATION

- A. Removal of asbestos-containing pipe and pipe fitting insulations shall be in accordance with all applicable regulations, including MassDEP's Asbestos Cement Pipe Guidance Document (June 2011). Prior to removal, the DESIGN-BUILDER, in consultation with the CONSULTANT, should determine whether the pipe is damaged, cracked or broken, and then follow the applicable Not Damaged or Damaged procedures as specified in the above guidance document. At a minimum, the following work practices shall apply:
 - 1. Workers shall wear protective clothing and half-mask, dual-cartridge, HEPA-filtered respirator, at a minimum.
 - 2. The work area shall be isolated as required by regulations and to the satisfaction of the CONSULTANT.
 - 3. Place 6 mil (0.006 inch) thick polyethylene sheeting below area where pipe and pipe fitting insulation is being removed.
 - 4. Using wet methods, remove the pipe and pipe fitting insulation in a manner which precludes the pipe and pipe fitting insulation from becoming friable.
 - 5. Properly decontaminate all non-ACM materials in contact with the asbestos-containing pipe and pipe fitting insulation, and dispose of as construction debris. All non-ACM materials in contact with the asbestos-containing pipe and pipe fitting insulation, not properly decontaminated, shall

be wrapped in two layers of 6-mil thickness polyethylene sheeting and disposed as asbestos contaminated waste.

6. Properly wet and double bag all pipe and pipe fitting insulation and associated debris, and all non-ACM materials contaminated with asbestos for disposal as asbestos containing waste material (ACWM).
7. Using a HEPA vacuum clean all residual asbestos-containing pipe and pipe fitting insulation remaining in the work area.

3.8 REMOVAL OF ELECTRICAL COMPONENTS

- A. Removal of asbestos-containing electrical and signal system components shall be in accordance with all applicable regulations. At a minimum, the following work practices shall apply:
 1. Workers shall wear protective clothing and half-mask, dual-cartridge, HEPA-filtered respirator, at a minimum.
 2. The work area shall be isolated as required by regulations and to the satisfaction of the CONSULTANT.
 3. Place polyethylene sheeting below area where electrical fuses are being removed.
 4. Remove the electrical components in a manner which precludes the asbestos material from becoming friable.
 5. Properly decontaminate all non-ACM materials in contact with the asbestos-containing electrical components, and dispose of as construction debris. All non-ACM materials in contact with the asbestos-containing electrical fuses, not properly decontaminated, shall be wrapped in two layers of six-mil thickness polyethylene sheeting and disposed as asbestos contaminated waste.
 6. Properly wet and double bag all electrical components and associated debris, and all non-ACM materials contaminated with asbestos for disposal as ACM debris.
 7. Using a HEPA vacuum clean all residual asbestos-containing material remaining in the work area.

3.9 SELECTIVE DEMOLITION AND REMOVAL OF ADDITIONAL SUSPECT ACM

- A. Selective exploration to check for additional ACM suspected to exist at the Site shall be performed by DESIGN-BUILDER to the extent required by CONSULTANT. DESIGN-BUILDER shall construct a total isolation work area at each point of selective exploration if the work cannot be performed in a manner which would not disturb the suspected materials.
- B. Removal of asbestos (if confirmed by the CONSULTANT's bulk sampling) identified during selective exploration will be performed according to this Specification, applicable regulations, and appropriate work plans acceptable to the AUTHORITY.

3.10 ASBESTOS WASTE DISPOSAL PROCEDURES

- A. The DESIGN-BUILDER shall package, label, and remove all asbestos waste (including asbestos waste contaminated by other hazardous materials) from the work area as specified below. Packaging shall be accomplished in a manner that minimizes waste volume, but insures waste containers shall not tear or break. Transportation and disposal of the containerized waste at a permitted landfill shall be the responsibility of the DESIGN-BUILDER.

- B. Definition: Wastes are defined as all asbestos-containing or potentially contaminated materials or other items which have not been completely cleaned or sealed to the satisfaction of the CONSULTANT while on the work area, and must be removed from the Site. Asbestos wastes may include building materials, insulation, disposable clothing and protective equipment, plastic sheeting and tape, exhaust systems or vacuum filters, DESIGN-BUILDER equipment, or other materials designated by state or local authorities or the CONSULTANT which have been potentially contaminated with asbestos and have not been fully cleaned.
- C. Waste Labeling:
1. Warning labels, having waterproof print and permanent adhesive in compliance with OSHA, USEPA and USDOT requirements, shall be affixed to or printed on the sides of all waste bags or transfer containers. Warning labels shall be conspicuous and legible.
 2. In compliance with NESHAPS, Title 40 CFR, Part 61.150, all waste containers or bags shall be labeled with the following generator information:
 - Name of waste generator.
 - Location of where waste was generated.
- D. Wetting of Waste: A fine water spray shall be used to keep the top layers of waste in containers thoroughly wet at all times. When a waste bag is full, air within the bags shall be evacuated with a HEPA-equipped vacuum and be securely sealed with tape or other secure fastener.
- E. Waste Container Decontamination and Removal Procedures: The following procedures shall be followed whenever containers or equipment are removed from the work area.
1. The clean room shall be considered a holding area only during the period of active waste transfer for the purpose of the loading of carts or drums. Storage of waste and carts (or drums) in the clean room is prohibited.
 2. Waste removal shall not occur during worker shift changes or when workers are showering or changing. Care shall be taken to prevent short circuiting and cycling of air outward through the shower and clean room when used for waste removal.
 3. Workers are to be stationed in each room/area of the decontamination facility to transfer the containers and equipment to or from adjacent sections. These workers shall not cross the airlocks into the adjacent areas/rooms until the waste or equipment transfer is finished for that period and the workers have gone through decontamination as required by these Specifications. The workers in the clean room or holding area shall enter from uncontaminated areas with appropriate personal protective equipment; or prior to the start of waste transfer, these workers shall exit the work area, fully decontaminated, and subsequently don clean personal protective equipment.
 4. External surfaces of contaminated containers and equipment shall be cleaned by wet cleaning and/or HEPA vacuuming in the work area before moving such items into the decontamination facility airlock. Workers shall not enter the airlock during this procedure.
 5. The containers of waste and the equipment shall be removed from the airlock by workers stationed in the washroom during waste removal operations.
 6. Once in the washroom, external surfaces of contaminated containers and equipment shall be cleaned a second time by wet cleaning.
 7. The cleaned containers of waste and equipment shall be placed in uncontaminated leak-tight plastic bags (or 6-mil thickness polyethylene sheeting if physical characteristics necessitate and permit). Air volumes shall be minimized, and the bags or sheeting shall be sealed.

8. The clean re-containerized items shall be moved into the airlock for subsequent transfer to the holding area. The washroom workers shall not enter this airlock or the work area until waste removal is finished for the period.
 9. Re-containerized items and cleaned equipment shall be removed from the airlock to the holding area by workers who have entered from uncontaminated areas with appropriate personal protective equipment.
 10. The re-containerized items of waste and cleaned, bagged equipment shall be placed in closed top, watertight plastic carts or drums. These carts or drums shall be held in the holding area pending removal. The carts or drums shall be HEPA-vacuumed or wet-cleaned following the removal of the containers of waste from them.
 11. The exit from the decontamination facility shall be monitored and secured at all times to prevent unauthorized entry.
 12. The carts or drums may be temporarily stored in a holding area at the work site outside the workplace until a transport vehicle arrives, but such storage areas must be acceptable to the CONSULTANT.
- F. If a separate equipment and waste decontamination unit is provided, take all equipment and waste material from the work area through the decontamination facility according to the following procedures:
1. Thoroughly wet clean contaminated equipment or waste container in work area and pass into Wash Room.
 2. Once inside the wash room, wet clean equipment or waste containers. Place poly bags in a second clean poly bag. Wrap large items in a second layer of 6-mil thickness poly.
 3. When cleaning is complete, pass items into holding area. Worker stationed in Wash Room shall not enter the holding area. This worker shall exit via the work area through the personnel/decontamination facility.
 4. Require worker stationed in holding area to wear full protective clothing and appropriate respiratory protection. These workers shall not enter the waste wash area.
- G. Guidelines for the Use and Decontamination of Fiber Drums: (These procedures apply to the use of fiber drums only.)
1. Prior to fiber drums entering the work area, the drums should be prepared in the following manner:
 - a. Place the drum in a two (2) mil thickness minimum plastic bag
 - b. Fold the top of the bag over the top of, and into the drum.
 - c. Seal the bag to the inside of the drum using tape and/or spray on adhesive.

NOTE: The bag must be sealed entirely to the inside of the drum prior to the drum being brought into the work area.
 2. In the work area, any material which is likely to puncture or tear a 6 mil thickness polyethylene bag (i.e., fire brick, demolition debris) shall be double bagged in 6 mil thickness polyethylene bags, sealed and placed inside the drum.
 3. Prior to removing the filled drum from the work area, the metal lid shall be applied to the top of the drum and fastened either with a locking-ring or with duct tape.
 4. The drum shall be cleaned and wet-wiped in the work area, then passed through the air lock into the waste wash room of the waste disposal decontamination enclosure system.

5. Cut the bag at the top of the drum directly underneath the lid. Remove the drum from the bag and dispose of the bag as ACM.
 6. Wet-wipe the metal lid of the drum and pass it through the air lock into the holding area of the waste decontamination enclosure system.
 7. At this time, the appropriate warning labels shall be applied to the drum and the drum may be removed for disposal.
- H. Use of Gaylord boxes for waste disposal shall only be permitted for asbestos waste where specifically identified in the DESIGN-BUILDER's Work Plan and approved by the MassDEP and CONSULTANT. The Work Plan shall describe in detail the proposed Gaylord boxes and waste loading procedures. Gaylord boxes shall be double lined with 6 mil polyethylene sheeting and be properly sealed, labeled, etc. The CONSULTANT may choose to disallow the use of Gaylord boxes at any time that do not meet the detail provided in the Work Plan, or if the work is found to deviate in any way from the Work Plan, or if damaged boxes are observed being used at the Site, or if the boxes are found to be leaking. If the use of Gaylord boxes is disallowed by CONSULTANT, all waste in such boxes shall immediately be properly repackaged into acceptable containers in the work area at DESIGN-BUILDER's own expense.
- I. Waste Container Storage: The container used for the storage of bagged contaminated waste shall be an enclosed dumpster. Dumpster shall have a solid metal roof, solid metal door with padlock. Line the cargo area with two layers of a 6 mil thickness polyethylene sheeting to prevent contamination from damaged or leaking containers. Floor sheeting shall be installed first and shall extend up the sidewalls 24 inches minimum. Wall sheeting shall be overlapped and taped securely into place. No un-bagged contaminated waste or non-asbestos waste shall be stored in these dumpsters. Ensure that bags placed in dumpsters are undamaged. Warning signs shall be posted on the dumpster in accordance with Sections Title 29 CFR, Part 1926.1101 of the OSHA regulations.
- J. Waste Removal Scheduling: All waste containers shall be decontaminated and removed from the site before final cleanup is started and isolation barriers are taken down. The DESIGN-BUILDER must pre-schedule and obtain the agreement of the CONSULTANT for all time periods DESIGN-BUILDER desires to remove waste bags from the facility. The CONSULTANT must observe removal of all waste containers to verify their condition and estimate the total volume of waste material (to the nearest cubic yard). DESIGN-BUILDER shall then insert the quantity on the Disposal Certificate and a hazardous waste manifest (if required), and arrange for the original of these forms to accompany the waste as it is transported to the landfill.
- K. Waste Transportation and Disposal Regulations: It is the responsibility of the DESIGN-BUILDER to determine and insure that he is complying with: 1) the current waste handling regulations applicable to each work site; and 2) the current regulations for transporting and disposing waste at each ultimate disposal landfill. The DESIGN-BUILDER must comply fully with these regulations; and with all USDOT, state, local, and USEPA requirements. Where required, the DESIGN-BUILDER's waste hauler and disposal DESIGN-BUILDER shall maintain a valid hazardous waste transporter's permit and identification number; and obtain, complete, and fully comply with any other local hazardous waste manifesting requirements. A copy of all shall be sent to the AUTHORITY after disposal is completed and all required data and signatures have been obtained. The DESIGN-BUILDER shall return the original WSR within 10 working days of waste shipment from the site and within the timeframes required by applicable regulations.

3.11 CLEANING AND FINAL DECONTAMINATION

- A. This section applies to cleaning all work areas where asbestos removal work has been performed. After all asbestos-containing (or contaminated) materials have been removed, the DESIGN-BUILDER shall

remove all wastes and perform a thorough final cleaning and decontamination of each work area per the methods indicated below. Final cleaning shall be performed only after all waste is packaged and removed, but prior to dismantling any barrier, decontamination facility, or protective coverings.

- B. Cleaning shall be subject to the CONSULTANT's acceptance based on a visual inspection (including surface dust wipe tests if appropriate) and air sampling performed using NIOSH Method 7400. HEPA-exhaust systems shall operate continuously throughout the cleaning and air testing processes until the CONSULTANT agrees to their shutdown and removal from the site. The DESIGN-BUILDER shall notify the CONSULTANT in writing at least 12 hours in advance of the expected completion time of site cleaning to allow the CONSULTANT to schedule air clearance sampling.
- C. Methods and Approvals: Cleaning methods and approvals shall consist of the following tasks performed in the listed order:
1. Remove all visible accumulations of asbestos debris on the protective coverings on floors, walls, and other surfaces, and then HEPA vacuum all surfaces to pick up excess water and gross saturated debris. A wet-dry shop vacuum, dedicated to asbestos abatement, may be used before HEPA vacuuming.
 2. After HEPA-vacuuming, the work area air shall be lightly misted, and then all protective coverings on ceilings, walls, floors, and other items in the work area shall be wiped thoroughly clean (first cleaning).
 3. After the DESIGN-BUILDER has completed the above steps (1) and (2), DESIGN-BUILDER shall request the CONSULTANT to inspect the site. To facilitate scheduling of this inspection, the DESIGN-BUILDER shall notify the CONSULTANT of the anticipated completion time of the above initial cleaning work 12 hours in advance.
 4. If the CONSULTANT observes any asbestos waste, debris or fibers within the work area during the inspection, the DESIGN-BUILDER shall perform additional cleanup and decontamination.
 5. If the CONSULTANT accepts the first cleaning, the waste bags shall then be removed from the work area using the procedures described herein. The bottom layer of protective poly coverings, the Decontamination Facilities, the HEPA exhaust systems and all barrier walls shall remain in place and in use. The DESIGN-BUILDER shall not apply any encapsulants to any surfaces except where noted herein.
 6. Carefully remove the upper layer of all protective poly coverings on walls and other surfaces and package them in 6-mil thickness waste bags. After these upper protective coverings are removed, the work area shall be completely vacated for at least twelve (12) hours to allow fiber settling while the CONSULTANT collects and analyzes an initial set of air samples according to NIOSH Method 7400 (PCM).
 7. The DESIGN-BUILDER shall then perform a second cleaning of all surfaces in the work area by HEPA-vacuuming and wet washing. Upon the acceptance of the CONSULTANT, all remaining protective poly coverings shall be carefully removed and disposed of as described herein. However, the barrier walls, decontamination facilities, HEPA-exhaust systems, and primary isolation seals shall remain in place and in use. The DESIGN-BUILDER shall then perform a third cleaning of all surfaces in the Work Area.
 8. After successful completion of the final air clearance testing, the DESIGN-BUILDER shall carefully remove the decontamination facilities and any temporary barrier walls or tunnels. The HEPA-exhaust systems shall be removed only after all other items are removed. A HEPA-vacuum shall be kept on-site during this final disassembly work to cleanup any dust or debris.

9. If any of the PCM air sample results are above 0.010 fibers per cubic centimeter of air (f/cc), the DESIGN-BUILDER shall be required to perform additional cleaning and decontamination; and the above inspection and air sampling shall be repeated by the CONSULTANT.
10. Workers shall wear approved respiratory and personal protective equipment throughout all cleaning and waste disposal activities.

3.12 MONITORING, TESTING AND INSPECTION

- A. The performance and execution of the Work will be closely and continuously monitored by the CONSULTANT. Monitoring required to demonstrate compliance with OSHA regulations is the responsibility of the DESIGN-BUILDER. The monitoring work shall be performed both inside the work area and the surroundings to ensure full compliance with these Specifications. The DESIGN-BUILDER shall provide full cooperation and support to the CONSULTANT throughout the work. Monitoring and inspections shall include air samples in the workspace, air samples in the areas surrounding the work area and the outside, checking of the DESIGN-BUILDER's standard operating procedures, engineering controls, respiratory protection equipment, packing, packaging, transporting and disposal of asbestos, decontamination facilities and procedures, and any other aspects of the abatement process that may impact the health and safety of the people and the pollution of the environment.
- B. The AUTHORITY shall bear all cost in connection with the air sampling performed by the CONSULTANT for the initial analyses. However, all costs of all subsequent laboratory analyses and CONSULTANT's labor taken because a final visual inspection was not satisfactory or the limits specified (i.e., 0.010 f/cc) were exceeded on the initial air clearance or other type of sampling and analysis, shall be borne by the DESIGN-BUILDER.

3.13 AIR MONITORING BY CONSULTANT

- A. This paragraph describes air monitoring carried out by the CONSULTANT to verify that the outside environment remains uncontaminated (from asbestos dust and airborne levels of 0.010 f/cc). This Section also sets the action required by the DESIGN-BUILDER if an OSHA PEL is met or exceeded. The CONSULTANT will be conducting air monitoring during the course of the Project. In no way shall this monitoring replace that required of the DESIGN-BUILDER.
- B. All perimeter air sampling and analysis will be performed by the CONSULTANT. A complete record of all air monitoring sampling and analytical results will be furnished to the AUTHORITY.
- C. Personnel air monitoring required by OSHA is work of the DESIGN-BUILDER and is not covered in this paragraph.
- D. Work Area Isolation: The purpose of the CONSULTANT's air monitoring will be to detect faults in the work area isolation such as:
 - Contamination of the environment outside of the work area with airborne asbestos fibers;
 - Failure of filtration or rupture in the negative pressure system

Should any of the above occur, the DESIGN-BUILDER shall immediately cease asbestos abatement activities until the fault is addressed. Work shall not recommence until authorized by the CONSULTANT.

- E. Work Area Airborne Fiber Count: The CONSULTANT will monitor airborne fiber counts inside the work area. The purpose of this air monitoring will be to detect airborne fiber counts which may

significantly challenge the ability of the work area isolation procedures to protect the nearby areas from contamination by airborne fibers.

- F. **Work Area Clearance:** To determine if the elevated airborne fiber counts encountered during abatement operations have been reduced to an acceptable level, the CONSULTANT will sample and analyze air per this Section and 453 CMR 6.00, using either PCM or Transmission Electron Microscopy (TEM) analysis, as determined by the CONSULTANT.

- G. **Airborne Fiber Counts:**
 - 1. **Inside Work Area:** Maintain an average airborne count in the work area of less than 0.5 fibers/cc. If the fiber counts rise above this figure for any sample taken, revise work procedures to lower fiber counts. If the TWA fiber count for any work shift or 8-hour period exceeds 1.0 fibers/cc, stop all work, leave negative air system in operation and notify CONSULTANT. Do not recommence work until authorized in writing by CONSULTANT. If airborne fiber counts exceed 2.0 fibers/cc for any period of time, cease all work until fiber counts fall below 0.5 fibers/cc and notify CONSULTANT. Do not recommence work until authorized in writing by the CONSULTANT.
 - 2. **Outside Work Area:** If any air sample taken outside of the work area exceeds 0.010 f/cc immediately and automatically stop all work.
 - a. Decontaminate the affected area in accordance with these Specifications.
 - b. Respiratory protection shall be worn in affected area until area is cleared.
 - c. Leave Critical Barriers in place until completion of work and insure that the operation of the negative pressure system in the work area results in a flow of air from the balance of the work area into the affected area.
 - d. If the exit from the clean room of the personnel decontamination unit enters the affected area, establish a temporary decontamination facility consisting of a Shower Room and Changing Room as specified herein. After cleaning and decontamination of the affected area remove the Shower Room and leave the Changing Room in place as an air lock.
 - e. After certification of visual inspection in the work area remove critical barriers separating the work area from the affected area. Final air samples will be taken within the entire area.

- H. **Fibers Counted:** The following procedure will be used to resolve any disputes regarding fiber types when a project has been stopped due to excessive airborne fiber counts. "Airborne Fibers" referred to above include all fibers regardless of composition as counted in the NIOSH 7400 Procedure. If work has stopped due to high airborne fiber counts, air samples may be secured in the same area by the AUTHORITY for analysis by TEM. "Airborne Fibers" counted in samples analyzed by TEM shall be only asbestos fibers, but of any diameter and length, and will be analyzed and reported consistent with the applicable regulations and practices.

3.14 AIR MONITORING BY DESIGN-BUILDER

- A. The DESIGN-BUILDER shall perform air monitoring as required to meet OSHA Requirements for maintenance of TWA fiber counts for types of respiratory protection provided. CONSULTANT will not be performing air monitoring to meet these OSHA requirements.

- B. The sampling person and analysis laboratory performing this work shall be an independent party not financially or managerially connected to the DESIGN-BUILDER, acceptable to the CONSULTANT, and shall meet all requirements of 453 CMR 6.00 and this Specification.

- C. The laboratory shall be successfully participating in the AIHA/NIOSH Proficiency Analytical Testing (PAT) program and be certified by the Commonwealth of Massachusetts.
- D. Air sampling materials and equipment requirements are as follows:
 - 1. Sampling for analysis by phase contrast microscopy shall employ cellulose ester collection filters with 0.8 μm pore-size or less. Cassettes shall be loaded with filters under clean laboratory conditions. A 5 μm pore-size multi-cellulose ester backing filter shall be placed behind the collecting filter, followed by the cellulose support pad and the cassette base. A metal cowl or an electrically conductive cowl shall be used in conjunction with the sampling train.
 - 2. The filter assembly shall be upstream of all other components in the sampling train. An air flow measuring device (when used) shall be downstream of the filter and the pump assembly, or integral with the pump assembly.
 - 3. Sampling pumps shall supply constant flow.
 - 4. An air flow measuring/metering device shall be used, and shall be high quality rotometer, mass flow, dry gas meter or critical orifice. Measuring devices shall have a range of at least 1.5 times the desired flow rate and be readable to at least + 5% of the desired flow rate. They shall be calibrated against standards of higher accuracy before and after sampling. The calibrations shall be recorded.
- E. Numbers and frequencies of personal air sampling shall be as required by OSHA regulations but not less than one (1) sample per eight (8) hour work shift during times of asbestos removal work.
- F. Results of sample analysis shall be provided to the CONSULTANT within twenty-four (24) hours of collection.
- G. The DESIGN-BUILDER shall use a pre-approved "chain-of-custody" form for all personal air samples he collected.
- H. Personal sampling, including all costs, shall be the complete responsibility of the DESIGN-BUILDER.

3.15 FINAL VISUAL INSPECTION AND WORK AREA CLEARANCE

- A. Upon completion of removal work, but prior to commencing encapsulation or cleaning of the work area, the DESIGN-BUILDER shall request the CONSULTANT to conduct a final visual inspection for any visible debris.
- B. Following a successful final visual inspection, the final clearance testing shall take place using aggressive air sampling techniques as specified in 453 CMR 6.00. The DESIGN-BUILDER shall supply and operate additional circulating fans and leaf blowers as directed by the CONSULTANT during this final testing to ensure effective air circulation. The final test shall consist of taking PCM or TEM air samples in the work area, and analyzing the samples per 453 CMR 6.00.
- C. Surface wipes and/or bulk samples may also be collected and analyzed at the option of the CONSULTANT to confirm that all microscopically detectable asbestos has been removed. If the results of the final visual inspection or final air sampling are not satisfactory, thorough wet cleaning and/or HEPA vacuuming shall be repeated until the required decontamination levels are achieved. The DESIGN-BUILDER shall bear all costs for additional inspections, sampling, analytical costs and cleaning until the area passes final air clearance air sampling.

- D. After achieving the level of cleanliness and decontamination as specified herein and as confirmed by the final inspections and sampling, the DESIGN-BUILDER shall carefully remove the decontamination facilities and any temporary barriers and DF's. Use HEPA vacuums during final disassemble work to cleaning any dust or debris.
- E. The DESIGN-BUILDER shall, at no additional charge, install and provide AC power, outlets, and extension cords for the CONSULTANT to collect the area and final air clearance samples as required herein.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02081

HAZARDOUS MATERIALS ABATEMENT

PART 1-GENERAL

1.1 GENERAL

- A. This Section specifies all labor, materials, tools and equipment necessary for the transportation and disposal of oil and hazardous materials (OHM) included in this section.
- B. The DESIGN-BUILDER shall be responsible for the characterization, handling, stockpiling, transportation and disposal/reuse/recycling of OHM, including, but not limited to, debris and containerized materials specified under this contract.
- C. All provisions of this Section relating to the health and safety of workers and the general public, as well as protection of the environment are minimum standards. The DESIGN-BUILDER is responsible for determining whether any legal requirements or prudent conservative work practices require any additional and/or more stringent protective measures, and implementing such measures if deemed necessary. Nothing in this Section shall be deemed to relieve the DESIGN-BUILDER from any liability with respect to any such legal requirements or requirements of prudent conservative practice.
- D. All work-site preparations and practices will be conducted in accordance with all Federal, State and appropriate City and other local regulations, standards and codes pertaining to worker health protection, protection of the public health and the environment, and the removal, sampling, transportation, and disposal of oil and/or hazardous materials.
- E. All personnel involved in the removal of potentially hazardous materials shall demonstrate that they are certified to the HAZWOPER requirements in accordance with applicable OSHA requirements for hazardous material handling.
- F. The DESIGN-BUILDER is responsible, subject to review by the AUTHORITY and their Engineer, to completely characterize the OHM in accordance with disposal facility requirements and all applicable laws and regulations and to dispose of the materials in a safe and legal manner.
- G. The DESIGN-BUILDER shall retain an environmental consultant to assist the DESIGN-BUILDER in identifying, managing and disposing of all OHM materials encountered at the Site.
- H. The DESIGN-BUILDER shall retain a laboratory to assist the DESIGN-BUILDER in providing guidance in dealing with all OHM materials encountered at the Site. The DESIGN-BUILDER's selected laboratory shall be certified, as applicable, by the Commonwealth of Massachusetts to perform the analyses required to properly dispose of waste material encountered.
- I. The DESIGN-BUILDER is required to recycle/reuse recovered materials in lieu of disposal if the material is of acceptable physical and chemical quality.

1.2 RELATED WORK

- A. Other specification sections that relate to the work include but are not limited to the following:
 - 1. Section 01060 – PERMITS AND REGULATORY REQUIREMENTS
 - 2. Section 01560 – TEMPORARY CONTROLS
 - 3. Section 01800 – SUSTAINABILITY REQUIREMENTS

- 4. Section 02080 – ASBESTOS REMOVAL
- 5. Section 02090 – LEAD ABATEMENT
- 6. Section 02091 – REMOVAL OF CONTAMINATED FIXTURES
- 7. Section 02092 – PCB BULK PRODUCT WASTE ABATEMENT
- 8. Section 02221 – DEMOLITION

1.3 DESCRIPTION

- A. Work covered by this Section consists of furnishing all labor, equipment, materials, and services to remove and dispose of potentially hazardous materials encountered during the Green Line Extension construction project.
- B. The materials encountered may be discovered in areas where demolition or alterations will take place that will not be described in other sections. These materials may include, but are not limited to, hazardous building materials, PCB-containing or mercury-containing equipment, motors/pumps, batteries, white goods, compressed gas cylinders, containerized paints, oils, and lubricants, miscellaneous cleaning/maintenance products and unlabeled containers. The materials may also include contaminated sediments, debris and/or miscellaneous waste contained within pipes, vaults or other structures. The DESIGN-BUILDER may encounter these potentially hazardous materials when performing Work covered by this Section.

1.4 DEFINITIONS

- A. Oil or Hazardous Materials (OHM)
 - 1. Material defined as OHM in accordance with 310 CMR 40.0000 and 310 CMR 30.000.
- B. Resource Conservation and Recovery Act (RCRA) and State Regulated Hazardous Waste
 - 1. OHM defined as a RCRA characteristic or listed hazardous waste in accordance with Title 40 CFR, Part 261 and/or;
 - 2. OHM defined as a hazardous waste in accordance with 310 CMR 30.000 or 310 CMR 40.0000.
- C. Toxic Substance Control Act (TSCA) Regulated Waste
 - 1. OHM which exceeds the TSCA criteria for Polychlorinated Biphenyls (PCBs) as defined in Title 40 CFR, Part 761, Subpart D.
- D. RCRA/TSCA Regulated Waste
 - 1. OHM which meets the requirements as both a RCRA hazardous waste and a TSCA-regulated waste as defined above.
- E. In-State Lined Landfill - This type of facility shall be approved by the Commonwealth of Massachusetts to accept waste that is not considered a hazardous waste, as defined in 310 CMR 30.000 and 310 CMR 40.0000, is not classified as a RCRA characteristic waste or RCRA listed waste as defined in Title 40 CFR, Part 261 and is not classified as a TSCA regulated waste as defined in Title 40 CFR, Part 761.
- F. Non-Hazardous Special Waste
 - 1. Materials containing OHM not otherwise categorized.

1.5 QUALITY ASSURANCE

- A. The DESIGN-BUILDER shall utilize hazardous waste removal and transportation firms experienced in hazardous waste work similar in material and extent to that indicated for this Project.
- B. Refrigerant Recovery Technicians must be certified by an EPA-approved certification program.
- C. DESIGN-BUILDER shall comply with governing EPA and DEP notification regulations before beginning or removing any hazardous waste materials.
- D. The DESIGN-BUILDER's Environmental Consultant will be knowledgeable in the characterization, removal, transportation and disposal of OHM to provide guidance during the work of this Section.
- E. Manifests/Bills of Lading
 - 1. A uniform hazardous waste manifest, bill of lading, or other applicable documentation is required for the removal from the premises, and disposal of all items included in this Section. The DESIGN-BUILDER shall obtain and prepare all such documents. The DESIGN-BUILDER shall provide the AUTHORITY and the Engineer with a copy of the manifest(s), bills of lading, and any other shipping documents at least 5 business days prior to transport of the material from the Site. The disposal manifests, bills of lading and any other shipping documents will be reviewed, authorized and signed by the AUTHORITY.
 - 2. Each manifest, bill of lading as well as all other documentation required herein, shall be clearly and distinctly marked with the contract number, specific waste origin, and removal and disposal order number as applicable. If blocks are not provided, the contract and removal and disposal order information shall be placed in the upper right hand corner of each document.
 - 3. Each manifest, bill of lading, or other applicable documentation, shall note the truck registration number, state of registration, name of driver, and date of removal of material from the Site.
- F. Inspection:
 - 1. All services shall be subject to inspection by the AUTHORITY or its authorized representatives. The AUTHORITY will have the right, but not the duty, to inspect and obtain copies of all written licenses, training records, permits, and approval issued by any entity or agency to the DESIGN-BUILDER or its subcontractors which are applicable to the performance of services under this contract; to inspect and test, at its own expense, transportation vehicles or vessels, containers, and disposal facilities provided by the DESIGN-BUILDER; and to inspect the handling, loading, transportation, storage and disposal operations conducted by the DESIGN-BUILDER in the performance of this contract.
 - 2. The Engineer will have the right to inspect and obtain duplicates of all samples collected by the DESIGN-BUILDER. If requested by the AUTHORITY or the Engineer, the DESIGN-BUILDER shall collect and supply these samples to the Engineer for analyses by the Engineer's laboratory.
 - 3. The AUTHORITY and its Engineer will be afforded free access to any facility used by the DESIGN-BUILDER in performing services under this contract, including, but not limited to, offices and facilities where contract related records are retained.
 - 4. The DESIGN-BUILDER is solely and exclusively responsible for the quality of all services performed under this contract. The AUTHORITY's right to conduct inspections at DESIGN-BUILDER's facilities does not relieve the DESIGN-BUILDER of this responsibility. Neither the AUTHORITY, nor their authorized representatives' failure to make such inspection, nor

failure to discover nonconforming services, will impose any liability on the AUTHORITY or their Engineer, nor shall it prejudice the rights of the AUTHORITY thereafter to reject services, and shall not relieve the DESIGN-BUILDER of its obligation to perform work strictly in accordance with the contract and applicable local, state and federal regulations.

5. The DESIGN-BUILDER in its agreement with its subcontractors, shall ensure that the inspection rights described herein are afforded to the AUTHORITY by each sub-SUBDESIGN-BUILDER performing services under this contract.
6. If any of the services do not conform with contract requirements, the AUTHORITY will require the DESIGN-BUILDER to perform the services again at no additional cost to the AUTHORITY. When the defects in services cannot be corrected by re-performance, the AUTHORITY may (1) require the DESIGN-BUILDER to take necessary action to ensure that future performance conforms to contract requirements and (2) reduce the contract price to reflect the reduced value of the services performed.

1.6 SUBMITTALS

- A. The DESIGN-BUILDER shall submit the name, address, and qualifications of the Environmental Laboratory which they intend to use for this project. The laboratory shall be certified, as applicable, by the Commonwealth of Massachusetts to perform the required analyses. A copy of any certifications shall be included in the submission.
- B. The DESIGN-BUILDER shall be responsible for obtaining any necessary licenses and permits and for complying with any applicable federal, state and local laws, codes, policies and regulations in connection with the performance of this work. The DESIGN-BUILDER shall provide a copy of all such permits and licenses to the Engineer at least 5 business days prior to the start of work on this contract. Applicable permits pertaining to disposal facilities to be utilized shall also be provided at this time.
- C. The DESIGN-BUILDER shall submit to the Engineer all analytical results including chain of custody records within 5 business days of receipt and at a minimum 5 business days prior to off-site transportation and disposal of the items included in this Section. In addition, the DESIGN-BUILDER shall submit to the Engineer summary tables of all analytical results and identify how the material shall be classified for disposal.
- D. The DESIGN-BUILDER shall submit to the AUTHORITY, for review and approval, completed copies of all waste profiles, applications and questionnaires, prior to forwarding them to the party requiring these documents.
- E. The DESIGN-BUILDER shall submit to the Engineer for approval, a Work Plan including all pertinent information relating to the removal and transportation of hazardous materials from the Site within 15 business days after issuance of the Notice to Proceed. The Work Plan, at a minimum, shall include:
 1. The name(s), address(es), and contact(s) of subcontractors including Environmental Consultant retained for Work of this section.
 2. A detailed description of Work activities and progress schedule for each phase of the Work associated with the removal, transportation, and disposal of hazardous materials.
 3. A summary estimate of the quantities of hazardous materials that will be recycled or re-used, and the destination for those quantities of materials by category.
 4. A statement of compliance, and evidence of said compliance, with applicable Federal, State, Regional, and Local regulations covering such work.

5. Name(s), address(es), and contact(s) of hazardous waste transporter(s) that transport hazardous waste from the Site(s) to a TSD facility, including EPA identification numbers(s) and proof of permit, license, or authorization to transport hazardous waste in all affected states.
 6. Name(s), address(es), and contact(s) of TSD facilities that will accept hazardous waste from the Site and a letter of acceptance indicating that the facilities will accept hazardous waste from the Site.
 7. List and match each TSD facility with the hazardous waste it will accept from the site.
- F. The DESIGN-BUILDER shall complete any manifests, bills of lading or other documents required to transport and recycle or dispose of the items identified in this Section. The DESIGN-BUILDER shall submit the completed forms to the Engineer for review. The DESIGN-BUILDER shall not transport any materials until authorized by the AUTHORITY. Completed copies of all manifests, bills of lading and other applicable documents and certified scale weight receipts or certified liquid quantity measurements, as applicable, must be furnished to the AUTHORITY as attachments to all invoices. The DESIGN-BUILDER shall also be responsible for processing and distributing, as necessary, the completed manifests, bills of lading or other applicable documentation, as required by local, state and federal regulations.
- G. The DESIGN-BUILDER shall prepare and submit, to the AUTHORITY, a report that summarizes and documents the removal and disposal of all hazardous materials which left the Site. The report shall be a prerequisite for payment. At a minimum the report shall include the quantity and origin of each material type, reason(s) that it was deemed unacceptable for recycling/re-use, name of the disposal facility, a summary of materials disposed of at each facility, and a copy of the manifest, bill of lading and other applicable documentation, for each load.

1.7 REGULATORY REQUIREMENTS

- A. The Work of this Section shall be performed in accordance with all applicable Federal, State, and Local regulations, laws, codes, and ordinances governing the removal, handling, transportation, and disposal of materials managed under this contract.
- B. The DESIGN-BUILDER shall obtain all Federal, State and Local permits required for the removal, handling, transport and disposal of materials managed under this contract. The DESIGN-BUILDER shall adhere to all permit requirements.
1. The DESIGN-BUILDER shall document that the disposal facilities proposed have all certifications and permits as required by Federal, State and Local regulatory agencies to receive and dispose of the material managed under this contract.
- C. The following regulations are cited for the information and guidance of the DESIGN-BUILDER. The list below is not all-inclusive; the DESIGN-BUILDER shall be responsible for a thorough knowledge and full implementation of all requirements for removal, transportation, and disposal of hazardous materials.
1. Massachusetts Hazardous Waste Regulations, 310 CMR 30.000.
 2. Massachusetts Contingency Plan (MCP) 310 CMR 40.0000.
 3. Massachusetts DEP Policy #COMM-97-001 – Reuse and Disposal of Contaminated Soil at Massachusetts Landfills.
 4. Solid Waste Management Facility Regulations, 310 CMR 19.00.
 5. Site Assignment Regulation for Solid Waste Facilities, 310 CMR 16.000.
 6. Universal Waste Management Standards, 310 CMR 30.1000 – MassDEP.

7. Rubbish Handling Regulations, 527 CMR 34.00 - Massachusetts Department of Fire Services (MADFS).
8. Transportation of Flammable and Combustible Liquids, 527 CMR 8.00 – MADFS.
9. “Hazardous Waste Operations and Emergency Response”, Federal Occupational Safety and Health Act (OSHA), Title 29 CFR, Part 1910.120.
10. “General Regulations for Hazardous Waste Management”, EPA, Title 40 CFR, Part 260.
11. “Regulations for Identifying Hazardous Waste, Hazardous Waste Generators and Hazardous Waste Transporters”, EPA, Title 40 CFR, Parts 261, 262 and 263.
12. Regulations for Owners and Operators of Permitted Hazardous Waste Facilities”, EPA, Title 40 CFR, Part 264.
13. “Interim Status Standards for Owners and Operators of Permitted Hazardous Waste Facilities”, EPA. Title 40 CFR, Part 265.
14. “Standards for Management of Specific Hazardous Wastes and Facilities”, EPA, Title 40 CFR, Part 266.
15. “Standards for Owners and Operators of Hazardous Waste Facilities under a Standardized Permit”, EPA, Title 40 CFR, Part 267.
16. Universal Waste Management Standards, Title 40 CFR, Part 273 – USEPA.
17. Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, And Use Prohibition, Title 40 CFR, Part 761 – USEPA (TSCA).
18. Hazardous Materials Regulations Relating to Transportation, Title 49 CFR, Parts 171-180 – U.S. Department of Transportation (U.S. DOT).
19. Recycling and Emissions Reduction of Refrigerants, Title 40 CFR, Part 82 - Subpart F – USEPA.
20. Management of Used Oil Standards, Title 40 CFR, Part 279 – USEPA.
21. 29 CFR 1910, “Occupational Safety and Health Standards” (General Industry Standards)
22. 29 CFR 1910.20, “Access to Employee Exposure and Medical Records
23. 29 CFR 1910.134, “Respiratory Protection” 29 CFR 1910.146 “Permit Required Confined Space”
24. 29 CFR 1910.1025 “Lead”
25. 29 CFR 1910.1200, “Hazard Communication”
26. 29 CFR 1926, “Safety and Health Regulations for Construction” (Construction Industry Standards)
27. 29 CFR 1926.62, “Lead-Construction”

PART 2 – PRODUCTS

2.1 GENERAL

- A. The DESIGN-BUILDER shall provide all personnel with personal protective equipment (PPE), protective clothing, and monitoring equipment consistent with the levels of protection required for each type of work. The DESIGN-BUILDER is responsible for determining the required level of PPE for any work associated with this contract.
- B. The DESIGN-BUILDER shall maintain on the worksite a sufficient quantity of granular absorbent such as Speedy-Dri™ or approved equal, and any other emergency spill response equipment as may be necessary to complete the work outlined in this specification.
- C. The DESIGN-BUILDER shall provide all containers, overpack containers, storage containers, recovery cylinders, packing materials, gaskets and related products and materials required for collecting, storing, and transporting OHM in compliance with MassDEP, USEPA, and USDOT requirements. All containers shall be structurally and chemically compatible for the materials to be disposed and shall meet the requirements of USDOT 49 CFR 173 and UN rated performance specifications.

All reconditioned containers and drums must be pre-approved before use.

- D. The DESIGN-BUILDER shall provide all monitoring equipment, equipment, and containers necessary to collect, sample, drain, evacuate, flush, handle, secure, remove, transport, and dispose of all hazardous materials and refrigerant gases at the Site.
- E. The DESIGN-BUILDER shall provide all materials, products, and equipment necessary to bulk, shred, sort, flush, dilute, pre-treat or otherwise prepare hazardous materials for disposal at approved facilities.
- F. The DESIGN-BUILDER shall provide all materials for temporary containment areas including: berms; containment pads; impervious barriers; covers; and absorbent materials.

PART 3 – EXECUTION

3.1 GENERAL

- A. The AUTHORITY will be the generator and will sign all manifests, bills of lading, and other applicable documentation as required. The DESIGN-BUILDER shall prepare a summary of analytical data as part of the document package. The applicable documents will be prepared by the DESIGN-BUILDER and may be subject to applicable local, state and federal agency review and approval. The Engineer shall review all manifests, bills of lading, and other applicable documentation on behalf of the AUTHORITY.
- B. Utilization of a hazardous material manifest shall require the use of a licensed hazardous material transporter in conformance with the Massachusetts Hazardous Material Regulations as required by 310 CMR 30.000. A Licensed Site Professional Opinion (310 CMR 40.0000) is not required when using a hazardous material manifest when transporting contaminated materials.
- C. All Work shall be performed in a manner as to prevent any spills and leaks.
- D. In the event that work is being conducted in the vicinity of catch basins, drains or open pipes, berms or other barriers shall be constructed to prevent the release of hazardous materials to the subsurface at the Site.
- E. The DESIGN-BUILDER shall be fully aware of all such requirements; ensure that all required permits are obtained and in place including those required of any subcontractor, prepare all manifests and certifications, and deliver all copies of completed manifests and final certifications and certification of destruction to the Engineer in the form of one complete trucking document.

3.2 CHARACTERIZATION OF WASTES

- A. The DESIGN-BUILDER shall be responsible for all waste segregation, characterization, sampling and analysis.
- B. The DESIGN-BUILDER is responsible to ensure that materials are characterized to meet disposal facility requirements.
- C. The DESIGN-BUILDER shall be required to submit a copy of all analytical results to the Engineer within 5 business days of receipt and at least 5 business days prior to transportation off-site.
- D. If requested by the AUTHORITY or the Engineer, the DESIGN-BUILDER shall, at the time of sample collection, provide duplicate samples for analysis by the Engineer's laboratory.
- E. In the event that there are discrepancies between the DESIGN-BUILDER's and Engineer's lab, the DESIGN-BUILDER shall have their lab check and verify their results and provide all laboratory analytical backup.
- F. If the DESIGN-BUILDER and the Engineer cannot agree on the results, the DESIGN-BUILDER shall collect and resubmit samples to his lab for analyses at no additional cost to the AUTHORITY.
- G. Sampling of material shall be done by the DESIGN-BUILDER at sufficient and adequately distributed locations so that the concentrations of the chemical constituents are adequately characterized.

3.3 REFRIGERANT

- A. Unless contents are clearly labeled, the DESIGN-BUILDER shall perform analytical testing to identify the refrigerant.
- B. The DESIGN-BUILDER shall discharge gases into appropriate USDOT-approved containers, and label for transport and disposal. Decontaminate all systems by means of steam cleaning or triple rinsing or both with an approved cleaning fluid to remove all residual contamination. Collect all decontamination fluids into approved containers. Label containers for transport and disposal.
- C. All activities associated with the removal and reclamation of refrigerant gases shall be in accordance with the USEPA Clean Air Act and under the control and/or supervision of a certified Refrigerant Recovery Technician as specified in the applicable regulations.

3.4 MACHINERY FLUIDS

- A. The DESIGN-BUILDER shall drain and collect liquids from all equipment containing lubricating oils, hydraulic oils, or other types of fluids. This equipment includes, but is not limited to air compressors, fans, motors, and pumps.
- B. The DESIGN-BUILDER shall decontaminate all equipment and systems by means of steam cleaning or triple rinsing or both with an approved cleaning fluid to remove all residual contamination, and collect all decontamination fluids into approved labeled containers for transport and disposal.

3.5 PAINTS, OILS AND LUBRICANTS

- A. DESIGN-BUILDER's Environmental Consultant and the AUTHORITY are to be immediately notified of the presence of containerized liquid wastes encountered during the course of the work.
- B. Once liquid wastes are discovered, all ignition sources are to be removed from the immediate area.
- C. Containerized wastes that can be identified are to be removed from their origin without creating or exacerbating a release to the environment.

- D. After removal, DESIGN-BUILDER shall segregate the containerized liquids by placing into separate containers by preliminary type prior to final characterization of wastes. Combining waste liquids of different preliminary characteristics is strictly prohibited.
- E. Once fully characterized, DESIGN-BUILDER shall prepare waste manifests for the transportation of the waste liquids to an approved facility.

3.6 ELECTRICAL EQUIPMENT

- A. All lighting-related or oil-filled electrical equipment shall be removed using appropriate techniques and personal protection gear as detailed in the submittals.
- B. Removal shall be performed using approved methods and tools that will minimize damage to the equipment and ensure a quick, neat removal with the equipment intact and undamaged. Once removed, the equipment shall be placed in 55-gallon drums or other appropriately sized container suitable for transportation and disposal.
- C. Once filled, the container shall be closed and properly labeled for transport and disposal.

3.7 BATTERIES

- A. All batteries shall be removed using appropriate techniques and personal protection gear as detailed in the submittals.
- B. DESIGN-BUILDER shall remove all batteries intact, and reuse, recycle or dispose of all batteries in accordance with all applicable state and federal regulations.
- C. Removal shall be performed using approved methods and tools that will minimize damage to the batteries or other equipment of which it is a part and leave the batteries intact and undamaged.
- D. Once removed, the batteries shall be properly containerized.
- E. Once filled, the appropriate containers shall be closed and properly labeled for transport and disposal.

3.8 MERCURY

- A. DESIGN-BUILDER shall remove items containing mercury as hazardous waste. These include, but are not limited to fluorescent lamps, high-intensity discharge lamps, manometer thermostats and relay switches. The following shall be followed for disposal of all mercury items:
 - 1. Collection, characterization and proper disposal of all fluorescent lighting tubes and mercury items found throughout the facility.
 - 2. Care must be taken to not break these items, as that may cause mercury exposure to individuals handling them and may require additional clean-up and decontamination.
 - 3. Provide all waste shipment records and incorporate in the final report.

3.9 OTHER MISCELLANEOUS OHM

- A. The DESIGN-BUILDER shall properly identify and characterize any other miscellaneous OHM at the Site. This includes white goods, mechanical equipment, fire extinguishers, and cleaning/maintenance products.
- B. Other miscellaneous OHM shall be removed using appropriate techniques and personal protection gear as detailed in the submittals.

- C. Removal of other miscellaneous OHM shall be performed using approved methods and tools that will minimize damage to the fixture of which it is a part.
- D. Environmentally hazardous materials and system components shall be removed from white goods items and properly recycled or disposed prior to disposal or recycling of the white good carcasses. Environmentally hazardous materials requiring removal from white good items include, but are not limited to:
 - a. Capacitors
 - b. Refrigerants
 - c. Dry-type transformers.
- E. Once removed, the other miscellaneous OHM shall be properly containerized or secured, as necessary.
- F. Once filled, the appropriate containers (if applicable) shall be closed and properly labeled for transport and disposal.

3.10 STORAGE OF MATERIALS

- A. Once removed, DESIGN-BUILDER shall segregate and store hazardous materials on-site for no more than 30 calendar days.
- B. At the conclusion of each work day, drums or other containers of hazardous materials shall be labeled, and stored in a designated secure location under lock and key until they are removed for transport and disposal.
- C. If outdoors, hazardous materials shall be stored in areas that are impervious and contained. At a minimum, the area shall be within a locked fenced enclosure or secured covered structure, on a level surface of concrete or pavement and protected from weather.

3.11 WASTE PROFILES AND MANIFESTS/BILLS OF LADING

- A. The DESIGN-BUILDER shall comply with the RCRA Hazardous Waste Manifest regulations and shall be responsible for obtaining a temporary EPA Identification Number for each Site within this contract if applicable. The DESIGN-BUILDER shall also provide a landline telephone number in accordance with the RCRA regulations for each manifest generated. One EPA Identification Number per Site shall be used for all hazardous waste management associated within this contract if hazardous waste disposal is warranted for that Site.
- B. The DESIGN-BUILDER shall be responsible for preparing and submitting to the Engineer for review all waste profile applications and questionnaires, and coordination with disposal facilities and all Federal and State Environmental Agencies as applicable. The DESIGN-BUILDER shall provide the Engineer with completed copies of all waste profile applications and questionnaires prior to transportation off site. The DESIGN-BUILDER shall not transport any material off site until the submitted paperwork is authorized by the AUTHORITY.
- C. The DESIGN-BUILDER shall be responsible for preparing all hazardous material manifests, bills of lading and any other applicable paperwork with all applicable analytical backup, notification, and control forms. The DESIGN-BUILDER shall be responsible for coordination with the disposal facilities.
- D. The DESIGN-BUILDER shall also provide certified tare and gross weight slips or certified liquid volume measurements for each load received at the designated facility, which shall be attached to each completed manifest and/or bill of lading. The completed manifest and/or bill of lading, with supporting documentation, shall be submitted to the Engineer.

- E. The AUTHORITY will be designated as generator and will sign all manifests and waste profile applications or questionnaires.
- F. The DESIGN-BUILDER shall furnish all generator copies of the hazardous material manifest to the AUTHORITY. The DESIGN-BUILDER shall submit copies to the applicable local, state and federal authorities.
- G. The DESIGN-BUILDER shall submit to the AUTHORITY and the Engineer, prior to receiving progress payment, documentation certifying that all materials were transported to, accepted, and disposed of, at the selected disposal facility. The Engineer shall review all manifests, bills of lading, and other applicable documentation on behalf of the AUTHORITY. The documentation shall include, at a minimum, the following:
 - 1. Documentation shall be provided for each load from the site to the disposal facility, including all manifests and any other transfer documentation as applicable.
 - 2. Certified tare and gross weight slips and/or certified liquid quantity measurements for each load, as applicable.

3.12 TRANSPORT OF CONTAMINATED MATERIAL

- A. The DESIGN-BUILDER shall not be permitted to transport contaminated materials off-site until all disposal or recycling facility documentation has been received, reviewed, and accepted by the AUTHORITY.
- B. The DESIGN-BUILDER shall transport contaminated materials from the site to the disposal or recycling facility in accordance with all USDOT, USEPA, OSHA, MassDEP regulations and any other applicable regulations.
- C. The Hauler(s) shall be licensed in all states affected by transport.
- D. The DESIGN-BUILDER shall coordinate the schedule for truck arrivals and departures at the disposal site to meet the approved schedule.
- E. The DESIGN-BUILDER shall not deliver waste to any facility other than the disposal facilities listed on the shipping manifest, bills of lading, and/or other applicable documentation.
- F. The DESIGN-BUILDER shall be responsible for inspecting the access routes for road conditions, overhead clearance, and weight restrictions, and shall provide traffic control when needed.
- G. The DESIGN-BUILDER shall provide to the Engineer copies of all weight slips (both tare and gross) and certified liquid quantity measurements, for every load disposed of at the accepted disposal facility. The AUTHORITY shall only make progress payments upon receipt of these slips.
- H. The temporarily stored items must be removed from the site by the DESIGN-BUILDER in accordance with applicable regulatory deadlines and no later than the completion date of this contract.
- I. The DESIGN-BUILDER shall be responsible for any and all actions and costs necessary to remedy situations involving material spilled in transit or mud and dust tracked off-site. This cleanup and other ancillary activities shall be accomplished at the DESIGN-BUILDER's expense.
- J. The DESIGN-BUILDER is responsible for adhering to all loading and coverage restrictions and requirements. When loaded, materials shall be kept several inches below the top of the truck or container. The waste materials shall be loaded in a manner not to exceed over-the-road weight restrictions for the container and/or vehicle. All trucks and containers shall be covered during transport as required by applicable law.
- K. The DESIGN-BUILDER shall clean the truck tires and bodies before leaving the site by either hand or mechanical means. Should wash down water be utilized in the process, the DESIGN-

BUILDER is responsible to fully contain and characterize the water and for complying with all laws and regulations prior to discharge or disposal. In addition, the DESIGN-BUILDER shall conduct street sweeping of all public ways and/or private ways as necessary, and as determined by the AUTHORITY, and shall collect and dispose of all materials and soil which may have migrated off site in the truck transfer process.

3.13 OFF-SITE DISPOSAL

- A. The DESIGN-BUILDER shall be responsible for the disposal of contaminated materials and liquid wastes at licensed disposal/recycling facilities in accordance with all federal, state and local regulations, laws, codes, policies or requirements.
- B. The DESIGN-BUILDER shall identify within 15 business days of receiving the Notice to Proceed and prior to the transportation of any items off-site, the storage, disposal, and recovery facilities which they intend to use for this project.
- C. The DESIGN-BUILDER shall be responsible for acceptance of the specific material at an approved treatment, disposal, or recovery facility, for ensuring that the facility is properly permitted to accept the stated material, and that the facility provides the stated treatment and/or disposal services.
- D. All hazardous wastes, as defined, shall be disposed of at a RCRA or RCRA/TSCA-permitted facility as appropriate. Alternative hazardous waste disposal facilities including those outside the United States must be pre-approved by the Engineer.
- E. The AUTHORITY reserves the right to contact and visit the disposal facilities and regulatory agencies to verify their agreement to accept the stated material and to verify any other information provided. This does not in any way relieve the DESIGN-BUILDER of any responsibilities under this contract.
- F. In the event that the identified and approved facilities ceases to accept the stated materials or the facilities ceases operations, it is the DESIGN-BUILDER's responsibility to locate any alternate approved and permitted facilities for accepting materials. No additional compensation shall be provided to the DESIGN-BUILDER for having to utilize alternative facilities. The DESIGN-BUILDER is responsible for making the necessary arrangements to utilize alternative facilities, and the alternate facilities must be approved by the AUTHORITY in the same manner and with the same requirements as for the original facilities.
- G. All materials collected under this contract must be segregated and kept physically separate from any other items until the disposal facility is reached. The items must be so marked, so that they are readily identified to this contract throughout this period. In addition, the DESIGN-BUILDER must ensure that there is a clear audit trail for all items until final treatment/disposal is accomplished and the AUTHORITY has received all documents regarding final disposition including but not limited to signed manifests from the final Treatment, Storage and Disposal Facility.
- H. The DESIGN-BUILDER shall coordinate the disposal of work generated waste materials which may be contaminated. These waste materials include, but are not limited to, decontamination rinse water, disposable PPE, and miscellaneous disposable support equipment. Disposal of DESIGN-BUILDER generated waste shall be done at no additional cost to the AUTHORITY.

Mere acceptance of a waste at a properly permitted treatment, storage, or disposal facility (TSDF) does not meet the definition of final treatment/disposal under this contract. It is the DESIGN-BUILDER's responsibility to obtain all necessary documentation to prove that the final treatment/disposal of all items has been accomplished. This documentation shall be attached to the certificate of disposal and submitted with, or prior to, the payment requests.

- I. Treatment of waste on the AUTHORITY's premises is not permitted. Treatment is defined as any process that meets the definition of treatment as set forth in applicable federal (including Title 40 CFR, Part 260.10), state and local laws, codes, policies and regulations.

3.14 SPILL RESPONSIBILITY

- B. The DESIGN-BUILDER is solely responsible for any and all spills or leaks during the performance of work under this contract, which occur as a result of or are contributed to by the actions of its agents, employees or subcontractors. The DESIGN-BUILDER agrees to clean up such spills or leaks to the satisfaction of the AUTHORITY or its representative, and in a manner that complies with applicable federal, state and local laws, codes, policies and regulations. The spill cleanup shall be at no cost to the AUTHORITY or its representatives.
- C. As required, the DESIGN-BUILDER shall notify all applicable local, state and federal authorities immediately if the transport vehicle is involved in an accident and a reportable quantity of OHM is released or suspected to have been released.
- D. The DESIGN-BUILDER is responsible for conducting response actions to mitigate any hazardous material releases encountered or created by the work. The DESIGN-BUILDER shall not wait for the Environmental Consultant's or the AUTHORITY's direction if a delay of response actions will create a potential hazard to the public or the environment.
- E. The DESIGN-BUILDER shall report all such spills or leaks of oil or hazardous material, regardless of their quantity, to the AUTHORITY immediately upon discovery. A written follow-up report shall be submitted to the AUTHORITY as soon as possible, but not later than 24 hours after the initial telephone report. The written report shall be in narrative form and, at a minimum, include the following:
 - 1. Description of item spilled (including identity, quantity, manifest number, etc.).
 - 2. Exact time and location of spill, including a description of the area involved.
 - 3. Containment procedures initiated.
 - 4. Description of cleanup procedures employed or to be employed at the site, including location of disposal of spill residues, and corrective measures to prevent recurrences.
 - 5. Agency or Agencies contacted in response to spill containment if any made.

3.15 DECONTAMINATION PROCEDURES

- A. General: The DESIGN-BUILDER shall furnish labor, materials, tools, and equipment for decontamination of all personnel, equipment and supplies that enter the contaminated work area or are exposed to contaminated material. The DESIGN-BUILDER shall provide equipment and decontamination pads, etc. necessary for the decontamination of equipment and personnel.
- B. Methods: The decontamination procedure shall follow the requirements of Title 29 CFR, Parts 1926.65 & 1910.120 as described in the DESIGN-BUILDER's Health and Safety Plan.
- C. Personnel Decontamination: The DESIGN-BUILDER shall provide and maintain a decontamination area which is to be located in the contamination reduction zone. The DESIGN-BUILDER shall coordinate the location of the decontamination area with the Engineer. Decontamination of personnel and equipment is required after performance of activities in the exclusion zone. The personnel decontamination area may be in the form of a mobile trailer or field station.
 - 1. Routine Decontamination: Routine decontamination shall follow the guidelines of Title 29 CFR, Parts 1926.65 & 1910.120.
 - 2. Emergency Decontamination: Should a worker be splashed with contaminants, the worker shall be immediately escorted to the field decontamination station and decontaminated in accordance

with DESIGN-BUILDER's health and safety plan. Site eye wash and shower stations shall be made available and operable.

D. Equipment:

1. All equipment shall be provided to the work site free of contamination. The Engineer retains express AUTHORITY to prohibit from the site any equipment that in his/her opinion has not been thoroughly decontaminated prior to arriving at the project location. Any decontamination of the DESIGN-BUILDER's equipment prior to arrival at the site shall be at the expense of the DESIGN-BUILDER. The DESIGN-BUILDER is prohibited from decontaminating equipment on the project site which is not thoroughly decontaminated upon arrival.
2. All equipment involved in Exclusion Zone activities shall be decontaminated and the effectiveness of the decontamination shall be determined each time it is removed from the Exclusion Zone. Equipment decontamination shall be performed in conformance with the requirements of Title 29 CFR, Parts 1926.65 & 1910.120 as described in the DESIGN-BUILDER's Health and Safety Plan.
3. The DESIGN-BUILDER shall decontaminate all equipment that comes in contact with contaminated material, either directly or indirectly, after completion of work at one location and prior to beginning work at another location.

E. Rinse water used for decontamination which contains chemicals used during decontamination or which contains hazardous chemicals from the equipment which was decontaminated shall be collected, characterized, handled and disposed of by the DESIGN-BUILDER at no additional cost to the AUTHORITY.

F. Decontamination wastewater shall be classified as a "remedial wastewater".

G. Payment for the removal and disposal/discharge of decontamination wastewater shall be included under the DESIGN-BUILDER's base bid and shall not be paid for separately under any allowance item.

H. The DESIGN-BUILDER is responsible for any sampling and characterization as required by local, state, federal or facility requirements.

I. If appropriate, the DESIGN-BUILDER shall be responsible and coordinate with the Authority and/or Engineer all applications, licenses and permits required for discharges with the Massachusetts Water Resources Authority (MWRA), Boston Water and Sewer Commission (BWSC), and/or other local municipal water and sewer departments.

J. The DESIGN-BUILDER shall provide, maintain, and pay for any permits or monitoring necessary of the disposal/discharge of decontamination wastewaters.

K. If onsite treatment is proposed, the DESIGN-BUILDER shall provide a licensed Treatment Plant Operator as required by local, state, federal, or facility requirements.

L. The DESIGN-BUILDER shall be responsible for all costs, such as penalties and fines, related to materials transported and or disposed of in a manner not consistent with governing laws and regulations.

3.16 DISCOVERY OF HAZARDOUS MATERIALS

- A. If unknown hazardous materials, such as chemicals, other hazardous materials, or suspect containers are discovered during the course of the work, DESIGN-BUILDER shall cease work in affected area and immediately notify the ENGINEER and the AUTHORITY of such discovery. Work shall not proceed in such areas until instructions are issued by the ENGINEER.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02090

LEAD ABATEMENT

PART 1 - GENERAL

1.1 OVERVIEW

- A. The intent of this section is to:
1. Outline DESIGN-BUILDER responsibilities for worker protection and to prevent the contamination of the air, soil, and water around the project site from lead based paint.
 2. Specify the requirements for Lead Paint Abatement at the Bridges, buildings and other structures to be demolished for the Green Line Extension Project.
 3. Specify the minimum work practice requirements for the recovery and disposal of leaded coatings and associated waste generated as a result of abatement and demolition activities.
Lead coated paint may be encountered on painted structures and on buried building materials uncovered during the work.
- B. Attention is directed to the CONTRACT AND GENERAL CONDITIONS and all sections within DIVISION I-GENERAL REQUIREMENTS which are hereby made a part of this section.
- C. In addition to the requirements specified herein, refer to all Contract Documents for complete description of work required to be performed under this Section.
- D. Examine all Drawings and all other Sections of the Specifications for requirements of related Sections affecting the work of this Section.
- E. The work of this section shall be performed as stated herein. In performing the work of this section, the DESIGN-BUILDER shall refer to other Sections (i.e., Section 02081 – HAZARDOUS MATERIAL ABATEMENT) for additional procedures. The DESIGN-BUILDER is responsible for the coordination of the work of this Section with related work. No delays in completion of the work may be claimed for lack of coordination.
- F. DESIGN-BUILDER shall comply with all applicable local, state, and federal guidelines and regulations regarding all work involving the presence of lead-containing paint.

1.2 RELATED WORK

- A. Other specification sections that relate to the work include but are not limited to the following:
1. Section 01060 - PERMITS AND REGULATORY REQUIREMENTS
 2. Section 01560 – TEMPORARY CONTROLS
 3. Section 02080 – ASBESTOS REMOVAL
 4. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
 5. Section 02091 – REMOVAL OF CONTAMINATED FIXTURES
 6. Section 02221 – DEMOLITION

1.3 DESCRIPTION OF WORK

- A. A. The procedures described herein apply to all abatement and excavation work where a worker may be occupationally exposed to lead or lead-contaminated debris. The DESIGN-BUILDER shall assume that any painted surface not tested under this specification contains lead paint and it shall be the DESIGN-BUILDER's responsibility to protect workers performing under this Contract.

This may require additional testing by XRF analysis by the DESIGN-BUILDER to verify lead content. The DESIGN-BUILDER must notify the AUTHORITY and obtain approval from the AUTHORITY prior to such testing. The DESIGN-BUILDER shall assume full responsibility for the compliance with all applicable Federal, State, and Local regulations pertaining to work practices, hauling and disposal of hazardous waste, protection of the workers, visitors to the Site, and persons occupying areas adjacent to the Site. The DESIGN-BUILDER shall hold the AUTHORITY harmless for failure to comply with any applicable work, hauling, disposal, safety, health, or any other type of regulation on the part of himself, his workers or his subcontractors.

- B. The DESIGN-BUILDER is required to ensure the protection of workers performing any work that will affect surfaces coated with lead containing paint as well as protecting the public and the environment from exposure to lead dust.
- C. DESIGN-BUILDER responsibilities established in this Section include the furnishing of all labor, materials, and equipment required to test, contain, recover, and dispose of lead coatings and associated waste as identified in these specifications.
 - 1. Removal of paint from structural steel, where cutting/grinding is necessary;
 - 2. Spot removal of paint from surfaces to facilitate demolition;
 - 3. Excavation, segregation, and disposal of lead painted debris uncovered during the work;
 - 4. Testing and disposal of all debris generated as a result of lead removal in accordance with requirements of this specification and federal and State regulations on hazardous and solid waste;
 - 5. Personal air sampling as required by OSHA for workers of the DESIGN-BUILDER or the MBTA that have the potential for exposure to airborne lead dusts as outlined in this specification.
- D. Codes and Standards
 - 1. All work shall conform to the standards set by applicable Federal, State and local laws, regulations, ordinances, and guidelines in such form in which they exist at the time of the work of the contract and as may be required by subsequent regulations.
 - 2. In addition to any detailed requirements of the Specification, the DESIGN-BUILDER shall at his own cost and expense comply with all laws, ordinances, rules, and regulations of Federal, State, Regional, and Local Authorities regarding handling and storing of lead waste material.
 - 3. The following references are cited as applicable standards and regulations as amended, and may not include all applicable standards and regulations:
 - a. Code of Federal Regulations (CFR) Publications:

29 CFR 1910	General Industry
29 CFR 1926.55	Gases, Vapors, Fumes, Dusts and
Mists 29 CFR 1926.57	Ventilation
29 CFR 1926.62	Lead in Construction
29 CFR 1926.200	Signs, Signals and Barricades
29 CFR 1926.354	Welding, Cutting and Heating in Way of Preservative Coatings
29 CFR Subpart T	Demolition

- 40 CFR 50 National Primary and Secondary Ambient Air Quality Standards for Lead
- 40 CFR 61 Subpart A General Provisions
- 40 CFR 61.152 Standard for Waste Manufacturing, Demolition, Renovation, Spraying, and Fabricating Operations.
- 40 CFR 241 Guidelines for the Land Disposal of Solid Wastes
- 40 CFR 257 Criteria for Classification of Solid Waste
- 40 CFR 261 - 263 Waste Disposal Facilities and Practices
- b. Massachusetts Regulations:
 - 310 CMR 30.000 Massachusetts Hazardous Waste Regulations
 - 310 CMR 40.0000 Massachusetts Contingency Plan
 - 454 CMR 22.00 Deleading
- c. American National Standards Institute (ANSI) Publications:
 - 29.2-79 Fundamentals Governing the Design and Operation of Local Exhaust Systems
 - 288.2-80 Practices for Respiratory Protection
- d. National Institute of Occupational Safety and Health (NIOSH) Publications:
 - Manual of Analytical Methods, 4th Edition
- e. Underwriters Laboratories, Inc. (UL) Fire Resistance Directory Publications:
 - 586-77 (R 1982) Test Performance of High Efficiency Particulate Air Filter Units
- 4. All regulations by the above and other governing agencies in their most current version are applicable throughout this project. Where there is a conflict between this Specification and the cited State, Federal, or Local regulations, the more restrictive or stringent requirements shall prevail.

E. THIS SECTION REFERS TO REQUIREMENTS FOUND IN THESE REFERENCES, BUT IN NO WAY IS IT INTENDED TO CITE OR REITERATE ALL PROVISIONS THEREIN OR ELSEWHERE. IT IS THE DESIGN-BUILDER'S RESPONSIBILITY TO KNOW, UNDERSTAND, AND ABIDE BY ALL SUCH REGULATIONS AND COMMON PRACTICES.

1.4 DEFINITIONS

- A. The following definitions apply to performance of the work of this project
 1. Action Level: An airborne concentration of lead above 30 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) as an 8-hour time-weighted average (TWA).
 2. Area Monitoring: Sampling of lead concentrations *within* the demolition work area and outside the work area which is representative of the airborne concentrations of lead.
 3. Clean Room: An uncontaminated change room directly adjacent to the work area having facilities for storage of employees' personal clothing and uncontaminated work clothes, materials and equipment provided when the airborne exposure to lead is above the Permissible Exposure Level (PEL).

4. Consultant: Authorized representatives who are under contract with the AUTHORITY or AUTHORITY's Engineer to provide lead paint consulting or monitoring services.
5. Decontamination Area: A contained area adjacent to or connected to the abatement work area and consisting of an equipment room, shower area, and clean room which is used for decontamination of workers, materials and equipment.
6. Demolition Subcontractor: The entity who is performing demolition involving lead containing paint under this Section.
7. HEPA Filter Equipment: High efficiency particulate air (HEPA) filtered vacuuming or exhaust ventilation equipment with a UL 586 filter system. Filters shall be of 99.97 percent efficiency for retaining 0.3 μ diameter particles as determined by Dispersed Oil Particulate (DOP) testing.
8. Lead Containing Paint or Coating: Paint, varnish, or stain which contains lead in excess of 0.1 milligrams per square centimeter (mg/cm^2 or 1.0 % lead by weight).
9. Lead Permissible Exposure Limit (PEL): 50 $\mu\text{g}/\text{m}^3$ of air, based upon an 8-hour TWA.
10. PM-10 Sampling: Sampling for suspended particulate matter particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers.
11. Sample Location: Area or place where an air sample is collected.
12. Surface Preparation: Paint removal such that surfaces are free of visible paint chips, dirt, and rust where cutting, torching, welding, etc. may be required to facilitate demolition.
13. Time Weighted Average (TWA): The TWA is an 8-hour time weighted average for the test of the concentration of lead for worker exposure.
14. TSP Sampling for Lead: Sampling for airborne total suspended particulate with lead analysis.
15. Wet Cleaning: The Process of removing lead contamination from surfaces, equipment and other objects by using cloths, mops, or other cleaning tools which have been dampened with water, and by afterwards disposing of these cleaning tools as lead contaminated wastes.
16. Work Area: A controlled-access work area which has plastic sheeting or other containment barriers erected to separate the trades.

1.5 SUBMITTALS

A. Notifications

1. Provide in proper and timely fashion, all necessary notifications to relevant federal, state, and local authorities and obtain and comply with provisions of all permits or applications required by the work specified as well as make all required submittals required under those auspices. DESIGN-BUILDER shall indemnify AUTHORITY, Engineer and Consultant from, and pay for all claims resulting from failure to adhere to these provisions. Costs for all permits, applications, and the like are to be assumed by DESIGN-BUILDER.

B. Provide five (5) copies of the following Submittals to the Engineer for review:

1. Copies of all notifications, permits, applications, licenses and like documents required by Federal, State, or Local regulations and this specification obtained or submitted in proper fashion.
2. List of total number of supervisors and workers intended to be assigned to the project, including name and lead awareness qualifications.
3. Copies of written medical opinions for each employee who may be occupationally exposed to lead as required by Title 29 CFR, Part 1926.62 (j)(3)(v).

4. Record of successful respirator fit testing performed by a qualified individual within the previous 12 months for each employee to be used on this project with the employee's name and social security number with each record.
5. Employer's Lead Compliance Program as required by Title 29 CFR, Part 1926.62, including proposed respiratory protection program and medical monitoring for all employees throughout all phases of the job, including make, model, and NIOSH approval numbers of respirators to be used; worker orientation plan; written description of all proposed procedures, methods, or equipment to be utilized. In all instances, DESIGN-BUILDER must comply with all applicable federal, state and local regulations.
6. Material Safety Data Sheets on potentially hazardous materials to be used on the project.
7. Waste Disposal Plan which describes the waste stream and the disposal means (i.e., landfill, recycle, etc.) and includes the name, address, and ID number of the proposed hazardous waste hauler, waste transfer route, and proposed disposal reclamation or treatment facility.
8. Details of any proposed work platforms and or containment system design features including description and/or drawings of the following:
 - a. Locations, sizes, elevations, and numbers of individuals work platforms and/or enclosure systems.
 - b. Manner of construction, anticipated loads during operations, and load bearing capacities for each work area platform and/or enclosure system designed by a Registered Professional Engineer.
 - c. Proposed use and engineering of any proposed contamination control features such as HEPA- filtered negative pressure systems and decontamination facilities.
 - d. Special considerations used to protect the containment Integrity from effects of the local climate (e.g., wind, rain, snow, etc.).
 - e. Discussion of special permitting and construction code requirements applicable to installation of any work platform and containment system.
9. Name and Address of the proposed recycler who will accept painted metal component construction debris, including letter stating that it will accept such waste.
10. Construction schedule including sequence of critical work.
11. Submit the following to the AUTHORITY and Engineer as a Post-Construction submittal package:
 - a. Copies of waste manifests and receipts acknowledging disposal of all lead waste material from the project, showing delivery date, quantity, and appropriate signature of landfill's authorized representative;
 - b. Summary report with quantities of lead painted wastes recycled;
 - c. All personnel monitoring results; and
 - d. All TCLP testing results.

1.6 REPORT OF FINDINGS

- A. The DESIGN-BUILDER must be thoroughly familiar with the lead paint conditions. The responsibilities established in this Section include the furnishing of all labor, materials, and equipment required to remove, contain, recover, and dispose of lead paint and associated waste identified in these specifications, including the spot removal of paint from surfaces to facilitate demolition of metal structures.
- B. The DESIGN-BUILDER shall assume that all painted surfaces impacted by the Work contain lead.

Alternatively, the DESIGN-BUILDER at his expense may conduct testing utilizing other approved methods.

- C. All lead-containing painted surfaces associated with the work are included in the scope of work. It is the DESIGN-BUILDER's responsibility to familiarize himself with existing conditions and the extent of painted surfaces within the work zones that will need to be managed and disposed of as waste material.

1.7 GENERAL WORK PROCEDURES

- A. Work requiring lead paint abatement shall be carried out in sequential phases. Inspection and approval of each phase by the Consultant shall be sought and gained before proceeding to the next phase and in accordance with the schedule agreed upon by the AUTHORITY. This shall include demolition requirements for work area clearance and work area release prior to DESIGN-BUILDER work. As a Contract requirement, any reasonable delay caused by this requirement will not constitute a basis for claim against the AUTHORITY or Consultant. DESIGN-BUILDER must coordinate the work of this Section with the work of all other trades.
- B. At no time will AUTHORITY permit debris generated from abatement, excavation or demolition activities to be stored inside buildings, and any storage of materials will be subject to AUTHORITY's approval. Assure security of debris at all times.

1.8 SPECIAL CONSIDERATIONS

- A. Work Affected – In general, the following activities are minimum requirements of this section and affect the demolition performed on the painted components:
 - 1. No torch cutting, mechanical sanding, or stripping utilizing abrasive methods without the use of HEPA vacuum attachments and appropriate personal protection equipment for paint removal shall occur.
 - 2. No demolition activities may occur which increase the workers' exposure above the Action Level. DESIGN-BUILDER shall fully comply with the OSHA lead standard at Title 29 CFR, Part 1926.62.
 - 3. Workers shall be informed of the components to be demolished that have been identified as containing lead.
 - 4. Separation of Trades: Unprotected, untrained workers or trades shall not perform any related work within the same vicinity as demolition involving components identified with lead.

1.9 FEES, PERMITS AND LICENSES

- A. The DESIGN-BUILDER shall pay all licensing fees, royalties, and other costs necessary for the use of any copyrighted or patented product, design, invention, or process in the performance of the work specified in this Section. The DESIGN-BUILDER shall be solely responsible for costs, damages, or losses resulting from any infringement of these patent rights or copyrights. The DESIGN-BUILDER shall hold the AUTHORITY harmless from any costs, damages, and losses resulting from any infringement of these patent rights or copyrights. If the Contract Specification requests the use of any product, design, invention, or process that requires a licensing, patent or royalty fee for use in the performance of the job, the DESIGN-BUILDER shall be responsible for the fee or royalty fee and shall disclose the existence of such rights.
- B. DESIGN-BUILDER shall be responsible for costs for all applicable licensing requirements, notification requirements, and all other fees related to the DESIGN-BUILDER's ability to perform the work in this Section.

- C. DESIGN-BUILDER shall secure all necessary permits for work under this Section, including hauling, removal, and disposal, fire and materials usage, or any other permits required to perform this specified work.

1.10 CLEAN-UP

- A. Maintain the work Site in a neat and orderly manner at all times, so as not to interrupt or infringe upon the work of other trades.
- B. Comply with all requirements for release of work area as described in the project specification.
- C. It is the prerogative of the Engineer or his authorized representatives to inspect whenever deemed necessary. The DESIGN-BUILDER is responsible for meeting and correcting any deficiencies discovered which do not meet the current applicable regulations and the requirements of these specifications.

1.11 COORDINATION

- A. Extend full cooperation to AUTHORITY in all matters involving the use of AUTHORITY's facilities. At no time shall DESIGN-BUILDER cause or allow to be caused conditions which may cause risk or hazard to the general public or conditions that might impair safe use of the facility.
- B. Coordinate the work of this section with that of all other trades. Phasing and scheduling of this project will be subject to the approval of the AUTHORITY. The work of this Section shall be scheduled and performed so as not to impede the progress of the project as a whole. The DESIGN-BUILDER shall be available within 24 hours notice of additional work if after acceptance of the work it is determined that complete lead abatement was not achieved from the initial work effort as determined by the AUTHORITY or Consultant.
- C. Unless specifically authorized by the AUTHORITY, the work of this project shall be conducted according to the hours established in Division 1.
- D. Inspections by Consultant: The Consultant may perform visual inspections during the work of this Section, as described below. DESIGN-BUILDER shall not proceed with work until DESIGN-BUILDER has received Consultant's approval at the stages identified below:
 - 1. During: Prior to the commencement of a proposed alternative method other than specified.
 - 2. Post Inspection: At the completion of work and final clean-up, prior to clearance or removal of any critical barriers and decontamination unit from the work area.
 - 3. Waste Removal Inspection: Prior to removal of hazardous waste from the site, AUTHORITY and Consultant will inspect the quantity and type.

1.12 AUTHORITY TO STOP WORK

- A. The AUTHORITY has the authority to stop the demolition work, at any time the AUTHORITY determines either personally or through the services of the AUTHORITY's retained Consultant that conditions are not within the specification and applicable regulations. The stoppage of work shall continue until conditions have been corrected and corrective steps have been taken to the satisfaction of the Consultant. Standby time required to resolve violations shall be at the DESIGN-BUILDER's expense, and shall not be cause for extending the completion date.

1.13 EMERGENCY PRECAUTIONS

- A. The DESIGN-BUILDER shall establish and maintain emergency and fire exits from the work area.
- B. When an injury occurs, the DESIGN-BUILDER shall stop work until the injured person has been removed from the work area.

1.14 DISPOSAL OF WASTE MATERIAL

A. General

1. DESIGN-BUILDER will be required to comply with the Resource Conservation and Recovery Act (RCRA) and with all applicable state and local regulations.
2. Lead paint waste shall be separated from other building components where possible prior to disposal as lead waste.
3. Demolition DESIGN-BUILDER shall be responsible for disposing all waste determined by Toxicity Characteristics Leachate Procedure (TCLP) to be hazardous. If TCLP testing has not been performed, the Demolition DESIGN-BUILDER shall be responsible for testing the waste and the costs associated with the testing and analysis.
4. Demolition DESIGN-BUILDER shall comply with all EPA regulations.
5. Appropriate disposal of all lead paint waste of this project shall be according to Title 40 CFR, Part 241, -261, and 262.
6. Separate all unpainted metal components removed under this Contract for recycling. Submit proof of delivery to recycling facility.
7. The DESIGN-BUILDER is required to recycle/reuse any other recovered materials in lieu of disposal if the material is of acceptable physical quality and chemical quality, and the DESIGN-BUILDER can identify a facility willing and permitted to accept the material.

PART 2 – PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. The DESIGN-BUILDER shall deliver all materials and equipment to the site in the original containers bearing the name of the manufacturer, and details for proper storage and use.
- B. All materials or equipment delivered to the site shall be unloaded, and temporarily stored, and transferred to the work area in a manner which shall not interfere with other trades working in the area.
- C. Unloading and temporary storage sites, and transfer routes, must be approved in advance by the AUTHORITY.
- D. Damaged or deteriorated materials may not be used and must be promptly removed from the premises. Material which becomes contaminated shall be packaged and legally disposed in an approved, secure landfill.

2.2 MATERIALS

- A. All materials and equipment proposed to be used on this project shall be subject to the acceptance of the AUTHORITY and the Consultant. The list of required materials shall include, but not necessarily limited to the following:
 1. Fire retardant polyethylene sheeting, minimum thickness of six (6) mil.
 2. Plastic bags, minimum thickness of six (6) mil.
 3. High quality duct tape.
 4. Lead Warning Signs, as required by the MADOLS Regulations, and OSHA Hazard Communication requirements.

5. Spray adhesive (fire retardant).
6. Personal Protective Equipment, NIOSH approved respirators and filters.
7. Ventilation units with HEPA filtration and exhaust fans.
8. HEPA vacuums.
9. Trisodium-Phosphate (TSP) and product data.
10. Cloth tarpaulin.
11. Chemical strippers, where applicable, not containing methylene chloride and/or flammable materials.
12. Other materials, tools, and equipment necessary for the work.

PART 3 – EXECUTION

3.1 SCHEDULE OF ABATEMENT

- A. The DESIGN-BUILDER shall coordinate all abatement scheduling with the AUTHORITY. A schedule of work shall be submitted to the AUTHORITY, prior to contract performance.

3.2 UTILITIES

- A. Provide all necessary connections for temporary utilities in the work place during work. Shut down and disconnect all electrical power to the work area so that there is no possibility of reactivation and electrical shock during the work. The temporary electrical power shall be in accordance with all OSHA requirements.

3.3 IDENTIFICATION OF HAZARDS

- A. Prior to any work involving lead abatement or excavation of lead containing items, the DESIGN-BUILDER shall identify all work activities in which a worker may be occupationally exposed to lead.
- B. The DESIGN-BUILDER shall initially determine if any worker may be exposed to lead above the action level.

3.4 BARRIERS, ISOLATION AREAS, AND INSTALLATION OF DECONTAMINATION FACILITIES

- A. Containment controls, including critical barriers, protective coverings, HEPA-filtered ventilation and decontamination facilities, may be required for paint removal work. The degree of containment shall be appropriate for the anticipated levels of airborne lead dust. The lower the level of airborne lead, the lesser the requirements necessary to control lead emissions at the job site.
- B. Work Area Isolation During Abatement:
 1. The DESIGN-BUILDER shall isolate work areas for the duration of abatement work by completely sealing off all openings in the work area. Isolation sealing shall be accomplished by constructing critical barriers where necessary around the work area perimeter. The work area shall be sealed airtight to the greatest extent possible, subject to the approval of the Consultant.
 2. Provide temporary power and lighting (with ground fault circuit interrupt protection) to the work areas and ensure safe installation of temporary power sources and equipment per applicable electrical code requirements, and OSHA requirements for temporary lighting in the environment normal to lead-containing paint abatement work areas.

- C. Equipment and Services: The DESIGN-BUILDER shall provide portable lighting, staging and scaffolding, utility hook-ups, portable fire extinguishers, first aid equipment, and all other equipment or items for the safe and efficient performance of work.
- D. Decontamination Facility:
1. The DESIGN-BUILDER shall erect one or more Decontamination Facilities (if applicable) to serve each work area. The facility will consist of a series of two or more connected chambers including, at a minimum, a clean room and a shower/wash room, separated by an air lock. Unless otherwise specified, the shower/wash room shall be contiguous to the work area. Non-contiguous, remote, three-chamber decontamination facilities may be substituted with the Consultant's prior written approval. Three chamber decontamination facilities shall include an equipment room to be used for removal and temporary storage of contaminated work clothing, equipment, and other items leaving the work area, prior to decontamination in the shower/wash room of the decontamination facility.
 2. In all cases, non-emergency access between contaminated and uncontaminated rooms or areas shall only be through the Decontamination Facility/Wash room.
 3. Ensure that barriers and linings are effectively sealed and taped at all times, and that the Shower/Wash Room floor is completely water tight. Repair damaged barriers, and remedy defects immediately upon discovery. Visually inspect enclosures at the beginning of each work period.
- E. All abatement or excavation work areas impacting materials containing lead paints shall remain isolated from all other trades on the project and remain inaccessible to the public. DESIGN-BUILDER shall monitor the access to these work areas. The below listed items are required to control the generation of lead-containing dust during demolition activities. The DESIGN-BUILDER is ultimately responsible for cleaning all generated dust and paint debris and must maintain work areas free from lead dust generated from abatement or excavation activities.
1. Signs shall be posted at all approaches to the work areas warning that work involving lead is being conducted in the vicinity. Signs shall be in bold lettering not smaller than two inches tall.
 2. Barriers shall not be removed until the work areas are thoroughly cleaned and approved by the Consultant.

3.5 LEAD PAINT ABATEMENT

- A. Paint Removal: This shall include the removal of paint from all metal surfaces where torch cutting or welding is required to allow installation of new materials and/or modifications/demolition of existing as specified and/or where shown on the drawings. Paint removal shall follow the below listed requirements:
1. Paint removal shall occur to remove all visible paint down to the bare substrate. The paint shall be removed from an area of at least eight (8) inches where cut lines or welding is to occur at all surfaces of the member. DESIGN-BUILDER shall coordinate with the General DESIGN-BUILDER where the cut lines and welding are to occur.
 2. The following methods are prohibited for use in lead paint removal on this project:
 - a. torch or flame burning;
 - b. dry abrasive blasting using sand, grit or any other particulate;
 - c. on-site use of methylene chloride or solutions containing methylene chloride; and
 - d. machine sanding.

3. DESIGN-BUILDER shall seek AUTHORITY and Consultant approval for the use of chemical strippers/caustic paste on this project.
4. All paint chips, slurry, waste, and debris generated from paint removal shall be collected and removed upon generation during the work.
5. Paint removal shall occur only when proper barriers and protection are in place and approval has been given regarding barrier set-ups and methods of paint removal.

3.6 PERSONAL EXPOSURE AIR SAMPLING - DESIGN-BUILDER

- A. Perform personal exposure air sampling during all abatement work to determine worker exposure limits. Personal exposure sampling shall be conducted in accordance with the DESIGN-BUILDER's written Lead Compliance Program and OSHA requirements. The results of such sampling shall be posted, provided to individual workers, and submitted to the AUTHORITY and Consultant as described herein.
- B. Air sampling results shall be transmitted to the AUTHORITY and individual workers available at the job site in written form no more than forty-eight (48) hours after the completion of a sampling cycle. The reporting document shall list each samples result, sampling duration, sample yield, cassette size, and analysts name and company, and shall include an interpretation of the results. Air sample analysis results will be reported in micrograms/cubic meter ($\mu\text{g}/\text{m}^3$).
- C. The DESIGN-BUILDER's testing lab shall be American Industrial Hygiene Association (AIHA) accredited for analysis of metals. DESIGN-BUILDER shall submit for AUTHORITY's review and acceptance the name and address of the laboratory, certification(s) of AIHA accreditation for metal analysis, listing of relevant experience in air lead analysis, and presentation of a documented Quality Assurance and Quality Control program.
- D. Air monitoring frequency will be established in accordance with the requirements set forth in Title 29 CFR., Part 1926.62.

3.7 ENVIRONMENTAL IMPACT TESTING AND FINAL INSPECTIONS

- A. Ambient Air Monitoring:
 1. The DESIGN-BUILDER shall be responsible for performance of all ambient air monitoring required in accordance with Title 40 CFR, Part 50.12, "National Primary and Secondary Ambient Air Quality Standards for Lead." The DESIGN-BUILDER shall be responsible for retaining a qualified Industrial Hygiene firm for performance of the ambient air monitoring services in accordance with their Lead Compliance Program.
 2. The AUTHORITY may choose to conduct ambient air monitoring to verify that dust particulates containing lead do not exceed ambient air standards outside of the work area. DESIGN-BUILDER will be responsible for corrective measures as necessary.
- B. After a thorough clean-up, the Consultant will visually inspect the work area for the detection of visible debris or contamination. If the visual inspections do not reveal visible debris or contamination, the area shall be cleared. The AUTHORITY retains the right to take wipe samples to verify compliance with final cleaning requirements.

3.8 WORK PROCEDURES

- A. The DESIGN-BUILDER shall initiate and continue sufficient engineering and work practice control, as described in their DESIGN-BUILDERS Lead Compliance Program, the project Health and Safety Plan, and the Work Plan, to reduce and maintain worker exposures to lead at or below the Action Level.

- B. The following work practices are specifically required by these specifications:
 - 1. All persons except those directly involved in the work shall be excluded from the work area. Physical barriers shall be used, where necessary, to limit access to the work area for the duration of any abatement or demolition operations.
 - 2. Provide hand washing facilities and assure that all workers thoroughly wash their hands and face upon exiting the work area. Workers shall pay careful attention to cleanse the hands and face when decontaminating.
 - 3. Thoroughly wet the areas to be disturbed and mist the air to reduce the potential for creating airborne lead and dust.
 - 4. All equipment used by the workers inside the work area shall be either left in the work area or thoroughly decontaminated before being removed from the area. Extra work clothing (in addition to the disposable suits supplied by the DESIGN-BUILDER) shall be left in the clean area until the completion of work in that area. The clean area shall be cleaned of all visible debris and disposable materials daily.
 - 5. Under no circumstances shall workers or supervisory personnel eat, drink, smoke, chew gum, or chew tobacco or apply cosmetics in the work area; to do so shall be grounds for the Consultant to stop all demolition operations. Only in the case of life threatening emergency shall workers or supervisory personnel be allowed to remove their protective respirators while in the work area. In this situation, respirators are to be removed for as short a duration as possible.

3.9 STORAGE OF WASTE

- A. DESIGN-BUILDER shall establish staging areas for the management and containment of lead paint debris.
- B. Use of waste containers on site shall be controlled under the following requirements:
 - 1. Location of waste containers on site shall be coordinated with the DESIGN-BUILDER, subject to AUTHORITY's approval.
 - 2. For waste classified as hazardous based on TCLP testing, waste containers shall be lined with two layers of six-mil polyethylene sheeting, be solid, be enclosed containers, and be locked and sealed at all times.
 - 3. DESIGN-BUILDER shall comply with all federal, state, and local regulations and ordinances regarding lead waste storage.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02091

REMOVAL OF CONTAMINATED FIXTURES

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies the furnishing of all labor, materials, facilities, equipment, services, employee training, testing, permits and agreements necessary to perform the work required for the removal and disposal/recycling of light fixtures containing polychlorinated biphenyls (PCBs) and mercury-containing fluorescent lamps as part of demolition and rehabilitation included in the Green Line Extension Project.
- B. Work shall be in accordance with these specifications, the EPA, OSHA regulations, and any other applicable Federal, State and local government regulations. Whenever there is a conflict or overlap of the above references, the most stringent provisions shall apply.
- C. Equality of material, article, assembly, or system, other than those named or described in this Section, shall be determined in accordance with the provisions of the Contract and General Conditions.
- D. The DESIGN-BUILDER is responsible for any and all damage to the site caused by DESIGN-BUILDER's work, and shall repair all damage to a condition equal to or better than its original condition.
- E. The DESIGN-BUILDER shall coordinate the work outlined in this section with the work outlined throughout the specifications. Removal of fixtures containing hazardous materials shall be performed in preparation for renovations and/or demolition.
- F. All provisions of this contract relating to health and safety of the workers and the public, and protection of the environment, are minimum standards. The DESIGN-BUILDER is responsible for determining whether any additional and/or more stringent protective measures are legally required or necessary by prudent conservative practice. The DESIGN-BUILDER shall also be responsible for implementing such measures. Nothing in this document shall be deemed to relieve the DESIGN-BUILDER from any liability with respect to any such legal requirement or prudent conservative practice.
- G. In addition to the requirements specified herein, the DESIGN-BUILDER shall refer to all Contract Documents for a complete description of work required under this Section.
- H. Fixtures identified as containing PCBs, mercury, or lead shall be considered completely and thoroughly by bidders during pre-bid meetings and other viewing times made available by the AUTHORITY. Bids shall be based on conditions, quantities, and locations existing at the site. All areas shall be made accessible. The AUTHORITY is not responsible for a bidder's failure to completely and accurately document conditions, quantities, and locations of fixtures containing hazardous materials which are to be removed.

1.2 RELATED WORK

- A. Other specification sections that relate to the work include but are not limited to the following:
1. Section 01060 - PERMITS AND REGULATORY REQUIREMENTS
 2. Section 01560 – TEMPORARY CONTROLS
 3. Section 01800 – SUSTAINABILITY REQUIREMENTS
 4. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
 5. Section 02092 – PCB BULK PRODUCT WASTE REMOVAL
 6. Section 02221 – DEMOLITION
 7. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 8. Section 02300 – EARTHWORK
 9. Section 02240 – DEWATERING

1.3 REGULATORY REQUIREMENTS

- A. The DESIGN-BUILDER shall comply with all federal, state, and local regulations pertaining to the Contract. These regulations include, but are not limited to, the following:
1. DOT: 49 CFR Part 171 - 180, Hazardous Materials Transportation Regulations
 2. 40 CFR 761, Polychlorinated Biphenyls Manufacturing, Processing, Distribution in Commerce and Use Prohibitions
 3. 29 CFR 1926.62 - Lead in Construction
 4. 15 U.S.C. 2605, Toxic Substances Control Act
 5. 310 CMR 30.0000, Massachusetts Hazardous Waste Regulations
 6. 40 CFR 273 and 310 CMR 30.1000 (Universal Waste Rule)
 7. 40 CFR 240-299, Resource Conservation and Recovery Act

The DESIGN-BUILDER shall also be responsible for complying with all other applicable OSHA construction and/or general industry standards, including, but not limited to, confined space entry, scaffolding, electrical, slips, trips and falls, lifting, respiratory standards, etc.

- B. The most recent edition of any relevant regulation, standard, document, or code shall be in effect. Where conflict among the requirements or with these Specifications exists, the DESIGN-BUILDER shall utilize the most stringent requirements.
- C. Copies of all applicable standards, regulations, codes, and other documents, including these Contract Documents and appropriate Drawings, shall be available for inspection in a clean area outside the work area, at the work site, at all times.
- D. The DESIGN-BUILDER shall be responsible for complying with all applicable labor regulations. The AUTHORITY shall not be held responsible, or liable, for labor and wage disputes between DESIGN-BUILDER and employees of the DESIGN-BUILDER.
- E. All disposals shall be undertaken in accordance with applicable federal, state, and local statutes, laws, and regulations.

1.4 REGULATORY NOTIFICATIONS

- A. The DESIGN-BUILDER is required to notify the following agencies, and any other agencies or entities which must be notified according to the applicable regulations, and to provide all information and pay all fees on forms acceptable to each agency or entity prior to each phase:

Environmental Protection Agency
One Congress Street, Suite 1100
Boston, MA 02114-2023 (to obtain RCRA generator ID, if needed)

1.5 NOTIFICATIONS TO WORKERS AND OTHER BUILDING OCCUPANTS

- A. Containers used to transport contaminated materials to disposal facilities shall be labeled in accordance with EPA, DOT, and OSHA requirements.
- B. DESIGN-BUILDER shall provide other signs, labels, warnings, and posted instructions that are necessary to protect, inform, and warn people of the hazard from PCB exposure. DESIGN-BUILDER shall post in a prominent place, convenient to the workers and visitors and other building occupants, if applicable, a copy of the latest applicable regulations from OSHA and EPA.

1.6 SUBMITTALS

- A. The DESIGN-BUILDER shall submit satisfactory proof to the AUTHORITY's representative that all required permits have been obtained and that all notifications pertaining to this project have been made.
- B. Name, address, and telephone number of transporter(s), and name, address, and telephone number of EPA-approved disposal/recycling site.
- C. The DESIGN-BUILDER shall submit a written project schedule, including the proposed work shift size and work hours for a minimum of the following activities:
1. Mobilization
 2. Preparation
 3. Removal of fixtures and packaging of PCB and fluorescent bulbs for disposal/recycling.
 4. Cleanup, inspection, and demobilization
- D. The DESIGN-BUILDER shall submit Material Safety Data Sheets (MSDS) for all materials and products to be used by the DESIGN-BUILDER on this project. Products containing methylene chloride or other components generally recognized as carcinogens shall not be allowed.
- E. The DESIGN-BUILDER shall submit the following documents no later than the pre-construction meeting:
1. A list of proposed electrical safeguards to be implemented, including but not limited to, location of transformers, ground-fault circuit intervention (GFCI) outlets, lighting, etc., necessary to safely perform the work, including a description of a plan for common safety practices concerning electrical hazards in the work area.
 2. A list of the chain of command at the work site, including supervisors, foremen, and competent persons and their names, resumes, certificates of training, and Department of Labor and Workforce Development (DLWD) licenses.

3. A written proposed emergency plan and route of egress from each work area in the event of fire or injury, including the name and telephone number of the nearest medical assistance center, fire department, and police department.
4. A list of the name(s), address(es), and identification number(s) of waste transporters and proposed disposal/recycling sites for PCBs and fluorescent bulbs.
5. Copies of completed waste manifests or recycling certificates.

PART 2 – PRODUCTS

2.1 TOOLS AND EQUIPMENT

- A. Other Tools and Equipment: DESIGN-BUILDER shall provide all other tools and equipment required for the removal and proper disposal of fixtures and lamps containing hazardous materials.

PART 3 – EXECUTION

3.1 WORK REQUIREMENTS

- A. The DESIGN-BUILDER shall take care not to break any electrical ballasts, capacitors, or other components containing PCBs or other hazardous materials during removal and packaging for disposal. If any of the ballasts are broken during removal or are observed to be leaking prior to removal, the disposal requirements under TSCA may be different and the DESIGN-BUILDER shall dispose of these broken/leaking ballasts accordingly.

3.2 WASTE PACKAGING AND DISPOSAL/RECYCLING REQUIREMENTS

- A. Waste containers shall include warning signs specific to the type of hazardous material contained within them and pre-printed labels indicating the name of the DESIGN-BUILDER, the name of the AUTHORITY, the site address, and the date of waste generation.
- B. Disposal or recycling must occur at facilities authorized to accept the materials and according to regulatory requirements of the EPA and applicable state and local guidelines and regulations.
- C. The appropriate shipping documentation shall be used to transport PCB and mercury-containing waste to the disposal/recycling facilities. The documentation shall include: (1) the name and address of the facility from which the waste is being removed; (2) the AUTHORITY's address; (3) the name(s), address(es), and telephone number(s) of the DESIGN-BUILDER and of the waste transporter(s); and (4) the name, address, and telephone number of the authorized disposal site. In addition, the document must include the type of waste materials generated, the number and type of waste containers used, and the quantity of each type of waste in pounds or tons.

3.3 TRANSPORTATION

- A. Workers shall load the containers that have been removed from the work area into an enclosed, lockable truck for transportation.
- B. When moving containers, workers shall utilize hand trucks, carts, and proper lifting techniques to avoid back injuries.

- C. The enclosed cargo area of the truck shall be free of debris and lined with 6-mil polyethylene sheeting to prevent containers that leak or spill from contaminating areas external to the cargo area. Floor sheeting shall be installed first and extended up the sidewalls. Wall sheeting shall then be overlapped and taped into place.
- D. Containers shall be placed, not thrown, on level surfaces in the cargo area or metal dumpster, and shall be packed tightly together to prevent shifting and tipping. Large structural components shall be secured to prevent shifting of containers placed on top. No worker shall throw any container into the cargo area of the truck.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02092

PCB BULK PRODUCT WASTE ABATEMENT

PART 1 – GENERAL

1.1 SUMMARY

- A. This Section establishes requirements for the removal, segregation, management, and disposal of assumed Polychlorinated Biphenyl (PCB) Bulk Product Waste and PCB Remediation Waste managed as a result of PCB Bulk Product Waste abatement, primarily in the form of PCB caulking/glazing/paint adhered to or released from building materials, including metal, glass, wood, masonry, asphalt and other building products.
- B. The removal and disposal of building materials with PCBs is regulated by the Toxic Substance Control Act (TSCA) pursuant to Federal regulation 40 CFR 761, and depends on whether the material is classified as a PCB Bulk Product Waste or PCB Remediation Waste. Waste derived from the demolition of man-made structures manufactured, coated, or serviced with PCBs at concentrations greater than or equal to 50 parts per million (ppm) are regulated as a PCB Bulk Product Waste (ref: 40 CFR 761.50(b)(4)). Non-manufactured materials (including substrates) that are “coated or serviced” with PCB Bulk Product Waste (from a greater than 50 ppm PCB source, such as caulk, paint, mastics, sealants) at the time of designation for disposal are also managed as PCB Bulk Product Waste. However, if the substrate is NOT “coated or serviced” (i.e., the PCB Bulk Product Waste, such as caulk or paint, has been removed from or fallen off of the substrate) at the time of designation for disposal, AND the substrate is contaminated with PCBs that have migrated from the Bulk Product Waste, the substrate would be considered a PCB Remediation Waste (ref: 40 CFR 761.50(b)(3)). (Ref: EPA Memorandum “PCB Bulk Product Waste Reinterpretation” dated October 24, 2012 and Federal Register Document Number 2012-4860, dated February 29, 2012).
- C. For the purposes of this project, caulking/glazing/paint materials at the site are known or assumed to contain PCBs in excess of 50 ppm. Therefore, all building materials currently in contact with the caulking/glazing/paint materials in contact with the caulking/glazing/paint materials confirmed through laboratory analysis to contain PCBs > 50 ppm will be treated as a PCB Bulk Product Waste or PCB Remediation Waste, as appropriate, and limited testing has been performed to confirm this assumption.
- D. This Section specifies requirements for the management of known or assumed PCB wastes classified as PCB Bulk Product Wastes and of the associated adhered substrate materials (wood, metals, glass, masonry, etc.) that may have been in contact with materials known or assumed to be classified as a PCB Bulk Product Waste. The substrate materials may be classified as either PCB Bulk Product Waste or as PCB Remediation Waste, as described in Section 1.1.B.
- E. The removal and disposal activities in this Section will be conducted as a “Performance Based” removal pursuant to applicable TSCA regulations (ref. 40 CFR 761.61(b) and 761.62(a)). Since limited sampling for PCBs has occurred, the TSCA regulations may not specifically apply to all portions of this project. Although this is the case, many of the performance requirements of TSCA have been included by reference in this Section as a basis for performing the work. These

performance requirements apply to the work irrespective of the results of any material testing which may take place in the future.

- F. Based on information received to date and correspondence with EPA, the proposed abatement/demolition summarized herein does not require notification or written approval from EPA, which is based on the assumptions presented herein.
- G. The DESIGN-BUILDER or affiliates of the DESIGN-BUILDER (subcontractors, subconsultants, etc.) shall not contact the EPA with respect to interpretations of the regulations or the performance of the work specified herein.
- H. For testing that may be deemed necessary during performance of the work of this Section or other related Sections (asbestos abatement), Engineer/AUTHORITY shall specifically review and approve in writing the proposed testing plan prior to samples being submitted for laboratory analysis.

1.2 RELATED WORK

- A. Other specification sections that relate to the work include but are not limited to the following:
 - 1. Section 01060 – PERMITS AND REGULATORY REQUIREMENTS
 - 2. Section 01560 – TEMPORARY CONTROLS
 - 3. Section 02080 – ASBESTOS REMOVAL
 - 4. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
 - 5. Section 02091 – REMOVAL OF CONTAMINATED FIXTURES
 - 6. Section 02221 – DEMOLITION

1.3 WORK INCLUDED

- A. DESIGN-BUILDER is informed that building renovations and/or demolition activities, including the abatement of asbestos materials, may involve the disturbance materials that are known or assumed to contain PCBs. The intent of this section is to define performance requirements that the DESIGN-BUILDER shall comply with in order to perform the work. Health and safety concerns, disposal requirements, worker training and demolition procedures are described in this Section.
- B. In general, the following activities are minimum requirements of this Section and affect the work performed on building components known or assumed to contain PCBs:
 - 1. No torch cutting, mechanical sanding or stripping, or abrasive methods of removal shall be performed on known or assumed PCB impacted materials unless performed in a controlled setting as summarized herein.
 - 2. No demolition activities shall occur that can reasonably be expected to increase the worker's exposure above the Permissible Exposure Limits (PEL) for PCBs unless certain worker protection is implemented.
 - 3. Workers shall be informed of the known or assumed PCB building components to be removed.

4. At a minimum, worker protection shall comply with applicable OSHA standards. Worker Right to Know and Health and Safety Standards of 1926 shall also apply to the work of this Section.
5. Unprotected, untrained workers or trades shall not perform any related work within or adjacent to work areas that may involve assumed PCB impacted building components.

1.4 SUBMITTALS

- A. Prior to the start of the work, DESIGN-BUILDER shall prepare and submit the following items, and, not commence work activities until submittals are reviewed and acknowledged as being complete by the Engineer/AUTHORITY:
 1. Written demolition and abatement work plan that summarizes the DESIGN-BUILDER's means and methods related to the demolition, containment, cleanup, and management of known or assumed PCB impacted building materials, some of which may also contain lead paint, asbestos or other hazardous materials. The work plan must be compliant with 40 CFR 761.
 2. The names and operating permits of all proposed receiving facilities that may receive PCB wastes.
 3. Proposed sampling plans of any materials the DESIGN-BUILDER proposes to sample. Written approval MUST be obtained from the AUTHORITY prior to any samples being submitted for laboratory analysis.
 4. DESIGN-BUILDER's Performance-Based Work Plan for the removal and disposal of PCB Bulk Product Waste.
 5. DESIGN-BUILDER'S Plan for confirmation sampling of remaining substrates for verification of abatement completion.
 6. Draft waste profiles for all waste streams generated as part of this project for the AUTHORITY's representative to review prior to submitting to the facility.
- B. Review of DESIGN-BUILDER's work plan does not constitute approval of any specified means, methods and health and safety measures to be implemented. Review is for general compliance with this specification and the referenced TSCA regulations.
- C. DESIGN-BUILDER is to provide the following Contract Closeout Submittals (throughout project and prior to authorization of final payment)
 1. Records of the amounts of waste generated, by waste type, and address of origin.
 2. Fully executed and completed waste manifests.
 3. Copies of laboratory analysis of confirmatory substrate sampling.
 4. Drawings showing specific locations of substrate samples and distance from assumed PCB material, for each property and building where PCB waste was removed.
 5. Final PCB Abatement Report with tabulated data demonstrating that PCB bulk product, and PCB remediation wastes were removed in entirety.

1.5 REGULATORY REQUIREMENTS

- A. 40 CFR 761 as it relates to the generation, staging, labeling, removal and off-site management of the PCB wastes summarized herein. As stated, TSCA is being cited as a performance criterion to be achieved during the performance of this work, although TSCA may not specifically apply to work areas where PCB sampling has not been performed to confirm the presence of PCBs above regulatory threshold of 50 parts per million.
- B. Comply with all other applicable federal, state, and local environmental, safety and health requirements regarding the renovation/demolition of structures and other site features and recycling or disposal of demolition debris, as applicable.
- C. All workers involved with abatement of assumed PCB materials must be 40-hour OSHA HAZWOPER trained.

PART 2 -PRODUCTS

2.1 PRODUCTS

- A. HEPA-Filtered Exhausts -Abatement areas of assumed PCB materials (if applicable based on DESIGN-BUILDER's approach) shall be exhausted through a High Efficiency Particulate Air (HEPA) filter. The DESIGN-BUILDER's decision to exhaust work areas is specifically based on the DESIGN-BUILDER's ability to control dust from migrating beyond the immediate work limits.
- B. Commercially manufactured HEPA-filtered exhaust units, with specification plates intact, must be provided for each work area to attain, at a minimum, four air volume changes per hour and an inward flow of clean air into each work area at the Decontamination Facility of at least 100 feet per minute. The HEPA filter shall be preceded by replaceable pre-filters and the unit must be designed so that it cannot be operated unless all filters are in place. The purpose of the containment system is to capture fugitive particulate while removing assumed PCB items. If DESIGN-BUILDER can control visible fugitive dust by others means, HEPA-filtered exhaust units are not necessarily required.
- C. The contactor's specific containment approaches may also include the following products:
 - 1. Polyethylene Sheeting ("Poly") - polyethylene or equivalent with a thickness of at least 6 mil for all applications.
 - 2. Tape and Glue - Shall be capable of sealing plastic joints and attaching plastic to finished surfaces. The bonding strength and resulting seal integrity shall not be affected by mist or water, wetting or encapsulating agent, or any other materials to be used in the work area.
 - 3. Worker personal protective equipment.
 - 4. Drums and containers for management and transport of PCB wastes.
- D. Please note that HEPA-filtered containments of certain asbestos abatement areas may be required as it relates to asbestos abatement work being performed under Section 02080.
- E. Warning Signs and Labels -Work areas shall be properly demarcated in accordance with OSHA.

PART 3 –EXECUTION

3.1 DEMOLITION AND REMOVAL METHODS

- A. Demolition activities shall be conducted in a manner that prevents the potential release of dusts to areas outside each specific abatement work zone and containment.
- B. Any dust generated as part of the work shall be contained to within the PCB abatement work area and workers shall implement appropriate personal protection (respiratory, dermal, etc.).
- C. Non-PCB impacted demolition debris shall be segregated from known or assumed PCB impacted demolition debris.
- D. Feasible engineering controls (e.g., water misters and physical separation and containments) shall be implemented by the DESIGN-BUILDER to minimize the possibility of areas adjacent to work areas (both interior and exterior spaces) from becoming impacted by dusts/debris.

3.2 WORKER PROTECTION

- A. DESIGN-BUILDER shall inform personnel which building materials are assumed to contain PCBs.
- B. The DESIGN-BUILDER shall be responsible for ensuring OSHA compliance for all personnel working with assumed PCB items, including providing appropriate personal protective equipment and training to use such protective equipment.
- C. During selective demolition activities, DESIGN-BUILDER shall ensure that workers are not exposed to any listed contaminant in excess of the permissible exposure limits (PEL). If exposure cannot be reduced to or below the PEL through the use of engineering controls or revised work practices, the DESIGN-BUILDER shall provide personal protective equipment including, but not limited to, respiratory and dermal protection.
- D. DESIGN-BUILDER is permitted to perform personnel air sampling for PCBs as necessary to monitor health and safety.
- E. DESIGN-BUILDER is advised that certain assumed PCB building materials may also contain lead and asbestos. Assumed PCB materials that also contain asbestos shall also be removed in accordance with Section 02080.

3.3 BARRIERS AND ISOLATION AREAS

- A. The DESIGN-BUILDER shall construct and maintain suitable polyethylene barriers to isolate the work areas and to eliminate the potential contamination of other exterior and interior spaces. Barriers shall be of sufficient size and strength to prevent the migration of dust and debris from the work area.
- B. A centralized clean area adjacent to the work area(s) shall be constructed. This clean area shall be of sufficient size for workers to decontaminate personnel and equipment.
- C. Barriers shall not be removed until the work areas are thoroughly cleaned and approved by AUTHORITYs' representative/Engineer.

3.4 NEGATIVE PRESSURE EXHAUST

- A. Negative pressure enclosures will be required if the DESIGN-BUILDER is unable to control visible dusts from migrating beyond the work areas, particularly into interior building spaces.
- B. DESIGN-BUILDER shall consider work approaches that reduce the generation and/or migrations of dust associated with the work summarized herein, including tools operated adjacent to or equipped with high-volume vacuum attachments.

3.5 ABATEMENT OF ASSUMED PCB BULK PRODUCT WASTE AREAS

- A. Storage of PCBs waste shall comply with the labeling and storage requirements established in TSCA (761.40 to 761.50).
- B. Except as otherwise noted, the removal limits of building materials known or assumed to be classified as a PCB Bulk Product Waste or PCB Remediation Waste shall include the removal limits necessary to meet the TSCA regulatory requirements of less than 1 part per million of PCBs in remaining substrates or soil.
- C. Caulking and Glazing
 - 1. All caulking and glazing applications associated with the window/door systems shall be removed in their entirety.
 - 2. Methods of removal shall also be in accordance with Section 02080 if material is also asbestos containing.
 - 3. DESIGN-BUILDER may elect to remove entire window/door system with associated intact caulking and/or glazing.
 - 4. Separation of caulking/glazing from window/door systems is not required.
 - 5. Any residual/visible caulking/glazing in place on building materials designated to remain shall be removed to a minimum of 6 inches beyond the no-visible standard.
- D. Window Systems/Door Frames
 - 1. Window systems/Door Frames, including metal window lintels, wood frames, metal window frames, and wood or metal window trim shall be removed to the limits identified on the Contract drawings.
- E. Masonry, Mortar, Stone, Cast Stone
 - 1. No visible caulking materials shall remain on masonry not removed as specified above in Paragraph 3.5.
 - 2. During removal of masonry and the PCB caulking materials, any other associated materials in contact with caulking shall also be removed, including but not limited to backer filler and flashing materials.
 - 3. During masonry repair following initial abatement, the abatement DESIGN-BUILDER shall collect and dispose of any additional dust and debris that may be generated as part of the final masonry repair work.
 - 4. During the installation of new window/door systems, the abatement DESIGN-BUILDER shall collect and dispose of any incidental dust/debris that may be generated as part of the installation.
- F. Soil

1. DESIGN-BUILDER is required to protect exposed soil areas located beneath and adjacent to work areas.
2. If soil becomes visually impacted from masonry products or other PCB remediation waste materials as a result of the abatement work being performed, DESIGN-BUILDER shall remove and dispose of impacted soil to TSCA regulatory standard of 1 part per million.

3.6 VERIFICATION SAMPLING

- A. Verification sampling following abatement of assumed PCB building materials will be performed by the DESIGN-BUILDER's Environmental Consultant.
- B. A minimum of 3 samples shall be collected of each type of porous material remaining after abatement. The sampling frequency shall be 1 sample per 5 linear feet of PCB material abated. Samples will be submitted for laboratory analysis for PCBs using the Soxhlet extraction method.

3.7 CLEANING PROCEDURES

- A. Upon completion of the removal of known or assumed PCB building materials, cleaning will be performed by the DESIGN-BUILDER. In general, cleaning shall be performed at the end of each work day to prevent the migration of dusts or debris to areas beyond the defined abatement work limits.
- B. A thorough final cleaning shall be performed on all surfaces using wet methods and HEPA filter-equipped vacuums or other approved vacuum equipment. Any water used for final cleaning shall be containerized and managed as PCB-impacted by the DESIGN-BUILDER.
- C. Final cleaning includes removal of any assumed impacted material, equipment or debris (including polyethylene sheeting) from the work area and removal of all visible dusts located on surfaces. All collected polyethylene sheeting shall be packaged for disposal.
- D. Special attention shall be given to personal hygiene and cleaning of supplies and/or equipment.
- E. Non-porous surfaces (metal window frames, metal window lintels, etc.) that may remain in place and that may have been contact with assumed PCB Bulk Product Materials shall be swabbed/wiped using a non-chlorinated organic solvent. Verification sampling of non-porous material that remains in place is not required.

3.8 DECONTAMINATION OF TOOLS

- A. DESIGN-BUILDER shall decontaminate tools that may have been in contact with assumed PCB materials. Decontamination procedures shall be in accordance with 761.79(c)(2)(i), which includes swabbing non-porous tools with a non-chlorinated organic solvent. Swabbing materials shall be disposed as specified in Paragraph 3.9.

3.9 MANAGEMENT OF PCB WASTES

- A. The following materials are assumed to contain PCBs and shall be collected, packaged, sampled and labeled by the DESIGN-BUILDER according to this Section for off-site disposal:
- B. Assumed PCB Bulk Product Waste Management
 1. In accordance with the provisions of TSCA and recent EPA interpretations, the following waste stream(s) shall be assumed to be a PCB Bulk Product Waste:
 - a. Window glazing

- b. Caulking
 - c. Any building material in contact with assumed PCB containing window glazing or caulking that must be removed as part of the DESIGN-BUILDER's overall scope of work at the time of designation for disposal, including:
 - Glass window panes
 - Glass block (only the glass block directly in contact with caulking)
 - Wood window trim, door frames/trim sashes and/or window frames
 - Metal window frames or window lintels (if removed)
 - Electrical components and wire
 - Masonry products (brick, mortar, concrete)
 - Stone and cast stone
2. Portions of the above waste stream may also contain asbestos associated with caulking and glazing applications and therefore shall be noted in the appropriate waste profiles. Coordination with Section 02080 is required.
 3. In accordance with the Performance-Based disposal provisions of 761.61 and 761.62, the assumed PCB Bulk Product Waste and PCB Remediation Waste streams shall be managed in accordance with 761.61(b) or 761.62(a), which is generally a TSCA chemical waste landfill, or for PCB Bulk Product Waste only, 762(b), which is a solid waste landfill. The DESIGN-BUILDER must provide evidence of the selection of the less costly method to transport and disposal of the PCB Bulk Product Waste and PCB Remediation Waste in accordance with applicable regulations.
 4. If a 761.62(b) solid waste landfill is selected, the DESIGN-BUILDER shall receive verification in writing that the landfill is not prohibited from receiving PCB Bulk Product waste generated in Massachusetts. The proposed landfill disposal location must be approved by the AUTHORITY.
- C. Liquid PCB Remediation-Generated Waste Management
1. Any collected wash water or decontamination water shall be managed in accordance with the Performance-Based disposal provisions established in 761.61 (b)(1) and the decontamination standards and procedures established in 761.79. Unless work is specifically being completed in accordance with a Self-Implementation Plan under 761.61(a), management of this waste stream under 761.61(a) is NOT permitted.
 2. DESIGN-BUILDER must pass the water at a minimum through a 5-micron filter to remove total solids.
 3. After filtering, DESIGN-BUILDER must characterize PCB liquids prior to either discharge or transport off-site.
 4. DESIGN-BUILDER shall manage the water as follows:
 - a. Achieve by on-site treatment a PCB concentration of less than 0.5 µg/L for unrestricted use,

- b. Achieve by on-site treatment a PCB discharge concentration permitted by the local sewer authority. DESIGN-BUILDER is responsible for any permitting to a local sewer; or
 - c. Assuming the wastewater contains PCBs less than 50 ppm, transport the remediation wastewater to an appropriately permitted non-TSCA facility for treatment.
5. Coordination with Section 02080 related to asbestos abatement and decontamination may be necessary. To the extent, this liquid remediation-generated waste stream may also contain asbestos; the required 5-micron filtering will address the potential presence of asbestos in the wash water.
- D. Non-Liquid PCB Remediation-Generated Waste Management
- 1. The following materials are assumed to contain PCBs and therefore shall be managed for off-site disposal:
 - a. Debris and dusts generated and collected throughout work activities subject to this Specification.
 - b. HEPA vacuum bags of assumed PCB dusts/debris and potential asbestos debris.
 - c. Filter media from decontamination wash water filtering, including potential asbestos debris.
 - d. Respirator cartridges, scrapers, tarpaulins, suits, plastic and other materials used for PCB abatement, including ground covers and the potential presence of asbestos debris.
 - 2. Management of these materials shall be in accordance with Performance-Based disposal provisions established in 761.61(a) and 761.61(a)(5)(v), as appropriate, and shall include disposal at a non-TSCA landfill for non-liquid materials containing less than 50 ppm of total PCBs, whenever possible. Disposal by incineration at a TSCA-approved facility or in a TSCA-approved chemical waste landfill will be employed for non-liquid materials assumed to contain total PCBs greater than 50 ppm. Waste profiling of the above waste stream shall also include the potential presence of asbestos and lead (if applicable).
- E. Soil
- 1. If DESIGN-BUILDER is required to remove visually-impacted soils due to the DESIGN-BUILDER's inability to adequately protect the ground surface, these soils shall be managed in accordance with Paragraph 3.9 at no additional cost to the AUTHORITY.
- F. Sampling
- 1. Any sampling specified in this Section shall be performed by the DESIGN-BUILDER, including bearing all analytical costs.
 - 2. Written approval for all sampling MUST be received by the DESIGN-BUILDER prior to shipping samples for laboratory analysis.
 - 3. Failure to adhere to the specific sampling program within this Section could result in significant consequential costs/damages to the AUTHORITY. In this case, if DESIGN-BUILDER violates the required sampling program, AUTHORITY will be due from the DESIGN-BUILDER the actual value of the consequential costs.

G. Labeling, Manifests and Shipping Documentation

1. All wastes shall be appropriately containerized and labeled based on the individual waste profiles and classification.
 2. DESIGN-BUILDER shall provide draft waste profiles for all waste streams generated as part of this project for the AUTHORITY's representative to review prior to submitting to the disposal facility.
 3. AUTHORITY will sign as generator on all profiles and shipping documents.
 4. PCB Bulk Product Waste and PCB Remediation Waste (paragraph 3.9(B)) - transport on a non-hazardous manifest.
 - a. PCB wastes greater than 50 ppm that are generated in Massachusetts are classified as a Massachusetts hazardous waste. Since portions of the PCB Bulk Product Waste and PCB Remediation Waste streams are assumed to be greater than 50 ppm, typical transport over the road in Massachusetts for these wastes would require a hazardous materials manifest.
 - b. Once the proposed facility is provided to the AUTHORITY, the AUTHORITY will receive approval from the MassDEP to transport these assumed PCB materials on a non-hazardous materials manifest. This approval requires the materials to be disposed at an out-of-state facility permitted/licensed to receive PCB Bulk Product Waste or PCB Remediation Waste, per applicable sections of TSCA.
 - c. Liquid PCB Remediation-Generated Waste (paragraph 3.9C)) shall be transported under a generic Bill of Lading/material shipping record/non-hazardous waste manifest for less than 50 ppm PCB wastes.
- H. DESIGN-BUILDER shall provide evidence that the PCB waste has been received at legal disposal locations. The means for such proof shall be truck weight slips from an approved disposal facility and copies of applicable waste shipment records (waste profiles, manifests, and Bills-of-Lading). Transport of all materials off site shall be in accordance with applicable Department of Transportation Regulations.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02100
SITE PREPARATION
PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The Design-Builder shall design, layout and install all site preparations at all work sites.

The Design-Builder may elect to substitute different materials or methods other than those specified herein. In that instance, it shall be the Design-Builder's responsibility to demonstrate to the MBTA that the proposed design is equal to or greater than these specifications and will comply with all permit and regulatory requirements.

- B. Work Included: This Section specifies the following items.

1. Clearing, grubbing, and disposing of vegetation, including bushes, brush, trees, stumps, fallen timber, logs, roots, rubbish, refuse, trash, and debris within the indicated limits.
2. Protection from injury or defacement of vegetation (including urban wild) and objects indicated or designated by the Owner to be preserved.
3. Removal, salvage, or other disposition of basement walls, slabs and footings; existing pavement, curbs and gutters, sidewalks, headwalls, walls, and steps; utility service facilities; guardrail and posts, highway and street signs and fences; and other miscellaneous structures and site improvements which interfere with construction, as indicated, or as required by the Owner.
4. Placing of siltation fence and straw bales for erosion and sedimentation control.
5. Preparing site access roadways, storage areas, and temporary construction fencing.
6. Temporary Construction Easement Zones shall be restored or replaced as required by the Owner.

- C. Related Work:

1. Volume 2 Technical Provisions Exhibit 21 "Additional Project Requirements"
2. Section 02060 – EROSION AND SEDIMENTATION CONTROL
3. Section 02221 – DEMOLITION
4. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
5. Section 02300 – EARTHWORK.
6. Section 02650 – EXISTING SITE UTILITIES.
7. Section 02444 – CHAIN-LINK FENCE AND GATES.
8. Section 02359 – MODULAR PRECAST BLOCK RETAINING WALLS

9. Section 02509 – PAVEMENT BASE COURSES

1.2 SUBMITTALS

- A. Submit copies of requests for and certificates of severance of utility services to the MBTA at least ten days prior to start of site preparation work. Submit product information for temporary construction fencing to the MBTA at least ten days prior to fence installation. See Section 02060 – EROSION AND SEDIMENTATION CONTROL for submittal requirements for siltation fence and straw bales.

PART 2 - PRODUCTS

2.1 TEMPORARY CONSTRUCTION FENCING

- A. Construction fence material shall be rolled chain link fence, 6-feet high, conforming to ASTM A392-96 Standard Specifications for Zinc-Coated Chain Link Fence. All posts shall be galvanized steel composition line posts, end posts and corner posts shall be galvanized steel with a minimum OD of 2.375-inches. Gate posts shall have a minimum OD of 4.0-inches.

2.2 WARNING SIGNS

- A. Diamond shaped warning signs with message of “Construction Zone – Keep Out” shall be attached to the construction fencing.
- B. The signs shall have minimum dimensions of 24-inch by 24-inch with orange background and black letters.

2.3 EROSION AND SEDIMENTATION CONTROL PRODUCTS

- A. See Section 02060 - EROSION AND SEDIMENTATION CONTROL for materials and products required to implement the Project Wide Erosion and Sedimentation Control Program.

PART 3 - EXECUTION

3.1 PROTECTION

- A. Protect indicated or designated trees to prevent damage to the trunk, foliage and root system by construction equipment or procedures.
- B. Protect other plants, monuments, existing improvements, adjacent property, and facilities from damage.
- C. Maintain protected vegetation in a healthy growing condition during construction.

3.2 CLEARING AND GRUBBING

- A. Clear materials specified herein to the limits shown and remove from the site. Remove stumps and roots completely in excavation areas and under embankments where the original ground level is within

3.5 feet of the sub-grade or slope of embankments. In embankment areas where the original ground level is more than 3.5 feet below the sub-grade or slope of embankment, cut off trees, stumps, and brush to within six inches of the ground. Do not start earthwork operations in areas where clearing and grubbing is not complete, except that stumps and large roots may be removed concurrently with excavation.

- B. Where the work includes the removal of elm trees or the branches or stumps of elm trees, dispose of such material immediately after cutting or removal, by covering with earth to a depth of at least six inches in areas off the jobsite where such disposal has been arranged.
- C. Where the work under the Contract includes the provision of wood chip mulch, acceptable material from clearing and grubbing activities may be used to produce such mulch. Material obtained from elm trees will not be acceptable for such use.

3.3 TREE BRANCHES

- A. Remove tree branches overhanging trackways, roadways, and other designated areas of the site to within 20 feet of the finish grade. Cut off branches neatly close to the tree boles. Remove other branches as necessary to present a balanced appearance. Treat scars resulting from tree branch removal with a heavy coat of an approved asphaltic tree paint.

3.4 REMOVAL

- A. Remove entirely existing miscellaneous structures and site improvements that interfere with construction, as indicated, or as designated by the MBTA. Remove walls and masonry construction to a minimum depth of two feet below existing ground level in areas where such items do not interfere with construction.
- B. Remove organic or otherwise deleterious soils below proposed foundations.
- C. Abandoned Rail and Track Materials. Take possession of, remove, and dispose of offsite, materials between boundaries located two feet outside of the rails and including the space between double tracks.
- D. Slabs may be broken and left in place where the MBTA determines it is not detrimental to the structural integrity of the fill or structure to be placed above.
- E. All removal shall be done in accordance with applicable state and federal laws.

3.5 SALVAGE

- A. Salvage indicated material or material determined by the MBTA to be suitable for reuse, including: grates, frames, other metal castings and miscellaneous parts of inlets and manholes; hydrants, fire alarm posts and boxes; metal light poles; sound pipe and valves; metal fencing; guard rail; and highway and street signs and posts.
- B. Protect metallic coatings on salvaged items. Remove adhering concrete from salvaged items.
- C. Repair, or replace with new material, salvaged material damaged or destroyed due to the Design-Builder's negligence.

3.6 BACKFILL

- A. Backfill and compact trenches and excavations resulting from work under this Section in accordance with Section 02300 - EARTHWORK.

3.7 SILT FENCE AND HAY BALE INSTALLATION

- A. Refer to Section 02060 – EROSION AND SEDIMENTATION CONTROL.

3.8 TEMPORARY CONSTRUCTION FENCING

- A. The temporary fence shall be installed in accordance with the manufacturer’s instructions.
- B. All posts except those located on existing bituminous concrete pavement, shall be driven 2-ft deep into the ground, with gate posts and corner posts encased in concrete. The posts set on pavement shall be secured with concrete bases.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection with the work are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02150

UNDERPINNING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section presents the performance requirements for underpinning and support of existing structures adjacent to and above new construction, and the restoration of those structures to the conditions existing prior to the commencement of underpinning and support operations.
- B. Related Work: Other specification sections that relate to the work of this section include, but are not limited to, the following:
1. Volume 2 Technical Provisions – Exhibit 2I - Additional Project Requirements
 2. Section 02015 - GEOTECHNICAL INSTRUMENTATION
 3. Section 02240 - DEWATERING
 4. Section 02260 - EXCAVATION SUPPORT AND PROTECTION
 5. Section 02300 - EARTHWORK
 6. Section 02360 - DRIVEN PILES
 7. Section 02369 - DRILLED MINI-PILES
 8. Section 03300 - CAST-IN-PLACE CONCRETE
 9. Section 05126 - STRUCTURAL STEEL FOR RETAINING WALLS
- C. Definitions
1. Shoring: Props or posts of timber or other material in compression or bending, used for temporary support of excavations, formwork, or structures.
 2. Sheeting: A line of steel sections or timber planks, plain or tongue-and-grooved on sides, driven endwise into the ground to protect subgrade operations.
 3. Underpinning: Permanent construction which directly transmits existing structure foundation loads to a lower bearing elevation, and which preserves the structures being underpinned.
 4. Support: Structural elements required to prevent movement of existing structures until completion of the underpinning.
 5. Lagging: A temporary or permanent excavation support structure consisting of heavy timber boards, planking, or sheathing secured in place by H-piles.

6. Restoration: Reconstruction, by repair or replacement, of portions of structures removed or altered by underpinning and support operations.
7. Parcel: An area as indicated, including the structures thereon and any adjacent vaults and permanent closure walls connected thereto.

D. The Work of this section also includes the following:

1. The construction of drilled shafts shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design-Builder at no additional cost to the MBTA.
2. Adjacent structures shall be monitored and protected as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
3. Construction operations not to exceed specified noise limits in accordance with Volume 2 Technical Provisions, Exhibit 2I, Additional Project Requirements.

1.2 SUBMITTALS

- A. Working and Shop Drawings. Submit Working and Shop Drawings a minimum of 21 calendar days prior to the start of underpinning. Show method, staging, and necessary details for the construction of underpinning and support for each structure on which work is to be accomplished. Show details of shop assemblies when required for restoration of structures. Working and Shop Drawings, and calculations shall be prepared, sealed, and signed by a professional engineer hired by the Design-Builder currently registered in the Commonwealth of Massachusetts.
- B. Computations. Submit design computations in a design submission with the working and Shop Drawings a minimum of 14 calendar days prior to the start of underpinning. The design submission shall include the applicable code requirements and design references and shall include computations to support Shop Drawings to the MBTA.
- C. Procedures. Submit the following a minimum of 21 calendar days prior to the start of underpinning
 1. Submit procedure for detection of movement, as specified in Section 3.1.
 2. Submit procedure for preloading (jacking load) new foundations.
 3. Submit procedure for proof load testing and preloading (jacking load) of lateral support systems, such as strut and tieback assemblies.
- D. Jacking Gage Calibration. Submit data for the pressure gage and jack combination certified by an accepted testing laboratory not earlier than 14 days prior to start of use for underpinning.
- E. Support and Restoration. Submit procedures, methods, and materials lists for support and restoration a minimum of 21 calendar days prior to the start of underpinning.
- F. Qualifications of Design-Builder's Engineer a minimum of 21 calendar days prior to the start of underpinning.

1.3 QUALITY ASSURANCE

- A. Tolerances - Piles and Piers:

1. Offset of Top of Pile or Pier from Design Center: 1-1/2 inches maximum.
 2. Out of Plumb: Two % maximum.
- B. Job Conditions
1. Access. Notify the MBTA at least 30 days in advance of the date on which the Design-Builder requires occupancy of parcels to be underpinned, supported, and restored.
 2. Permits. The Design-Builder shall obtain and pay for permits for entry into structures and for the right to do underpinning, support, and restoration as required.
 3. Temporary Partitions
 - a. Build closed temporary partitions to isolate the work site from the portions of the structure not occupied by the Design-Builder.
 - b. Upon completion of the work, remove temporary partitions and restore the area to its condition prior to the start of underpinning.
 4. Maintenance of Services. Locate, protect, support, and maintain uninterrupted, utilities, equipment, and services within the limits of the underpinning work, or relocate same to the satisfaction of the Parcel owner.

PART 2 - PRODUCTS

2.1 REQUIREMENTS

- A. The Design-Builder shall furnish all materials, tools, equipment, facilities, and services as required for providing the necessary shoring and underpinning work and facilities.

2.2 CONCRETE AND REINFORCING STEEL

- A. Refer to Section 03300 - CAST-IN-PLACE CONCRETE.

2.3 STRUCTURAL STEEL

- A. Refer to Section 05126 - STRUCTURAL STEEL FOR RETAINING WALLS.

2.4 PILING

- A. Refer to Section 02360 - DRIVEN PILES.

2.5 DRILLED MINI-PILES

- A. Refer to Section 02369 – DRILLED MINI-PILES.

PART 3 - EXECUTION

3.1 DETECTION OF MOVEMENT

- A. Inscribe or firmly affix on each column, pile cap, or wall to be underpinned or supported, and at additional locations as directed by the MBTA, visual methods of determining movements. The method used is optional but shall be capable of being read to an accuracy of 0.005 foot.
- B. Take and record readings continually during excavation, jacking, and refounding operations under the existing structure.
- C. Stop work, notify the MBTA, and take immediate remedial action if movement of the existing structure occurs during progress of the work.
- D. Upon completion of underpinning of an existing structure, take daily readings of the measurement points for a minimum period of 30 days, or until movement stops, and report the results to the MBTA.
- E. Refer to Section 02015 – GEOTECHNICAL INSTRUMENTATION for additional requirements.

3.2 CONCRETE PIERS, WALLS, AND PILE CAPS

- A. Install concrete piers, walls, and pile caps with the top approximately three inches below the structure to be underpinned. Dry pack the space between the foundation and the concrete with 4,000 psi non-shrink grout within three days after concrete placement is completed.
- B. Where earth form is required, install a waterproof barrier between the earth and the concrete to prevent water loss from the fresh concrete.
- C. Do not remove support of the existing structure until concrete piers, walls, or pile caps have attained design strength.

3.3 PILES

- A. Install piles extending from the underside of existing footings to the elevations required to develop the design working load of the pile.
- B. Distribute jacking reactions over the existing structure in a manner that will not overstress or deflect the existing structure to cause damage. Provide computations of allowable stresses and deflections and show on the Shop Drawings.
- C. Provide watertight welds capable of developing the full strength of the pile. Align splices to ensure the straightness of the pile from top to tip. Use outside sleeves and backup rings as necessary.
- D. Load Testing. Load test each pile to demonstrate the load carrying capacity as required by the Shop Drawings and computations. Apply a minimum load of 150% of the design working load of the pile. Load-test piles in those sequences and groupings which will eliminate eccentric loadings and the associated structural damage to the existing structure and foundations.

- E. Securely fasten or wedge in place those piles which have satisfied the load-testing requirements. Weld and encase in concrete all wedges, plates, wedging struts, and piles, as indicated on the Shop Drawings
- F. Concreting Pits. Following completion of load transfer, fill the underpinning pits with concrete as indicated on the Shop Drawings. Without limitation, the Design-Builder shall furnish and install reinforcement, shear keys, dowels and waterstops as indicated on Shop Drawings. Place concrete to within three inches of the underside of the existing foundation. Dry pack the space between foundation and concrete with 4,000 psi non-shrink grout.

3.4 BACKFILL

- A. Backfill in accordance with Section 02300 - EARTHWORK, after acceptance of underpinning by the MBTA.

3.5 SUPPORT INSTALLATION

- A. Install supports where necessary to temporarily support structures to be underpinned and those which will be affected by underpinning and restoration work.

3.6 RESTORATION

- A. Restore existing structures and landscaping to conditions equivalent to those existing prior to the start of underpinning and support work, unless otherwise indicated. Any damage to affected buildings caused by the underpinning work shall be repaired by the Design-Builder at no additional cost to the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02195

GROUND IMPROVEMENT – AGGREGATE PIERS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work shall consist of designing, furnishing, and installing aggregate pier ground improvements as necessary to improve the strength and/or stiffness of the soil. Other methods of ground improvement may be proposed by the Design-Builder for review and approval by the MBTA. Ground improvement may be used for support of foundation loads, but may also be used for other situations where improved soil strength and/or stiffness is required.

1.2 WORK INCLUDED

- A. Without limitation, Design-Builder shall provide all equipment, material, labor, and supervision to design and install ground improvement including aggregate piers. The work of spoil removal, footing excavations, and subgrade preparation following aggregate pier installation is described in other specification sections.
- B. The aggregate pier design and installation shall adhere to all performance criteria and standards described in this Specification.
- C. The construction of ground improvements shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design-Builder at no additional cost to the MBTA.
- D. Adjacent structures shall be monitored and protected as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
- E. Vibration monitoring for ground improvement installation will be performed by the Design-Builder's Instrumentation Engineer as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
- F. Construction operations not to exceed specified noise limits in accordance with Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements".

1.3 APPROVED INSTALLERS

- A. The Aggregate Pier Installer (the Installer) shall be approved by the MBTA. Prior to approval, the Installer shall submit to the MBTA a qualification statement to demonstrate a minimum of 5 years of experience with the installation of aggregate pier systems and shall have completed at least 10 projects of a similar scope and nature. Without exception, no alternate installer will be accepted unless approved by the MBTA.

1.4 REFERENCE STANDARDS

- A. Modulus Testing
 - 1. ASTM D 1143 - Pile Load Test Procedures

2. ASTM D 1194 - Spread Footing Load Test
- B. Materials and Inspection
1. ASTM D 1241 - Aggregate Quality
 2. ASTM D 422 - Gradation of Soils

1.5 CERTIFICATIONS AND SUBMITTALS

PART 2 - PRODUCTS

2.1 AGGREGATE

- A. Aggregate used by the Aggregate Pier Installer for pier construction shall be pre-approved by the Designer and shall demonstrate suitable performance during modulus testing.
- B. Potable water or other suitable source shall be used to increase aggregate moisture content where required. The Design-Builder shall provide such water to the Aggregate Pier Installer.

PART 3 - EXECUTION

3.1 AGGREGATE PIER DESIGN

- A. The design of the aggregate pier system shall be based on the service load bearing pressure and the allowable total and differential settlement criteria of the structure foundations. The aggregate pier system shall be designed in accordance with generally-accepted engineering practice.
- B. The aggregate pier elements shall be designed using an aggregate pier stiffness modulus to be verified by the results of the modulus test described in Section 3.7 of these specifications.

3.2 DESIGN SUBMITTAL

- A. The Design-Builder shall submit detailed design calculations, construction drawings, and shop drawings (the Design Submittal), for approval at least six week(s) prior to the beginning of construction. A detailed explanation of the design parameters for settlement calculations shall be included in the Design Submittal. Additionally, the Design Submittal shall include a quality control test program for aggregate pier system, meeting these design requirements. All computer-generated calculations and drawings shall be prepared and sealed by a Professional Engineer, licensed in the Commonwealth of Massachusetts.
- B. The following shall be included in the design calculation submittal:
 1. A written summary report that describes the overall ground improvement design
 2. Applicable code requirements and design references.
 3. Ground improvement critical design cross-section(s) and geometry including soil/rock strata and location, magnitude and direction of external surcharge loads, and piezometric levels with critical slip surface shown along with a minimum calculated global stability factor of safety

4. Design criteria including, soil/rock shear strengths including friction angle and cohesion, unit weights, aggregate pier hole diameter, aggregate pier spacing, aggregate pier unit weight and friction angle, composite shear strength parameters, and any other design assumptions.
 5. Design calculation sheets with project number, wall location, designation, date of preparation, initials of designer and checker, and page number at the top of each page. An index page with the design calculations shall be provided.
 6. Design notes including an explanation of any symbols and computer programs used in the design.
 7. Detailed subgrade preparation notes and requirements.
- C. Working Drawings. Utility locations, right of way, and other applicable information is available on the plans. Without limitation, Working Drawings shall include:
1. A plan view of the ground improvement for identifying:
 - a. Right of way, permanent or temporary construction easement limits, location of all known active or abandoned existing utilities, adjacent structures, or other potential interferences. Any drainage structure or drainage pipe centerline behind, passing through, or passing under the structure.
 - b. Limits of the ground improvement and layout of the individual aggregate piers.
 2. Subsurface exploration locations shown on a plan view of the proposed structure alignment with appropriate reference base lines to fix the locations of the explorations relative to the structure.
 3. Elevation view showing aggregate pier locations, elevations and depth of improvement, location of drainage elements and expansion/contraction joints when applicable.

3.3 APPROVED INSTALLATION PROCEDURES

- A. Unless otherwise approved by the Designer, the installation method used for aggregate pier construction shall be that as used in the construction of the successful modulus test.

3.4 PLAN LOCATION AND ELEVATION OF AGGREGATE PIERS

- A. The as-built center and bottom elevation of each pier shall be within 6 inches of the locations indicated on the Working Drawings. Piers installed outside of the above tolerances and deemed not acceptable shall be rebuilt at no additional expense to the MBTA.

3.5 REJECTED AGGREGATE PIERS

- A. Aggregate Pier elements installed beyond the maximum allowable tolerances shall be abandoned and replaced with new piers, unless the Designer approves the condition or provides other remedial measures. All material and labor required to replace rejected piers shall be provided at no additional cost to the MBTA, unless the cause of rejection is due to an obstruction or mislocation.

3.6 CONTROL TECHNICIAN

- A. The Installer shall have a full-time, on-site Control Technician to verify and report all installation procedures. The Installer shall immediately report any unusual conditions encountered during installation to the Aggregate Pier Designer, the Design-Builder, and to the MBTA. The quality control procedures shall include the preparation of Aggregate Pier Progress Reports completed during each day of installation containing the following information:
1. Footing and aggregate pier location.
 2. Pre-auger diameter and soil conditions encountered during drilling (if required).
 3. aggregate pier length.
 4. Planned and actual aggregate pier elevations at the top and bottom of the aggregate pier.
 5. Average lift thickness of each aggregate pier.
 6. Volume of aggregate used in each aggregate pier.
 7. Documentation of any unusual conditions encountered.
 8. Type and size of densification equipment used.

3.7 AGGREGATE PIER MODULUS TEST

- A. A minimum of one (1) Modulus Test is required per structure or change in soil conditions, whichever is greater. When authorized, an Aggregate Pier Modulus Test(s) shall be performed at locations agreed upon by the Aggregate Pier Designer and the MBTA to verify or modify aggregate pier designs. Modulus Test Procedures shall utilize appropriate portions of ASTM D 1143 and ASTM D 1194, as outlined in the aggregate pier design submittal. aggregate piers shall be tested to 150% of the maximum design stress as shown in the aggregate pier design submittal. The aggregate pier used for each modulus tests shall be constructed using the same equipment and procedures and in similar soil conditions as production aggregate piers.
- B. A telltale shall be installed at the bottom of the test pier so that bottom-of-pier deflections may be determined. Acceptable performance is indicated when the bottom of the pier deflection is no more than 30% of the top of pier deflection at the design stress level.
- C. ASTM D-1143 general test procedures shall be used as a guide to establishing load increments, load increment duration, and load decrements. The loading increment shall be a minimum of 17% of the design load and shall be held for a maximum of 15 minutes. At least one load increment per test shall be held for 60 minutes to provide data to evaluate creep.
- D. All load increments shall be held for a minimum of 15 minutes. Loads are then maintained until the rate of deflection reduces to 0.01 inch per hour or for the maximum of 1 hour, whichever is occurs first.
- E. A minimum of one load increment that represents greater than 100% of the design maximum stress on the aggregate pier shall be held until the rate of deflection reduces to 0.01 inch per hour or for the maximum of 4 hours, whichever is occurs first.
- F. A seating load equal to 5% of the total load shall be applied to the loaded steel plate prior to application of load increments and prior to measurement of deflections to compensate for surficial disturbance.

3.8 BOTTOM STABILIZATION TESTING (BSTS) / CROWD STABILIZATION TESTING (CSTs)

- A. Bottom stabilization testing (BSTs) or Crowd stabilization testing (CSTs) shall be performed by the Control Technician during the installation of the modulus test pier. The installer shall perform a minimum of one test per Modulus Test. The tests are performed by applying downward vertical energy to the tamper, mandrel or probe following lift construction and monitoring the amount of additional deflection from the applied energy. Additional BST/CST testing as required by the Aggregate Pier Designer (a minimum of 10% of the production aggregate piers) shall be performed on selected production aggregate pier elements to compare results with the modulus test pier.

3.9 INDEPENDENT ENGINEERING TESTING AGENCY (MBTA'S QUALITY ASSURANCE)

- A. The Design-Builder is responsible for retaining an independent engineering testing agency to provide Quality Assurance services.

3.10 RESPONSIBILITIES OF INDEPENDENT ENGINEERING TESTING AGENCY

- A. The Testing Agency shall monitor the modulus test pier installation and testing. The Installer shall provide and install all dial indicators and other measuring devices.
- B. The Testing Agency shall monitor the installation of aggregate piers to verify that the production installation practices are similar to those used during the installation of the modulus test elements.
- C. The Testing Agency shall report any discrepancies to the Installer, Design-Builder, and MBTA immediately.
- D. The Testing Agency shall observe the excavation, fill placement and compaction, and preparation of subgrades for the construction of foundations supported by the aggregate piers.
- E. The Testing Agency shall observe subsurface soils are consistent with the design assumptions.

3.11 SITE PREPARATION AND PROTECTION

- A. The Design-Builder shall locate and protect underground and aboveground utilities and other structures from damage during installation of the aggregate piers.
- B. Design-Builder shall prepare site grades for aggregate pier installation to minimize aggregate pier installation depths. Ground elevations and bottom of footing elevations shall be determined in sufficient detail to estimate installation depth elevations to within 3 inches.
- C. The Design-Builder shall prepare and maintain a stable working surface required for the efficient installation of aggregate piers. Design-Builder to provide wet weather protection of the subgrade and to provide access for efficient operation of the aggregate pier installation.
- D. Prior to, during and following aggregate pier installation, the Design-Builder shall provide positive drainage to protect the site from wet weather and surface ponding of water.
- E. If spoils are generated by aggregate pier installation, Design-Builder shall remove spoils from the aggregate pier work area in a timely manner to prevent interruption of aggregate pier installation.

3.12 AGGREGATE PIER LAYOUT

- A. The Design-Builder shall layout individual aggregate pier elements in the field using survey stakes or similar means at locations shown on the drawings in accordance with Section 3.4 PLAN LOCATION AND ELEVATION OF AGGREGATE PIERS.

3.13 EXCAVATIONS FOR OBSTRUCTIONS

- A. The Design-Builder shall remove obstructions encountered during installation, or the pier shall be relocated or abandoned in accordance with a design change provided by the Designer. Obstructions include, but are not limited to, boulders, timbers, concrete, bricks, utility lines, which shall prevent placing the piers to the required location and depth.

3.14 UTILITY EXCAVATIONS

- A. The Design-Builder shall coordinate all excavations made subsequent to aggregate pier installations so that excavations do not encroach on the piers as shown in the aggregate pier construction drawings. Design-Builder shall protect completed aggregate piers. In the event that utility excavations are required in close proximity to the installed aggregate piers, the Design-Builder shall contact the Aggregate Pier Designer immediately to develop construction solutions to minimize impacts on the installed aggregate pier elements.

3.15 FOOTING BOTTOMS

- A. Excavation and surface compaction of all improved subgrades shall be the responsibility of the Design-Builder.
- B. Foundation excavations to expose the tops of aggregate piers shall be made to protect the subgrade and aggregate piers until concrete placement, with procedures and equipment best suited to: (1) avoid exposure to water; (2) prevent softening of the matrix soil between and around the aggregate piers before pouring structural concrete; and, (3) achieve direct and firm contact between the dense, undisturbed aggregate piers and the concrete footing.
- C. Subgrade Preparation: Following aggregate pier installation, the Design-Builder shall prepare the subgrade prior to the placement of structures to be supported.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02196

GEOTEXTILE MATERIALS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Work of this Section consists of all labor, materials, equipment and incidentals required to furnish and install Geotextile Fabric for Stabilization (generally 2:1 or greater slopes) and for seeded drainage channels to minimize erosion of soils as shown on the contract documents and as directed by the MBTA.
- B. The Design-Builder shall design, layout and install all geotextile materials at all work sites necessary to stabilize soils and minimize soil erosion.

The Design-Builder may elect to substitute different materials or methods other than those specified herein. In that instance, it shall be the Design-Builder's responsibility to demonstrate to the MBTA that the proposed design is equal to or greater than these specifications and will comply with all permit and regulatory requirements.

- C. Related Work:
1. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 2. Section 02100 – SITE PREPARATION
 3. Section 02270 – SLOPE PROTECTION
 4. Section 02300 – EARTHWORK
 5. Section 02357 – CAST IN PLACE CONCRETE RETAINING WALLS
 6. Section 02509 – PAVEMENT BASE COURSES

1.2 SUBMITTALS

- A. Design-Builder shall provide the following samples and submittals for approval. Do not order materials until MBTA's approval of samples, certifications and/or test results has been obtained. Delivered materials shall closely match the approved samples. Samples and approvals which are not obtained prior to the ordering of materials or the completion of work shall result in possible disapproval of obtained materials or completed work.
- B. Manufacturer's Literature: Submit manufacturer's literature indicating material descriptions, physical properties and installation instructions for the following:
1. Geotextile Fabric for Stabilization.
- C. Samples: Submit 2 foot x 2 foot samples of each of the following materials:
1. Geotextile Fabric for Stabilization.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Substitutions for alternative materials shall meet the equivalent specifications, and shall be requested in writing for approval by the MBTA.
- B. Testing for physical properties shall be completed at a Geosynthetic Accreditation Institute Program (GAI-LAP) accredited laboratory. Material property values shall be reflective of Minimum Average Roll Values (MARV). Letters of MARV values from a GAI-LAP accredited laboratory and signed by a manufacturer representative shall accompany all materials shipped to the job sites.

2.2 GEOTEXTILE FABRIC

- A. Fabric netting and fiber body shall be a composed of biodegradable materials approved by the MBTA.
- B. Limiting shear stress for soil loss shall be 4 pounds per square foot in vegetated state at 0.5 hours peak flow duration.
- C. Geotextile fabric shall be used in the ballast mat

2.3 ANCHORS

- A. Anchoring devices shall consist of U-shaped wire staples. Wire shall be a minimum of 8 gauge. All anchors should be 8-10 inches. Longer anchors may be necessary for loose soils.

PART 3 - EXECUTION

3.1 GENERAL INSTALLATION

- A. Alternate construction methods, if required, shall be approved by the MBTA prior to construction. Specific written installation instructions of the manufacturer shall supplement the instructions in these Specifications and as shown on the Approved Drawings.
- B. Before placing erosion control fabric, the sub-grade shall be inspected by the Design-Builder and MBTA to ensure that it has been evenly graded, properly compacted, that it is smooth, without soft areas, voids, obstructions, stones or other foreign matter. All plantings shall have been installed with watering saucers or seeded as shown on the Approved Drawings prior to installation of fabric. Refer to Approved Drawings for specific details regarding installation of Geotextile Fabric for Stabilization. Work shall not be undertaken when it is raining or when rain is forecast for that workday. Weather forecast printout shall be given to the MBTA prior to commencing this work.
- C. Open bales of jute fabric according to manufacturer's printed instructions.
- D. At tops of slopes or channels, as shown on the Approved Drawings, cut a 6-inch deep trench at least two feet from the crown of the slope, where possible, and backfill and compact the fill. Insert wire staples one foot on center to secure the top edge. Unfold the fabric down the slope, ensuring that it lies smoothly but loosely on the surface without tension. Where plantings are present, make perpendicular cuts in the fabric to allow the fabric to work around the base of the plant, making

any additional cuts as required. Insert staples 6 inches on center to join the cut fabric and to secure around plant bases. Staple center area of fabric at 3 feet on center and 6 inches on center at edges after overlapping adjacent panels of fabric. At junction overlaps of fabric joints, fold under upper panel bottom edge 6 inches and insert lower panel 20 inches, shingle-like, under the upper panel. Inset staples 6 inches on center at junction overlaps. Terminate fabric 2 feet beyond toe of slope where possible. Adjacent longitudinal fabric panels should extend by 6 inches at side overlaps. Cover outside edges of fabric with existing topsoil with added Compost Topsoil and tamp in place. Ensure that fabric covers all areas shown on the Drawings which are to be protected from erosion. All surfaces shall be rolled with a 75-pound per linear foot roller to ensure complete contact with soil below. Any seeded areas that are disturbed by installation of fabric shall be overseeded. All completed areas of Geotextile Fabric for Stabilization shall be approved by the MBTA.

3.2 SLOPES

- A. Refer to General Installations preceding and modify as shown herein. Unless otherwise directed by the Approved Drawings, where cut or fill slopes extend into channels, channels shall be lined with fabric prior to placement of fabric on slopes.
- B. Where slopes extend into channels, trench for the top of the channel shall serve as the anchor for the slope material. Bury the ends of the fabric in the trench as specified below. Fabric shall be placed in such a way as to ensure continuous contact with soil without folds or wrinkles. Provide a minimum 6- inch seam overlap.

3.3 CHANNELS

- A. Refer to General Installations preceding and modify as shown herein. Dig anchor trenches minimum at the crest on either side of the channel. Where the side of the channel extends to become part of a cut or fill slope, cut the trench at or above the elevation of the trench at the corresponding point on the crest on the opposite side.
- B. Fabric for channels shall be laid out beginning at the bottom of the channel, at the drainage structure or low point, and rolled upstream parallel with the flow. Successive courses of mat shall be laid out with a minimum 20-inch overlap on the edges and a minimum of 12 inches overlap on the ends. At all overlaps, place the up-slope mat over the down-slope portion, to produce a shingled effect. Mat shall be placed in such a way as to ensure continuous contact with soil without folds or wrinkles. Bury ends of mat as specified below.
- C. Provide check slots in channel at intervals no greater than 30 feet.
- D. Place staples in evenly staggered rows to achieve at least 2.5 anchors per square yard. In addition, seams and overlaps shall be stapled at 12" on center.
- E. Reseed all backfill and disturbed areas around slopes and channels with specified seed as shown on the Approved Drawings and as directed by the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02202

MECHANICALLY STABILIZED EARTH RETAINING WALLS

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This work shall consist of the designing, furnishing, and construction of Mechanically Stabilized Earth Retaining Walls (MSE) in accordance with these specifications and in close conformity with the lines, grades, and dimensions shown on the Design Builders Approved Drawings or established by the MBTA. Final design details for these structures, such as concrete unit thickness, connection details, and loading appurtenances, shall be as designed by the manufacturer from design parameters contained herein. This specification is intended to cover all mechanically stabilized earth retaining wall systems, some of which may be proprietary.
- B. The mechanically stabilized earth retaining walls shall consist of precast concrete units, geosynthetic reinforcement, select fill, filter fabric, a cast-in-place leveling pad, and a precast or cast-in-place coping cap or curb. Steel reinforcement for soils shall not be used to avoid stray current issues. The precast concrete units shall be sized to have sufficient external stability resistance at each module course to satisfy the design criteria. The material, fabrication, and construction shall comply with this specification and the requirements specified by the supplier of the wall system.

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
 - 1. Section 02100 – SITE PREPARATION
 - 2. Section 02196 – GEOTEXTILE MATERIALS
 - 3. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 - 4. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 - 5. Section 02300 – EARTHWORK
 - 6. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 7. Section 03300 – CAST-IN-PLACE CONCRETE
 - 8. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE
 - 9. Section 03450 – ARCHITECTURAL PRECAST CONCRETE

1.3 REFERENCE STANDARDS AND DEFINITIONS

- A. Reference herein to any technical society, organization, group, or body is made in accordance with the following abbreviations. Unless otherwise noted or specified, all Work under this Section shall conform to the latest edition, as applicable.
 - 1. ASTM: American Society for Testing and Materials
 - 2. OSHA: Occupational Safety and Health Administration
 - 3. Building Code: Commonwealth of Massachusetts Building Code, Current Edition
 - 4. DEP: Massachusetts Department of Environmental Protection
 - 5. MCP: CMR 40.0000, Massachusetts Contingency Plan

6. Contractor: Entity responsible for completing the Work of this Section.
7. MBTA: Massachusetts Bay Transit MBTA
8. Earthwork: All excavation, handling, conditioning, and backfilling operations of all soil, rock, and other materials for new foundation, pavement, and all other construction and site development, including obstructions and utility relocation and construction, regardless of the nature of the material encountered, the water content thereof, and type of equipment required for excavation, removal, or placement.
9. Geosynthetic Reinforcement (grid reinforcement): A regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with surrounding fill material.

B. Precast Panels

1. Refer to specification Section 03450 – ARCHITECTURAL PRECAST CONCRETE, for related reference standards, definitions, and additional requirements.

C. Geosynthetic Reinforcement

1. ASTM D 1238 – Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer (PP&HDPE)
2. ASTM D 1248 – Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
3. ASTM D 1505 – Test Method for Density of Plastics by the Density-Gradient Technique (HDPE only)
4. ASTM D 2455 – Test Method for Identification of Carboxylic Acids in Alkyd Resins (PET only)
5. ASTM D 4354 - Practice of Sampling Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
6. ASTM D 4595 - Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method (modified for geogrids)
7. ASTM D 4603 – Test Method for Determining Inherent Viscosity of Poly (Ethylene Terephthalate) (PET) by Glass Capillary Viscometer (PET only)
8. ASTM D 4759 – Practice for Determining the Specification Conformance of Geosynthetics
9. ASTM D 5262 - Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
10. GRI GG-1: Single Rib Geogrid Tensile Strength (Quality Control only)
11. GRI GG-4(a): Determination of the Long-Term Design Strength of Stiff Geogrids
12. GRI GG-4(b): Determination of the Long-Term Design Strength of Flexible Geogrids
13. GRI GG-5: Geogrid Pullout
14. GRI GG-7: Determining Carboxyl End Groups in Polyethylene Terephthalate (PET) Geotextiles and Geogrids
15. GRI GG-8: Determining the Average Molecular Weight Based on a Relative Viscosity Value

D. Reinforced Backfill and Drainage Aggregate

1. ASTM D 1557 – Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort
2. ASTM D 422 – Test Method for Particle-Size Analysis of Soils
3. ASTM D 424 - Atterberg Limits of Soils
4. ASTM G 51 – Test Method for pH of Soil for Use in Corrosion Testing
5. ASTM D 448 - Classification for Sizes of Aggregate for Road and Bridge Construction
6. ASTM D 5321 – Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear
7. ASTM D 2974 – Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

E. High Density Polyethylene (HDPE)

1. ASTM F 405 – Specification for Corrugated Polyethylene (PE) Pipe and Fittings

1.4 PROJECT CONDITIONS

- A. Subsurface investigation data are available for the project area. Prior to submitting his bid, the Contractor shall review and understand the information contained in the geotechnical report and all Contract Documents. The geotechnical report is made available to the Contractor for information on factual data only and shall not be interpreted as a warranty of subsurface conditions whether interpreted from written text, boring logs, or other data.
- B. The Contractor shall draw his own conclusions regarding site conditions based upon site history, Contractor site observations, and from available sources, for which the MBTA and its Consultants assume no responsibility. The Contractor shall assume that subsurface conditions between subsurface explorations could differ from conditions shown in the records of the explorations.

1.5 SUBMITTALS

- A. The Contractor shall submit the following to the MBTA for review:
1. The manufacturer’s product data for the MSE wall system including all materials, manufacture and erection specifications, all specialized erection equipment necessary, details of buried MSE wall elements, special details required of reinforcing layout, design properties, type of backfill, and details for connection between facing panels.
 2. A proposed narrative describing the means and methods for the proper construction of the wall, particularly including the following:
 - a. Sequence and schedule of all operations.
 - b. Method(s) of maintaining and monitoring horizontal and vertical position and orientation during installation of each course of facing elements.
 - c. Achieving and maintaining tension in the geosynthetic reinforcement during installation.

- d. Placement and compaction of backfill materials.
- e. Connection of the geosynthetic grid to the facing units.

The means and methods are subject to review by the MBTA's Representative prior to start of MSE wall construction.

- 3. A list of at least three reference projects performed within the past five years having similar wall heights and face areas with references, to demonstrate that the installer and its project personnel are experienced in constructing walls comparable to the proposed MSE wall. One additional reference project from the wall facing units' manufacturer shall be submitted having used the same facing units and type of geosynthetic reinforcement proposed for this project.
- 4. Geosynthetic Reinforcement: At least thirty (30) days prior to installation of the geogrid, the Contractor shall submit a certificate of compliance. The submittal shall include all applicable test data to support the minimum average roll value (MARV) based T_{ult} values and also the reduction factors used for the calculation of T_{al} . The test data shall be obtained in full accordance with the test methods and standards defined in the section of the AASHTO/ASTM Standard Specifications referenced herein. Each roll shall be clearly labeled so as to easily identify the product in the field. The label shall include as a minimum, the manufacturer's name, product name and number, and the contract item name and number. The Contractor shall submit the following information regarding the Geosynthetic Reinforcement proposed for use:
 - a. Manufacturer's name.
 - b. Full product name and manufacturers' literature and material specifications.
 - c. Geosynthetic Reinforcement structure and polymer type.
 - d. Samples: A representative square yard sample. The machine direction shall be clearly marked on each sample.
 - e. Laboratory Testing Results: ASTM-D4595 – At least 3 Geosynthetic Reinforcement samples shall be tested from the rolls to be delivered and used for the project. Wide width tests shall be performed at a strain rate of 10 ± 3 percent per minute as per ASTM D 4595. Actual data points shall be shown on graphs. Raw test data from any test or used test specimens shall be submitted to the MBTA upon request. All test results must meet the Geogrid requirements specified herein.
 - f. Laboratory Testing Results: ASTM-D5321 – At least 2 tests shall be completed using the proposed Granular Fill and Geosynthetic Reinforcement samples from rolls to be delivered and used for the project. For the specified soil to geosynthetic direct shear tests (ASTM D5321), a Standard Proctor compaction test shall be performed in accordance with AASHTO T99. The soil shall be compacted to 95 percent of the maximum Standard Proctor dry density with moisture content from 0 to 2 percent above optimum. The normal pressures for the direct shear tests shall be 250 psf, 500 psf, 1000 psf, and 2000 psf. Soil shall not be used for more than one data point. The soil and geosynthetic samples shall be inundated and soaked for 12 hr. (minimum) before testing. All test results must meet the Geosynthetic Reinforcement requirements specified herein.
- 5. Provide manufacturer's specifications and working drawings and calculations for the precast facing units.

- a. The precast facing units shall contain connection compatibility with the geosynthetic reinforcement type, spacing, and other installation details as referenced in this section.
 - b. The front face of the units shall receive form liner finish compatible with architectural finishes of other concrete elements specified elsewhere in these Contract Documents.
 - c. Refer to Section 03450 – ARCHITECTURAL PRECAST CONCRETE for additional requirements.
- B. Shop Drawing Submittals. Three weeks prior to the start of work on the wall, the Contractor shall submit to the MBTA for approval the following:
- 1. Details for the proposed MSE wall system including: drainage system; pipe penetrations; guardrail and/or fence post details; facing units; geosynthetic materials; backfill and fill materials; connections; cap blocks/copings; wall terminations; corner details. Contractor shall include details for pointing posts, or installing drive shoes to penetrate reinforcement and membrane materials, or include details for installing sleeves for posts as the wall system is constructed.
 - 2. Refer to specification Section 03450 – ARCHITECTURAL PRECAST CONCRETE for precast facing unit for additional drawing requirements.
- C. Submit Plan of Actions to be implemented in the event any Response Value for deformation, as specified in Table 02202-1, is reached.

**TABLE 02202-1
RESPONSE VALUES**

Monitoring Type	Value
<u>Lateral Deflection of Earth Support Wall</u>	
Top of wall	1%
Mid-Point of wall	0.5%
<u>Vertical Deflection of Earth Support Wall</u>	
Top of wall	1/2 inch
<u>Ground Surface Settlement</u>	
Top of Rail	1/4 inch

- D. The Plan of Actions shall be positive measures by the Contractor to limit further movement of the wall. The details of the mitigating measures shall include a schedule of implementation, location and/or availability of materials, and a detailed description of the method of implementation. The Contractor shall be prepared to work twenty four (24) hours per day to implement such measures

1.6 QUALITY ASSURANCE

- A. The MBTA's Geotechnical MBTA shall perform on-site observation and testing during various phases of the construction operations. The Geotechnical MBTA's presence does not constitute supervision or direction of the Contractor's work. Neither the presence of the Geotechnical MBTA, nor any observations and testing performed by him, nor any notice or failure to give notice shall excuse the Contractor from conformance with these Specifications or from defects discovered in its work or from the Contractor's responsibility for site safety including both persons and property.
- B. All costs and schedule delays related to testing or replacement of nonconforming materials shall be paid for by the Contractor at no additional cost to the MBTA. Testing in excess of two samples per material type shall be paid for by the Contractor at no additional cost to the MBTA.
- C. Approvals given by the MBTA, Geotechnical MBTA or MBTA shall not relieve the Contractor of his responsibility for performing the Work in accordance with the Contract Documents, nor shall they be construed to relieve the Contractor from full responsibility for the means and methods of construction and for safety on the construction site.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. The Contractor shall inspect the materials upon delivery to assure that proper type and grade of material has been received.
- B. The Contractor shall store and handle materials in accordance with the manufacturer's recommendations.
- C. The Contractor shall protect the materials from damage, deterioration, and contamination. Damaged or contaminated material shall not be incorporated into the MSE wall.

1.8 LINES, GRADES, AND TOLERANCES

- A. The Contractor shall be responsible for establishing all lines, grades, and other survey control to complete the Work. The Contractor shall be responsible for the maintenance and protection of the survey control reference points and location stakes. The Contractor shall employ a Registered Land Surveyor, licensed in Massachusetts, familiar with the required construction, which shall establish lines and levels. The Contractor shall be responsible for the correct location of the Work in this section, including locations and elevations and limits of excavations and fills.
- B. Construct finished grades to within 1/2-inch of the elevations indicated on the Design Builders Approved Drawings.
- C. Maintain the moisture content of the fill material during placement as required to achieve project specified compaction.

1.9 PERMITS, CODES, AND SAFETY REQUIREMENTS

- A. Comply with all local, state, and federal rules, regulations, laws, and ordinances having jurisdiction over the project site. All labor, materials, equipment, and services necessary to make the Work comply with such requirements shall be provided by the Contractor without additional cost to the MBTA.
- B. Comply with the provisions of the requirements of the Occupational Safety and Health Administration (OSHA), United States Department of Labor.
- C. The Contractor shall procure and pay for all permits and licenses required for the complete Work specified herein and shown on the Design Builders Approved Drawings.

PART 2 – PRODUCTS

2.1 GENERAL

- A. The Contractor shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Contractor, or the supplier as his agent, shall furnish the MBTA a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the MBTA.

2.2 MATERIALS

- A. Refer to specification Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE for precast facing unit requirements.
- B. Geosynthetic reinforcement shall consist of geogrids manufactured for soil reinforcement applications, and shall be manufactured from high density polyethylene conforming to the requirements of ASTM D 1248. Geosynthetic reinforcement shall consist of manufactured geogrid materials, having a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding soil. The geogrid structure shall be dimensionally stable and able to retain its geometry during manufacture, transport, installation, and use. All geosynthetic reinforcement shall be from the same manufacturer and of the same type, manufacturing process, and polymer. For all geogrid layers, Tensar UX1700MSE geogrid, or an equivalent approved by the MBTA, shall be used. The type, strength, placement, and location of the geosynthetic reinforcement shall be as shown on the Design Builders Approved Drawings and as stated herein. Do not use steel for soil reinforcement.
- C. Earth materials for use as fill and backfill shall be as described below. All soil materials proposed for importing to the site shall be clean, mineral soil materials from approved natural borrow sources, free of any contamination and recycled materials, as described above. Materials from construction sites or other non-commercial, natural borrow sources shall not be imported to the site. All materials imported

to the site shall contain no detectable amounts of oil and/or hazardous materials as defined by the MCP.

- D. All soil materials proposed to be used as fill shall be evaluated by the Geotechnical MBTA, based in part on information submitted by the Contractor. Materials shall be rejected for use based on the results of the evaluation. Materials shall not be brought to the site without prior approval of the Geotechnical MBTA. Off-site materials, which are rejected for use, if brought to the site, shall be immediately removed by the Contractor at its own expense.
- E. Stone Drainage Aggregate shall be used immediately behind the precast concrete panels and shall meet the requirements for processed 57 aggregate in accordance with AASHTO M 43-88. Drainage Aggregate shall consist of durable angular rock fragments, free from a detrimental quantity of thin, flat, elongated pieces or other objectionable pieces, or durable crushed stone obtained by artificial crushing of gravel, boulders or fieldstone with a minimum diameter before crushing of 8 in.
- F. Compacted Granular Fill shall conform to the requirements of Gravel Borrow, M1.03.0, Type b, of the Massachusetts Highway Department Standard Specifications for Highways and Bridges, current Edition. The material shall consist of clean, well-graded sand and gravel, free of organic material, snow, ice, recycled materials, debris, crushed or angular stones, or other objectionable materials. Compacted Granular Fill shall be compacted to at least 95 percent of the maximum dry density determined in accordance with ASTM D1557.
- G. Drainage pipe shall consist of 4-in. diameter Class I, perforated, corrugated, HDPE piping or approved equal in conformance with ASTM F405.

2.3 CERTIFICATION OF MATERIALS

- A. The Contractor shall submit a manufacturer's certification that the materials supplied meet the respective criteria in this Specification, measured in full accordance with all test methods and standards specified and as set forth in these Specifications. Refer to specification Section 03450 - ARCHITECTURAL PRECAST CONCRETE for additional precast facing unit requirements.
- B. The Contractor shall submit a manufacturer's certification that the geosynthetic materials supplied meet the respective criteria in this Specification, measured in full accordance with all test methods and standards specified and as set forth in these specifications. The manufacturer's certificate shall state that the furnished geosynthetic meets the requirements of the Specifications as evaluated by the manufacturer's quality control program. The certificates shall be attested to by a person having legal authority to bond the manufacturer. In case of dispute over validity of values, the Geotechnical MBTA can require the Contractor to supply test data from a laboratory accredited by the Geosynthetic Accreditation Institute (GAI) to support the certified values submitted. The quality control certificate shall include:
 - 1. Roll numbers and identification
 - 2. Sampling procedures
 - 3. Result of quality control tests, including a description of test methods used.

Manufacturer's certification shall include the manufacturer's tests and reports that substantiate the reduction factors for durability, creep and installation damage applicable to this project, including pull-out and connection strength values.

C. Geosynthetic Reinforcement

The geosynthetic reinforcement shall be manufactured with a high degree of quality control. The manufacturer is responsible for establishing and maintaining a quality control program to ensure compliance with the requirements of these Specifications.

Conformance testing shall be performed as part of the manufacturing process and shall vary for each type of product. As a minimum, the following index tests shall be considered as applicable for an acceptable QA/QC program.

Property	Test Procedure
Specific Gravity (HDPE only)	ASTM D 1505
Wide Width Tensile Strength	ASTM D 4595*; GRI GG1
Melt Flow (HDPE and PP only)	ASTM D 1238
Intrinsic Viscosity (PET only)	ASTM D 4603
Carboxyl End Group (PET only)	ASTM D 2455

* ASTM D 4595 or correlated to GRI GG-1.

2.4 SAMPLING, TESTING, AND ACCEPTANCE

A. Precast Panels:

Precast facing units shall be accepted for use in wall construction provided the concrete strength meets or exceeds the minimum compressive strength requirement, the soil reinforcement connection devices and the panel dimensions are within tolerances and any chipping, cracks, honeycomb or other defects are within acceptable standards for precast concrete as determined by the MBTA. The face side of the units shall receive the appropriate finish to match the architectural requirements for the project specified in Section 03450 - ARCHITECTURAL PRECAST CONCRETE.

It is recognized that certain cracks and surface defects are not detrimental to the structural integrity of the panel if properly repaired. The MBTA shall determine the need for and proper method of such repair. All repairs shall be approved by the MBTA prior to acceptance of the panel for use in wall construction.

The date of manufacture, the production lot number, and the piece-mark shall be clearly marked on the side of each panel.

Refer to specification Section 03450 - ARCHITECTURAL PRECAST CONCRETE for precast facing unit sampling, testing and acceptance requirements.

B. Geosynthetic Reinforcement:

Sampling and conformance testing shall be in accordance with ASTM D 4354. Geosynthetic product acceptance shall be based on ASTM D 4759. The Contractor shall submit testing results to the MBTA for review.

C. Reinforced Backfill and Drainage Aggregate:

Submit samples of reinforced backfill and drainage aggregate at a rate of 100 lbs. per 2,500 cu. yds. The Contractor shall provide sieve and compaction testing results performed in accordance with ASTM D442-63 and ASTM D1557-09 for each sample of submitted material for review by the MBTA. The MBTA shall perform in-place density tests of the materials during placement.

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS

- A. A coordination meeting shall be held prior to initiating the geogrid installation and related work. The purpose of the meeting shall be to review all aspects of the MSE wall construction and to facilitate coordination among all involved parties. The coordination meeting shall not take place until the Contractor has submitted and received approval for the geogrid materials. Individuals attending the meeting shall include the MBTA, Geotechnical MBTA, the Contractor, the Geosynthetic Reinforcement Technical Representative, and all other personnel deemed appropriate by the previously mentioned personnel.
- B. The Contractor shall exercise necessary care while handling, storing and installing the Geosynthetic Reinforcement. Prior to installation, the Geosynthetic Reinforcement shall be protected from weather, damage, direct sunlight, other ultra-violet exposure, mud, cement or other elements which shall affect its performance. Geogrid shall be stored above -20° F. Geosynthetic Reinforcement which is torn, punctured or in the opinion of the Geotechnical MBTA is otherwise damaged, shall not be used.
- C. Prior to placement of the Geosynthetic Reinforcement and related backfill, the foundation soil shall be compacted to provide a firm and stable surface. Areas determined to be unsuitable by the Geotechnical MBTA shall be over-excavated and replaced with Granular Fill as defined herein or other materials as directed by the Geotechnical MBTA.
- D. The Contractor shall determine exact configurations, lengths, sizes and quantities of all facing units, connections, geosynthetic reinforcement materials, backfill and fill, drainage aggregate, drainage pipe material, and associated ancillary construction items required for the MSE wall. The Contractor shall be responsible for layout, elevation, length, quantity and quality of each work item required by this section, and request MBTA approval of underlying materials before proceeding with construction of succeeding MSE wall activities. The MBTA reserves the right to monitor the Contractor's MSE wall construction operations and installation of all geosynthetic materials, and modify the design as necessary.

3.2 FOUNDATION PREPARATION

Prior to beginning construction of the MSE wall, the MBTA shall observe the prepared subgrade to confirm that it is dry, firm, stable, level, and free from deleterious or loose materials or otherwise unsuitable soils and rock. If, according to the MBTA, any areas do not meet the above criteria, the Contractor shall dewater areas which are wet, excavate and replace soft areas with suitable compacted backfill, perform compaction, and raise or lower grades to reach the MSE wall subgrade. The MBTA shall require proof-rolling of the subgrade to demonstrate its suitability.

3.3 PRECAST FACING UNIT AND GEOSYNTHETIC REINFORCEMENT INSTALLATION

- A. All materials shall be installed at the proper location, elevation and orientation as shown in the wall details on the Design Builders Approved Drawings or as directed by the MBTA. The MSE wall panels and geosynthetic reinforcement shall be installed in general accordance with the manufacturer's recommendations, unless otherwise modified by these Specifications. The Design Builders Approved Drawings shall govern in any conflict between the two requirements.
- B. Direct overlap (geogrid on geogrid) of the geosynthetic reinforcement in the design strength direction shall not be permitted, except at wall corners or elsewhere as indicated on the Design Builders Approved Drawings. The design strength direction is that length of the geosynthetic reinforcement perpendicular to the wall face, and shall consist of one continuous piece of material. Adjacent sections of geosynthetic shall be placed in a manner to assure that the horizontal coverage shown on the Design Builders Approved Drawings is provided.
- C. Construction of the MSE wall shall be performed in a continuous and time efficient manner such that no layer of geosynthetic reinforcement shall be left exposed for a significant period of time during the day, leaving the material potentially subject to damage due to construction activities. Install only that amount of geosynthetic reinforcement that can be immediately backfilled. No layer of geosynthetic reinforcement, once installed, shall be left exposed overnight.
- D. Geosynthetic reinforcement shall be installed on level subgrades to lay flat and be pulled tight prior to backfilling. Means and methods of achieving and maintaining tension during installation until the subsequent soil layer can be placed shall be submitted. Under no circumstances shall a track-type vehicle be allowed on the geosynthetic reinforcement before at least 8 in. of soil has been placed and compacted.
- E. The geosynthetic reinforcement vertical spacing indicated on the Design Builders Approved Drawings is the maximum vertical spacing allowed.
- F. During construction, the surface of the reinforced zone shall be kept approximately horizontal. Geosynthetic reinforcement shall be placed directly on the compacted horizontal fill surface. Geosynthetic reinforcements are to be placed at the level of the connection with the MSE wall facing units and extend to the lengths as shown on the Design Builders Approved Drawings unless otherwise directed by the MBTA. Correct orientation of the geosynthetic reinforcement with the principal strength direction perpendicular to the wall face shall be verified by the Contractor.

- G. Install MSE wall facing units by placing, positioning, and aligning MSE wall facing units in conformance with the manufacturer’s recommended installation criteria, unless otherwise modified by the Contract Documents or the MBTA. MSE wall facing units shall be placed side by side for the full length of the wall while maintaining alignment. Install and verify that the facing units are installed and maintained within the following tolerances:

Vertical control	0.5 in. over a distance of 10 ft.
Horizontal location control	0.5 in. over a distance of 10 ft, and 1.0 in. overall.
Rotation from established plan wall batter	0.5 in. over 10 ft height

After placement, maintain each MSE wall facing unit in position. Correct all misalignments of installed MSE wall facing units that exceed specified tolerances allowed, by method acceptable to the MBTA. Control all operations and procedures to prevent misalignment of the MSE wall facing units. Install each succeeding MSE wall facing unit course after appropriate backfill levels are reached. Maintain alignment and verticality, adjusting as necessary to meet the above requirements.

- H. Construction equipment shall not be operated directly upon the Geosynthetic Reinforcement. A minimum fill thickness of 8 inches is required prior to the operation of construction vehicles over the Geosynthetic Reinforcement. Turning of construction vehicles shall be kept to a minimum to prevent tracks from displacing the fill and Geosynthetic Reinforcement. Sudden braking and sharp turning shall be avoided. Any Geosynthetic Reinforcement which has been damaged or disturbed during or after installation shall be corrected, or removed and replaced with an equivalent undamaged section of Geosynthetic Reinforcement at the Contractor’s expense.
- I. Broken, chipped, stained or otherwise damaged MSE wall facing units shall not be placed in the wall and any such units shall be replaced at no cost to the MBTA.

3.4 BACKFILL PLACEMENT

- A. Reinforced Backfill and Drainage Aggregate shall be placed in maximum 8 in. compacted lift thicknesses. Backfill placement shall closely follow placement of each course of MSE wall facing units. Backfill shall be placed, spread, and compacted in such a manner that eliminates development of wrinkles or movement of the geogrid and the MSE wall facing units. Any MSE wall facing units or geogrid that become damaged as deemed by the MBTA during backfill placement shall be removed and replaced at the Contractor’s expense. Any misalignment or distortion of the MSE wall facing units outside the limits set by these Specifications shall be corrected at the Contractor’s expense. At each level of geosynthetic reinforcement, the backfill in the reinforced zone shall be placed and compacted to the level of the connection to the MSE wall facing units. Backfill placement methods near the facing shall assure that no voids exist directly beneath the reinforcing elements.
- B. All soil material shall be placed and compacted to 95 percent of the maximum dry unit weight determined in accordance with ASTM D1557, and otherwise as required by the project specifications or indicated on the Design Builders Approved Drawings.

- C. Filling and backfilling shall be performed in accordance with Section 02300 - EARTHWORK. Backfill more than 3 ft laterally from wall facing units shall be compacted using hand-guided vibratory plate compactors or hand-guided vibratory rollers delivering a minimum dynamic force of 8,000 lbs. Within 3 ft behind the wall facing units, compactors imparting a dynamic force of 2,000 to 3,000 lbs shall be used.
- D. Drainage aggregate shall be placed immediately behind the MSE wall facing units, and extend 1-ft beyond back of panel. Drainage aggregate shall be placed in lifts as the lifts of reinforced backfill are placed. The drainage aggregate shall be compacted in lifts with each lift compacted with two passes using hand-guided plate compactors imparting a dynamic force of 2,000 to 3,000 lbs.
- E. Backfill and drainage fill shall be protected from freezing and other disturbances in accordance with Section 02300 – EARTHWORK.
- F. Tracked construction equipment shall not be operated directly on the geosynthetic reinforcement. A minimum backfill thickness of 8 in. is required prior to operation of tracked vehicles over the geosynthetic reinforcement. Turning of tracked vehicles shall be kept to a minimum to prevent displacing the fill and damaging or moving the geosynthetic reinforcement.
- G. Rubber-tired equipment shall not be allowed to traffic directly on exposed layers of the geosynthetic reinforcement. Rubber-tired equipment shall be allowed to pass over areas which have received geosynthetic reinforcement if a) a minimum 8-in. thick layer of backfill has been placed and compacted over the most recent layer of geosynthetic reinforcement, b) the equipment is sufficiently sized to limit depressions in the backfill to no more than 1 in., c) trafficking is performed in accordance with the equipment manufacturer’s recommendations, and d) field tests are performed to demonstrate the geosynthetic reinforcement shall not be damaged more than the geosynthetic manufacturer’s installation damage reduction factor would indicate under the equipment access conditions. If allowed, all equipment shall operate at speeds less than 8 miles per hour. Sudden braking and sharp turning are prohibited.
- H. At the end of each day’s operation, the Contractor shall slope the last lift of backfill away from the wall facing to direct storm water runoff away from the wall face. In addition, the Contractor shall not allow surface water runoff from adjacent areas to enter the MSE wall construction site.

3.5 PANEL COPING/CAP BLOCK PLACEMENT

If shown on the Design Builders Approved Drawings, the coping and/or top MSE wall facing unit shall be bonded to the facing units below using approved methods as described herein, and as described in Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02205

RETAINING WALL REHABILITATION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies retaining wall rehabilitation work including the following:
 - 1. Reface existing crib walls.
 - 2. Concrete repairs to the existing evergreen walls.
 - 3. Surface rehabilitation of existing cast-in-place retaining walls.
- B. Existing retaining walls within the project limits are listed in Technical Provision Article 8.1, Table 8.1-1 indicating the existing walls to remain, be rehabilitated or to be replaced as listed in the Table.
- C. Vegetation and organics shall be cleared from the face of the existing wall and between the existing cribs. Vegetation shall also be cleared at the top of the wall for distance of 2 feet behind the top of wall.
- D. Rehabilitation of existing walls may consist of soil nails and concrete or shotcrete re-facing, soil screws and concrete or shotcrete re-facing, modular precast block retaining walls or soldier pile retaining walls in front of existing retaining walls or any other means to protect the in-situ walls to remain.
- E. Rehabilitated walls shall maintain equivalent drainage characteristics of the original existing wall. Drainage details shall be submitted as part of the rehabilitation details which may include filter fabric with crushed stone, dimpled drainage board, weep holes or any other equivalent details designed to drain water from behind the wall and retain soil fines.
- F. The tops of the rehabilitated walls shall be finished with a cap of either cast-in-place or precast concrete. The design shall take into account surface runoff and not create a "dam-like" situation where surface water may back up behind the wall.
- G. Rehabilitated wall facing shall include architectural striations in accordance with Design Builders Approved drawings. Wall re-facing patterns shall not include horizontal striation patterns which may be used for climbing.
- H. Rehabilitated walls shall not incur additional loads greater than their current loading condition. If existing walls incur additional loading based on the Design Builders redesign, then the existing wall shall be redesigned for the new loads or replaced.
- I. Wall re-facing details, which include continuous concrete or shotcrete re-surfacing, shall include provisions for construction joints, expansion joints and stray current control.
- J. Cast-in-Place Concrete Wall repairs shall meet the requirements of Specification 03930 – CONCRETE REHABILITATION AND REPAIR.
- K. Existing walls designated as requiring rehabilitation may be replaced with a new wall by the Design Builder in lieu of rehabilitation at the Design Builders discretion and shall be submitted for approval.

1.1 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
- 1.
 2. Section 02196 – GEOTEXTILE MATERIALS
 3. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 4. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 5. Section 02300 – EARTHWORK
 6. Section 02356 – SOLDIER PILES AND LAGGING RETAINING WALLS
 7. Section 02357 - CAST-IN-PLACE CONCRETE RETAINING WALLS
 8. Section 02358 - SOIL NAIL RETAINING WALLS
 9. Section 02359 – MODULAR PRECAST BLOCK RETAINING WALLS
 10. Section 03300 – CAST-IN-PLACE CONCRETE
 11. Section 03371 - SHOTCRETE
 12. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE
 13. Section 03930 – CONCRETE REHABILITATION AND REPAIR
 14. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS

1.2 SUBMITTALS

- A. Working Drawings
1. Submit working drawings at least two (2) weeks before beginning excavation or installation of any excavation support system and bracing used for the rehabilitation of existing walls. Submit each existing wall location under separate cover and in the sequence of their installation.
- B. Additional Requirements for Working Drawings – Working drawings shall include the following:
1. Grades and strengths of all construction materials used.
 2. Full excavation depth.
 3. Depths below the main excavation to which the excavation support system shall be installed if necessary.
 4. Materials, details, arrangement, and method of construction of the proposed excavation support system, per Section 02260 – EXCAVATION SUPPORT AND PROTECTION, and sequence of construction (including bottom elevation of excavation at each stage).
 5. Method for wall rehabilitation.
 6. Loads on the excavation support system for various stages of excavation.
 7. Anticipated equipment, traffic (and other surcharge) loads on adjacent ground during construction.
- C. Existing utility facilities, including underground and overhead utilities. After checking locations of utilities by field investigations, determine which affect or potentially may affect the wall rehabilitation.

- D. Submit descriptive data and operating procedures for all equipment to be used. This shall include, at a minimum, machinery required to install wall and bracing, excavate soil, and remove obstructions. Submit all pertinent data including sizes, weights, capacities, torques and operating frequencies.

1.3 PROJECT CONDITIONS

- A. Visit the site to review all details of the work and working conditions affecting Work under this Section and to verify dimensions in the field including potential interference from adjacent structures and utilities. Notify the Engineer in writing of any discrepancy before performing any work. The Design Builder is hereby notified that the job site is located adjacent to the active railroad and existing low rise buildings. Refer to Section 00700 – GENERAL CONDITIONS.
- B. The Design Builder shall be responsible for implementing all necessary traffic control measures, which may include traffic cones, barriers, barrels, signage, flagmen, and police details.
- C. Consult official records of existing utilities, both surface and subsurface, and their connections to be fully informed on all existing conditions and limitations as they apply to this work and its relation to other construction work. Proceed with caution in areas of utility facilities. Expose them by hand excavation or by other methods acceptable to the utility owner. Protect existing utilities to remain within and adjacent to the work area in accordance with the requirements of authorities having jurisdiction over same. The Design Builder is responsible for any damage to utilities caused by the Design Builder's operations and shall restore them to equal or better operation at no additional cost to MBTA.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The Design Builder shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Design Builder, or the supplier as his agent, shall furnish the MBTA a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the MBTA.

2.2 MATERIALS

- A. Structural Steel for soldier piles shall conform to applicable requirements of Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- B. Reinforcement Steel for use within cast-in-place concrete shall conform to Section 03300 – CAST-IN-PLACE CONCRETE.
- C. Concrete for drilled shaft hole fill (below bottom of excavation as shown on Design Builder's Detailed Shop Drawings) shall conform to relevant articles of Section 03300 – CAST-IN-PLACE CONCRETE (4000 psi, 3/8").

- D. Concrete for cast-in-place shall conform to relevant articles of Section 03300 – CAST-IN-PLACE CONCRETE (4000 psi, 3/4”).
- E. Concrete for precast panels for retaining walls shall conform to relevant articles of Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE (5000 psi, 3/4”).
- F. Controlled Density Fill (CDF), Type 2E in accordance with specification Section 02300 - EARTHWORK.
- G. Headed welded studs shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- H. Threaded welded studs shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- I. All structural timber used as lagging shall be rough sawn and conform to MBTA Guide Specifications for Structural Design of Rapid Transit and Light Rail Structures Article 9.6 and AREMA.
- J. Filter fabric shall conform to Section 02196 - GEOTEXTILE MATERIALS.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

- A. Rehabilitate the wall in accordance with the Design Builder’s Approved Drawings, and in such a manner as to prevent movement, settlement, loss of ground, removal of fines from the adjacent ground, and damage to or movement of the existing wall or adjacent structures and utilities. This could include the use of drilling slurry during installation of soldier piles in drilled shaft holes to maintain stable drill holes and limit the loss of ground outside the drill hole.
- B. Perform work from track side of the proposed wall unless temporary easements have been granted to minimize adjacent property impacts. Heavy equipment shall be placed on the track side of the proposed wall.
- C. Perform field welding by certified welders in accordance with American Welding Society Standards AWS D 1.1, "Structural Welding Code - Steel."
- D. Implement the Plan of Actions as submitted under Paragraph 1.3D, if Response Values as specified in Table 02356-1 are reached.
- E. Borings indicate below ground obstructions may be encountered. Such obstructions may include boulders and various other demolition and construction debris.

- F. Temporary casings if used for drilled shaft holes for soldier piles shall be installed where needed to the top of weathered bedrock, as a minimum, using rotary drilling techniques over their full depth to limit potential vibration damage to adjacent structures and facilities.
- G. Protection of Existing Properties
1. Design Builder shall protect existing properties in accordance with specification Section 01545 – PROTECTION OF WORK AND PROPERTY.
 2. Restore existing structures to conditions equivalent to those existing prior to the start of retaining wall rehabilitation and support work, unless otherwise indicated. Any damage to affected properties caused by the retaining wall rehabilitation shall be repaired by the Design Builder at no additional cost to the MBTA.
 3. If in the opinion of the MBTA the integrity of the adjacent railroad tracks, bridge, buildings, structures, or paved areas is jeopardized due to movement, the Design Builder shall immediately discontinue further excavation in the affected area and implement accepted Plan of Action to mitigate further movement. Mitigating measures shall remain in effect until such time that the MBTA evaluates the impact on the structure and may direct the Design Builder to perform any remedial work. The Design Builder shall submit proposed remedial measures to the Geotechnical MBTA for review and approval. Submittals shall include methods and names of subcontractors. The Design Builder shall proceed with remedial work upon acceptance by the MBTA. Mitigating measures shall be at no additional cost to the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02220

DEMOLITION FOR ROADWAY BRIDGES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. The demolition and partial demolition of existing Roadway Bridges.
- B. Related Work:
1. Section 01560 – TEMPORARY CONTROLS.
 2. Section 02090 – LEAD ABATEMENT.
 3. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 4. Section 02221 – DEMOLITION.
 5. Section 02223 – SEGREGATION OF DEMOLITION DEBRIS AND WASTE TRANSPORTATION AND DISPOSAL.
 6. Section 05420 – TEMPORARY STEEL UTILITY BRIDGES.
- C. Description of Demolition: The work to be done under this Section shall be performed in accordance with approved drawings from MassDOT, and shall consist of furnishing all labor, materials, and equipment necessary for the removal and satisfactory disposal the bridge structure.
- D. Description of Partial Demolition: The work to be done under this Section shall be performed in accordance approved drawings from MassDOT, and shall consist of furnishing all labor, materials, and equipment necessary for the modifications or partial removal and satisfactory disposal of the bridge structure.
- E. Bridge Structures: The following bridge structures are associated with the Green Line Extension Project:
1. Walnut Street Bridge, No. S-17-006 (AGV)
 2. School Street Bridge, No. S-17-008 (3G5)
 3. Medford Street Bridge, No. S-17-007 (3G4)
 4. Cedar Street Bridge, No. S-17-012 (AE7)
 5. Lowell Street Bridge, No. S-17-011 (AW2)
 6. Broadway Bridge, No. S-17-013 (3GA)
 7. College Avenue Bridge, No. M-12-012 (AN4)
- The Walnut Street Bridge, School Street Bridge, Medford Street Bridge, Cedar Street Bridge, Lowell Street Bridge and College Avenue Bridge involve only partial demolition. The Broadway Bridge is to be completely demolished.
- F. Prohibition on Blasting: No Blasting or use of explosives is permitted.

- G. **Jobsite Conditions:** The Contractor shall serve written notice to all Utility Companies and Municipal Departments and Agencies at least two weeks prior to the start of any work involved in the demolition of the bridges mentioned above, requesting discontinuance of service to or across the structures scheduled for demolition. The Contractor shall coordinate work with the utility relocation plans and the bridge staging plans.

- H. **Demolition Requirements:** The Contractor shall furnish all labor, materials and equipment necessary to remove and legally dispose of existing bridge elements, including but not limited to, reinforced concrete sidewalks, reinforced concrete bridge decks, bituminous pavement, earth fill, steel girders and bracing, reinforced concrete abutments and piers, bridge bearings, bridge railings, all pipelines and utility conduits, all pipe and utility supports and contents, and other incidental items associated with the existing bridge structures.

- I. **Limitations of Information Sources:** The Massachusetts Department of Transportation does not guarantee or represent that the bridge materials will actually coincide with any descriptions contained herein or represented on the drawings. The Contractor must visit the bridge site to become familiar with the scope of work and bridge conditions. No additional compensation shall be made if the site conditions, materials, or the scope of work provided, are different than that inferred or described herein or shown on the drawings. Drawings of the existing bridges are available on request from the office of the Director of Bridges and Structures, Massachusetts Department of Transportation, 10 Park Plaza, Boston, MA 02116.

- J. **Submittals:** The Contractor shall submit shop drawings that show the sequence of operations, measures to protect the public, and temporary supports. The sequence of operations must be planned so that at no time does an unsafe condition exist.

- K. **Applicability of the MassDOT Standard Specifications:** The Roadway Bridge Demolition requirements in this Specification are supplemented by MassDOT Standard Specifications (with Supplemental Specifications) Section 112.
 - 1. Replace all references to Measurement and Payment with the Section 4.1 below.
 - 2. For Roadway Bridge Demolition submittal requirements, including, but not limited to, shop drawings, working drawings, Requests For Information, Non Conformance and testing reports, refer to Section 01300 – SUBMITTALS of the Contract Specifications.
 - 3. Per Division 1 of the Contract Specifications, the Contractor is responsible for all sampling and testing as outlined in their approved Quality Management Plan and Testing Plan. The Contractor is also responsible for all costs related to the sampling, testing, and related work.

PART 2 – PRODUCTS

**2.1 TEMPORARY PROTECTIVE SHIELDING FOR BRIDGE DEMOLITION
DESCRIPTION OF WORK**

- A. The work to be done under this item shall provide for the safety beneath and adjacent to the bridges from falling debris during the removal of the existing bridge superstructure, substructure, sidewalks and any other miscellaneous materials that may fall during the course of demolition and reconstruction. This shall be accomplished by the utilization of adequate shielding placed beneath and adjacent to the existing structure prior to the work. Temporary Protective Shielding shall also be provided during the construction of the proposed superstructure.

The Contractor shall submit calculations and drawings stamped by a Professional Structural Engineer registered in the Commonwealth of Massachusetts, of the proposed shielding to the Engineer for his approval prior to the installation. The Design shall include a complete description of the equipment and construction methods proposed for the deck removal and also the maximum size of deck area being removed. The shielding shall be designed to withstand the maximum size of removed area should it fall during the removal. The drawings shall include details of all connections, brackets and fasteners and shall be submitted prior to the start of the demolition.

No portion of the bridge superstructure shall be removed or constructed until the Temporary Protective Shielding is completely in place and the Contractor has the approval from the Engineer to proceed. The protective shields shall remain in position for the duration of the work for each stage of construction. The shields shall be installed, relocated or removed only upon approval of the Engineer.

Shielding shall be designed to safely withstand all loads that it will be subjected to. The allowable design stresses shall be in accordance with AASHTO Standard Specifications for Highway Bridges.

The Contractor shall not be permitted to reduce the existing bridge clearances at any time.

Shielding shall extend a sufficient distance beyond the area to be removed and have all spaces along the perimeter and seams sealed to prevent dust and debris from escaping and falling below.

Shielding shall be installed or removed only upon approval of the Engineer.

All materials used in the shielding system shall become the property of the Contractor and shall be removed from the site upon completion of the project.

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS FOR DEMOLITION AND WORK INVOLVING PAINTED STEEL

- A. To ensure worker and public safety, hazardous materials shall be removed in the immediate area of any intended cutting or burning. Removal of hazardous material is not required for mechanical disassembly, i.e. bolt and rivet removal unless heat is applied. Hazardous material removal is required to allow the demolition of structural steel, railings, drainage systems, utility supports, etc.
- B. Reference Standards: The Contractor shall comply with all applicable regulations even if the regulation is not specifically referenced herein. If a State or local regulation is more restrictive than the requirements of this Specification, follow the more restrictive requirements.
 - 1. State Regulations
 - a. 310 CMR 7.00 Air Pollution Control
 - b. 310 CMR 30.00 Hazardous Waste Regulations
 - c. 310 CMR 40.00 Massachusetts Contingency Plan
 - d. 310 CMR 19.00 Solid Waste Management Regulations
 - e. 314 CMR 1.00 – 30.00 Water Pollution Control Regulations
 - 2. Federal Regulations
 - a. 29 CFR 1910, Occupational Safety and Health Regulations for General Industry
 - b. 29 CFR 1926, Occupational Safety and Health Regulations for the Construction Industry 29 CFR 1926.62, Lead

- c. 40 CFR 50, National Primary and Secondary Ambient Air Quality Standards
 - d. 40 CFR 58, Ambient Air Quality Surveillance
 - e. 40 CFR 60, App. A, Method 22, Visual Determination of Fugitive Emissions from Material Sources and Smoke Emissions from Fires
 - f. 40 CFR 265, Subpart D, Contingency Plan and Emergency Procedures
3. The U.S. Environmental Protection Agency (EPA)
 - a. SW 846 Test Methods for Evaluating Solid Waste – Physical / Chemical Methods
 - b. Method 1311, Toxicity Characteristic Leaching Procedure (TCLP)
 4. Society for Protective Coatings (SSPC)
 - a. SP 1, Solvent Cleaning
 - b. SP 11, Power Tool Cleaning to Bare Metal
 - c. SP 10, Near White Blast Cleaning
 - d. Vis 1, Visual Standard for Abrasive Blast Cleaned Steel
 - e. Vis 3, Visual Standard for Power and Hand Tool Cleaned Steel
 - f. Guide 6, Guide for Containing Debris Generated During Paint Removal Operations
 5. American Society for Testing and Materials (ASTM)
 - a. D 4285, Detecting Oil or Water in Compressed Air

B. Cleaning / Removal

1. Cutting or Burning of Steel: All surfaces to be cut or burned shall be cleaned so as to remove all contaminants and/or hazardous materials, which could be discharged to the environment as a function of the subsequent operations.

Lead paint, if present, shall be removed in its entirety in an area prescribed by a one-foot minimum offset from the required work. Proper level of containment shall be used when performing this work. Full containment is not required during chemical stripping operation however; the Contractor shall install proper shielding and/or tarpaulins under the chemical stripping operations in order to catch all debris generated during this procedure. A cleaned area must be inspected and approved before the demolition operations are started.

During cleaning operations, the Contractor shall be required to furnish and erect temporary floodlights illuminating the steel surface at a minimum of 30 foot candles. This lighting shall be used in areas where there is insufficient lighting for proper cleaning operations and inspection. The Contractor shall supply electrical power.

The Contractor shall provide support for interim and final inspection of the bridge during cleaning operations. This support shall include the necessary traffic controls, safe access to the work and 9 volt lantern.

2. Mechanical Disassembly of Steel: All surfaces to be mechanically disassembled, i.e. bolt or rivet removal shall not require deleading. However, heating of the steel to facilitate mechanical disassembly shall require the removal of lead paint to a one foot off-set.

When removing bolts or rivets, the Contractor shall not use any method that will cause dust and/or particles to be emitted and/or dispersed into the environment to an extent that would expose the workers above the Action Levels of 30ug/cm.

Hazardous material shall be collected during the disassembly and shall be disposed of as outlined in Section 961.68 "Handling of Hazardous Waste and Reporting Release Programs" in the Supplemental Specifications dated June 2012, and all subsequent Interim Supplemental Specifications.

For purposes of limiting the lead (Pb) dust, the Contractor will be required to dampen the lead paint work areas.

The Contractor shall install a proper shielding and/or tarpaulins under all lead-paint-coated bolts or rivets ordered removed in order to catch any loose lead paint chips, dust or particles.

C. Worker Health & Safety Compliance Program

1. The Contractor shall develop a written program under the direction and approval of a Certified Industrial Hygienist (CIH) to establish and implement practices and procedures for protecting the health. Rely on respiratory protection only after feasible engineering and work practice controls have been first implemented to reduce airborne exposures.
2. The program shall identify the project competent person(s) by name, his or her qualifications, and indicate the frequency of inspections that will be undertaken. Daily inspections of the work area shall be made by the competent person and documented in the project logbook. All worker protection requirements shall apply to the Contractor, Subcontractors, and MassDOT and MBTA personnel on site.

D. Exposure Monitoring / Initial Assessment: Exposure monitoring shall be performed as required by 29 CFR 1926.62. All laboratory analysis must be performed by a State Certified Laboratory for each designated test. Protect workers during the initial monitoring to the anticipated exposure levels as dictated by 29 CFR 1926.62. The use of previous data as a substitute for initial exposure monitoring may be used when reviewed and approved by a CIH. The Contractor shall forward all data and the CIH's approval for review by the Engineer.

E. Action Level: The Action Level for lead is $30 \mu\text{g}/\text{m}^3$ as an eight (8) hour Time Weighted Average (TWA). In addition to the initial protection provided, invoke the following protective measures when the airborne exposure to lead exceeds the Action Level:

1. Exposure Monitoring
2. Housekeeping
3. Employee Medical Surveillance and Medical Removal Protection
4. Employee Information and Training
5. Signs and Regulated Areas
6. Recordkeeping

F. Permissible Exposure Limit (PEL): The PEL for airborne lead exposure is $50 \mu\text{g}/\text{m}^3$ as an 8 hour TWA. In the event that extended work shifts are allowed, use the following formula to adjust the PEL:

$$\text{PEL} = 8 \text{ hr. PEL} \times (8 \div \text{hours worked in a day})$$

In addition to complying with the requirements identified when exceeding the Action Level, invoke the following protective measures when the airborne exposure to lead exceeds the PEL:

1. Compliance Program, including engineering, administrative, and work practice controls
2. Respiratory Protection

3. Protective Clothing and Equipment
4. Hygiene Facilities and Practices

G. Protective Clothing and Equipment

1. Clothing: Provide protective clothing and equipment and ensure they are worn by all employees whose exposures exceed the PEL or TLV. Provide protective clothing and equipment and ensure all employees who enter regulated areas wear them. Provide all required protective clothing and equipment for use by three MassDOT representatives for the duration of the contract.

Clean or replace the protective clothing as required by the appropriate OSHA standard for lead that is present. Clean or replace the clothing weekly if the airborne exposure levels are less than $200 \mu\text{g}/\text{m}^3$ as an 8 hour TWA, or daily if the exposure levels are greater than or equal to $200 \mu\text{g}/\text{m}^3$.

Do not remove or clean the clothing by any means that reintroduces the lead into the ambient air such as brushing, shaking, or blowing. Use vacuums equipped with HEPA filters for cleaning. Store the used clothing in labeled sealed containers. If the clothing is to be laundered and it has been exposed to lead, label the containers with the following:

“CAUTION: CLOTHING CONTAMINATED WITH LEAD. DO NOT REMOVE DUST BY BLOWING OR SHAKING. DISPOSE OF LEAD CONTAMINATED WASH WATER IN ACCORDANCE WITH APPLICABLE LOCAL, STATE, OR FEDERAL REGULATIONS.”

If the clothing is disposable, label the containers as clothing contaminated with lead. Apply hazardous waste labels as appropriate after testing.

If the clothing is washed on site, provide containers for the collection and retention of the water after filtration. Provide ample filtration (e.g., through a multi-stage filtration system ending in 5 microns or better if needed) until the water can be disposed of as non-hazardous, or discharged into the sanitary sewer system if allowed by the Publicly Owned Treatment Works (POTW). Test the water in accordance with EPA Method 6010 for the parameters established by the POTW to confirm the acceptability of the filtration. The Contractor shall be required to obtain all necessary permits for disposal in accordance with applicable Federal, State, and local regulations.

2. Personal Hygiene facilities and Equipment: Provide clean lavatory and hand washing facilities in accordance with OSHA sanitation standard 29 CFR 1926.51. Locate the hand washing facilities in close proximity to the paint removal operation, in an area that is convenient for washing prior to eating or smoking.

Provide showers when exposures exceed the PEL or TLV. Confirm that all employees whose exposures exceed the PEL or TLV shower prior to leaving the project site. Allow MassDOT and MBTA representatives to use the lavatory and hand washing / shower facilities. Provide filtration and testing of the wastewater as described above under Protective Clothing and Equipment.

A decontamination / changing facility must be provided and used along with hot water washing and respirator cleaning facilities during lead (Pb) paint removal operations except for chemical stripping operations. A handwashing facility must be provided and used along with hot water washing and respirator cleaning facility during chemical stripping and mechanical disassembly

i.e. bolt and rivet removal.

Prohibit eating, drinking, smoking, chewing of food or tobacco products, or the application of cosmetics in any area where the exposure to lead exceeds the Action Level or within regulated areas, and confirm that workers thoroughly wash hands and face prior to undertaking any of these activities.

Provide clean lunch and break areas for use by all employees, and maintain airborne concentrations in these areas below the Action Levels.

Provide clean change area(s) for employees whose exposures exceed the PEL or TLV. Equip the change area(s) with separate storage facilities for street clothing that is adequately segregated to prevent cross-contamination from work clothing. Assure that employees do not leave the project site wearing any clothing that was worn while performing activities where exposures exceeded the PEL or TLV.

- H. Housekeeping: Clean accumulations of dust or debris containing lead daily, at a minimum. Clean more frequently if visible accumulations are observed that could be carried outside of the regulated area by wind, workers shoes, rainwater, or other means.

Conduct all cleaning with HEPA (High Efficiency Particulate Air)-filtered vacuums. Do not use compressed air for housekeeping purposes unless it is used in conjunction with a ventilation system capable of capturing the resulting airborne particulate. Containerize the debris for proper disposal.

- I. Establishment of Regulated Areas: Establish zones (regulated areas) around project locations or activities that might generate airborne emissions of lead in excess of the Action Level (e.g., paint removal and clean-up locations, dust collector staging areas, waste storage areas, etc).

Use ropes, ribbons, tape, or other visible means to define the areas. Prohibit entrance into the regulated areas by unprotected or untrained personnel to ensure that they are not exposed to lead from project activities. Establish the regulated area boundary a minimum of 15 feet away from any equipment or operations that might generate airborne emissions of lead.

Individuals who enter the regulated area shall have the proper training, blood analysis and medical examinations, and must wear the required protective clothing and equipment. Prohibit eating, drinking, smoking, and chewing of food or tobacco products in any area where the exposures exceed the Action Level. Maintain a log at the entrance of the regulated area and have all personnel sign in and out.

The adequacy of a regulated area shall be verified visually by the Engineer. Although it is recognized that airborne debris are not always visible, any observance of dust or debris passing outside the zone is cause for immediate shut down of the work and corrective action taken by the Contractor. The work activities and/or containment shall be modified to provide better control of emissions or the area will be reestablished as directed and approved by the Engineer.

- J. Cleaning Abutments: The horizontal surfaces of all abutments and pier caps as directed by the Engineer shall be swept clean of all debris, which may include but is not limited to, sand, gravel, bituminous material and bird droppings. This material shall be removed and disposed of as construction waste unless otherwise determined by the required testing as outlined in Section 961.68 "Handling of Hazardous Waste and Reporting Release Programs" in the Supplemental Specifications dated June 2012, and all subsequent Interim Supplemental Specifications. After the debris has been removed the Contractor shall wash down the horizontal surfaces of the abutments with fresh water under pressure.

3.2 CONSTRUCTION METHODS FOR TEMPORARY PROTECTIVE SHEILDING

- A. The installation of the protective shield including connections, fasteners, erection procedures and maintenance shall be undertaken in accordance with the following criteria:
1. The protective shield shall be designed to support all construction and dead loads safely, but not less than 100 pounds per square foot; to be stiff enough to limit deflection to 1/2 inch under maximum loads; and to be sealed tightly at all joints.
 2. The protective shield shall extend horizontally a minimum of three feet beyond the bridge parapet and shall extend vertically to a point one foot above the top of the bridge parapet or barrier wall.
 3. The protective shield shall be placed to protect the entire area of demolition.
 4. The protective shield shall be sufficiently tight to prevent leakage of slurry from cutting tools, dust, chips or other small debris to the surface below.
 5. The protective shield shall be tongue and groove or ship lap with 6 mil polyethylene unless otherwise specified or approved by the Engineer.

Alternate methods for protective shielding will be considered and reviewed by the Engineer.

Their use will be subject to the approval of the Engineer. If the Contractor proposes an alternate method, the Contractor shall submit shop drawings showing complete details of this method along with a detailed plan for traffic control. These drawings and details shall be designed and stamped by a Professional Structural Engineer registered in the Commonwealth of Massachusetts.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02221

DEMOLITION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items:
1. Demolition, selective demolition and removal of structures and buildings including and not limited to:
 - a. Existing Lechmere Station
 - b. Existing Bus Depot at existing Lechmere Station
 - c. Homan's Building at 350 Medford Street
 - d. Sako Auto Body Shop at 662 Boston Ave
 - e. Bowling Alley at 664 Boston Ave
 - f. Veterinary Office and Karate Studio at 675 Broadway
 - g. ACPA Building at 40-48 Third Ave
 - h. Walker Building at 20 Third Ave
 - i. Former Aerocycle Building at 642 Boston Avenue and Building at 646 Boston Avenue
 - j. Existing Viaduct structure
 2. Demolition, selective demolition and removal of site improvements
 3. The removal of all below-grade construction
 4. Disconnecting, capping or sealing and removing abandoned site utilities
 5. Salvaging items for reuse by the Authority
 6. All other works including support of excavation and dewatering as necessary to provide a safe adequate work site in accordance with applicable regulations
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
1. Section 01545 – PROTECTION OF WORK AND PROPERTY
 2. Section 01560 – TEMPORARY CONTROLS
 3. Section 01800 – SUSTAINABILITY REQUIREMENTS
 4. Section 02080 – ASBESTOS REMOVAL
 5. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
 6. Section 02090 – LEAD ABATEMENT
 7. Section 02091 – REMOVAL OF CONTAMINATED FIXTURES
 8. Section 02092 – PCB BULK PRODUCT WASTE ABATEMENT
 9. Section 02100 – SITE PREPARATION
 10. Section 02222 – REMOVAL, STOCKPILING, AND PROTECTION OF SELECTED STONework
 11. Section 02223 – SEGREGATION OF DEMOLITION DEBRIS AND WASTE TRANSPORTATION AND DISPOSAL
 12. Section 02224 – REMOVAL, PRESERVATION, AND REUSE OF HISTORIC ELEMENTS
 13. Section 02282 – HANDLING, TRANSPORTATION AND DISPOSAL OF EXCAVATED MATERIALS
 14. Section 02300 – EARTHWORK
 15. Section 02369 – DRILLED MINI-PILES
 16. Section 02650 – EXISTING SITE UTILITIES

17. Section 02852 – TRACKWAY DEMOLITION AND SALVAGE
18. Section 16802 – EQUIPMENT REMOVAL FOR THE LIGHT RAIL SIGNAL SYSTEM
19. Section 16902 – SIGNAL EQUIPMENT REMOVAL FOR THE COMMUTER RAIL SIGNAL SYSTEM

1.2 DEFINITIONS

- A. Demolish: Completely remove and legally dispose of off-site.
- B. Salvage: Carefully detach from existing construction, in a manner to prevent damage, and deliver to the Authority ready for reuse. Include fasteners or brackets needed for reattachment elsewhere.
 1. Repurpose: Carefully document existing materials designated to be photo-documented in situ, tagged, cataloged, detached from existing construction, in a manner to prevent damage, delivered to an approved storage site, document each item for ease of identification, protect during storage, and prepare to deliver materials for reuse.
- C. Hazardous Material: Includes but is not limited to asbestos and materials regulated under TSCA, RCRA, Massachusetts Hazardous Waste Regulations (310 CMR 30.000) and the Massachusetts Contingency Plan (MCP) (310 CMR 40.000) and building construction material defined by OSHA. Consideration shall be given to MSDS in determining if a material could be potentially hazardous.

1.3 MATERIALS OWNERSHIP

- A. Unless otherwise indicated, demolition waste becomes the property of the Contractor.
- B. Historic items, relics, antiques, and similar objects including, but not limited to, cornerstones and their contents, commemorative plaques and tablets, and other items of interest or value to the Authority that may be uncovered during demolition remain the property of the Authority.
 1. Carefully salvage in a manner to prevent damage, transport in a manner to prevent damage and promptly return to the Authority at a location designated by the Authority.

1.4 SUBMITTALS

- A. Proposed Protection Measures: Submit informational report in accordance with OSHA Part 1926 procedures, including drawings, that indicates the measures proposed for protecting individuals and property, for environmental protection, for dust control and for noise control. Indicate proposed locations and construction of barriers.
 1. Adjacent Buildings and Structures: Detail special measures proposed to protect adjacent buildings and structures to remain.
- B. Schedule of Building and Structure Demolition Activities: Indicate the following:
 1. Prepare and submit a list of Salvaged and materials designated for Repurposing.
 2. Detailed sequence of demolition work, with starting and ending dates for each activity.
 3. Temporary interruptions of utility services.
 4. Shutoff and capping or re-routing of utility services.
- C. Building and Structure Demolition Plans: Submit demolition drawings, Sealed and Signed by a Professional Engineer registered in the Commonwealth of Massachusetts (refer to 3.1D) and indicating the following:
 1. Locations of temporary protection and means of egress for adjacent occupied buildings.

- D. Inventory: Submit a list of items to be removed and salvaged and deliver to the Authority prior to start of demolition.
- E. Predemolition Photographs or Video: Show existing conditions of adjoining construction and site improvements, including Stone deigned for Repurposing, and finish surfaces that might be misconstrued as damage caused by building demolition operations. Documentation of existing damage shall include a close up with a readable scale in the photograph or video. Submit before the Work begins.
- F. Hazardous material remediation plan (HMRP). Include in the plan landfill recordkeeping. Submit landfill records indicating receipt and acceptance of hazardous wastes by a landfill facility licensed to accept hazardous wastes. Submit documentation of recycling of hazardous material per Section 01800 – SUSTAINABILITY REQUIREMENTS. Landfilling should be used only when recycling is technically or financially infeasible.
- G. Statement of Refrigerant Recovery: Signed by refrigerant recovery technician responsible for recovering refrigerant, stating that all refrigerant that was present was recovered and that recovery was performed according to EPA regulations. Include name and address of technician and date refrigerant was recovered.
- H. Results of Professional Engineer’s survey required by Article 3.1D.
- I. Storage plan for Repurposed Stone Blocks.

1.5 QUALITY ASSURANCE

- A. Regulatory Requirements: Comply with governing EPA notification regulations before beginning demolition. Comply with hauling and disposal regulations of authorities having jurisdiction. Comply with governing EPA and OSHA regulations during all phases of demolition.
- B. Standards: Comply with ANSI A10.6 and NFPA 241.
- C. Prepare a hazardous material remediation plan and submit to the Authority for approval.
- D. Predemolition Conference: Conduct conference at Project site to review the methods and procedures related to building and structure demolition including, but not limited to, the following:
 - 1. Review of hazardous material remediation plan.
 - 2. Inspect and discuss condition of construction to be demolished.
 - 3. Review structural load limitations of existing structures.
 - 4. Review and finalize building and structure demolition schedule and verify availability of demolition personnel, equipment, and facilities needed to make progress and avoid delays.
 - 5. Review and finalize protection requirements.
 - 6. Review procedures for noise control and dust control.
 - 7. Review procedures for protection of adjacent buildings.
 - 8. Review and list items to be salvaged and returned to the Authority.
 - 9. Review stone designated for Repurposing.

1.6 PROJECT CONDITIONS

- A. Buildings and structures to be demolished will be vacated and their use discontinued before the start of the Work.

- B. Buildings or other structures immediately adjacent to demolition areas may be occupied. Conduct demolition so operations of occupied buildings and structures will not be disrupted.
 - 1. Provide not less than 72 hours' notice of activities that will affect operations of adjacent occupied buildings.
 - 2. Maintain access to existing walkways, exits, and other facilities used by occupants of adjacent buildings.
 - a. Do not close or obstruct walkways, exits, or other facilities used by occupants of adjacent buildings without written permission from authorities having jurisdiction.
- C. The Authority assumes no responsibility for buildings and structures to be demolished.
 - 1. Conditions existing at time of inspection for bidding purpose will be maintained by the Authority as far as practical.
- D. Hazardous Materials: Hazardous materials may be present in buildings and structures to be demolished. Reports on the presence of hazardous materials are on file at the Authority for review and use. Examine the reports to become aware of locations where asbestos, lead paint or other hazardous materials are present. Do not disturb hazardous materials or items suspected of containing hazardous materials except under procedures specified or required by a licensed professional and/or agency having jurisdiction.
- E. On-site storage or sale of removed items or materials is not permitted.

1.7 COORDINATION

- A. Arrange demolition schedule so as not to interfere with the Authority's operations and operations of adjacent occupied buildings and structures.
- B. Accommodate site visits by representations of any regulatory agency having jurisdiction over the work.

PART 2 - PRODUCTS

2.1 FILL MATERIALS

- A. Comply with excavating, backfilling, and compacting procedures for soils used as backfill material to fill basements, voids, depressions or excavations resulting from demolition of structures.
 - 1. Un-contaminated soil excavated during removal of foundations may be re-used as fill material at the same location without sampling and analysis to verify it is un-contaminated. Excavated soil/fill material that is not re-used within the area of excavation must be characterized prior to re-use or disposal.
 - 2. Excavated material which exhibits chemical odors, staining and/or constituents which indicate the potential for contaminants to be present above MassDEP reporting thresholds, shall be pre-characterized prior to re-use.
 - 3. Re-used on-site soil and imported fill soil shall meet the requirements in Section 02300 – EARTHWORK and Section 02282 – HANDLING, TRANSPORTATION AND DISPOSAL OF EXCAVATED MATERIALS.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that utilities have been disconnected and capped before starting demolition operations.
- B. Review Project Record Documents of existing construction provided by the Authority. The Authority does not guarantee that existing conditions are the same as those indicated in Project Record Documents.
- C. Inventory and record the condition of items to be removed and salvaged. Provide photographs or video of conditions that might be misconstrued as damage caused by salvage operations.
- D. Engage a Professional Engineer registered in the Commonwealth of Massachusetts to perform an engineering survey of condition of building to determine whether removing any element might result in structural deficiency or unplanned collapse of any portion of structure or adjacent structures during building demolition operations.
- E. Verify that hazardous materials have been remediated before proceeding with building demolition operations.

3.2 PREPARATION

- A. Existing Utilities: Locate, identify, disconnect, and seal or cap off indicated utilities serving buildings and structures to be demolished.
 - 1. Arrange to shut off indicated utilities with utility companies.
 - 2. If removal, relocation, or abandonment of utility services will affect adjacent occupied buildings, then provide temporary utilities that bypass buildings and structures to be demolished and that maintain continuity of service to other buildings and structures.
 - 3. Cut off pipe or conduit a minimum of 24 inches below grade. Cap, valve, or plug and seal remaining portion of pipe or conduit after bypassing according to requirements of authorities having jurisdiction.
- B. Existing Utilities: Refer to Section 02650 – EXISTING SITE UTILITIES for shutting off, disconnecting, removing, and sealing or capping utilities. Do not start demolition work until utility disconnecting and sealing have been completed and verified in writing.
- C. Temporary Shoring: Provide and maintain interior and exterior shoring, bracing, or structural support to preserve stability and prevent unexpected movement or collapse of construction being demolished.
 - 1. Strengthen or add new supports when required during progress of demolition.
- D. Salvaged Items: Comply with the following:
 - 1. Clean salvaged items of dirt and demolition debris.
 - 2. Pack or crate items after cleaning. Identify contents of containers.
 - 3. Store items in a secure area until delivery to the Authority.
 - 4. Transport items to storage area designated by the Authority.
 - 5. Protect items from damage during transport and storage.
- E. Site Clearance: As required to complete demolition and provide a safe work site. Remove vegetation in those areas where removal is indicated on the drawings in conformance with Section 02100 - SITE

PREPARATION. Protect vegetation to remain in conformance with Section 01545 – PROTECTION OF WORK AND PROPERTY.

3.3 PROTECTION

- A. Existing Facilities: Protect adjacent walkways, loading docks, building entries, and other building facilities during demolition operations. Maintain exits from existing buildings.
- B. Existing Utilities: Maintain utility services to remain and protect from damage during demolition operations.
 - 1. Do not interrupt existing utilities serving adjacent occupied or operating facilities unless authorized in writing by the Authority and authorities having jurisdiction.
 - 2. Provide temporary services during interruptions to existing utilities, as acceptable to the Authority and authorities having jurisdiction.
 - a. Provide at least 72 hours' notice to occupants of affected buildings if shutdown of service is required during changeover.
- C. Temporary Protection: Erect temporary protection, such as walks, fences, railings, canopies, and covered passageways, where required by authorities having jurisdiction and as indicated. Comply with requirements in Division 1.
 - 1. Protect adjacent buildings and facilities from damage due to demolition activities.
 - 2. Protect existing site improvements, appurtenances, and landscaping to remain.
 - 3. Erect a plainly visible fence around drip line of individual trees or around perimeter drip line of groups of trees to remain.
 - 4. Provide temporary barricades and other protection required to prevent injury to people and damage to adjacent buildings and facilities to remain.
 - 5. Provide protection to ensure safe passage of people around building demolition area and to and from occupied portions of adjacent buildings and structures.
 - 6. Protect walls, windows, roofs, and other adjacent exterior construction that are to remain and that are exposed to building demolition operations.
 - 7. Erect and maintain dustproof partitions and temporary enclosures to limit dust, noise, and dirt migration to occupied portions of adjacent buildings.
- D. Remove temporary barriers and protections where hazards no longer exist. Where open excavations or other hazardous conditions remain, leave temporary barriers and protections in place.

3.4 DEMOLITION, GENERAL

- A. General: Demolish indicated existing buildings, structures and site improvements completely, unless otherwise indicated to be salvaged. Use methods required to complete the Work within limitations of governing regulations and as follows:
 - 1. Do not use cutting torches until work area is cleared of flammable materials. Maintain portable fire-suppression devices during flame-cutting operations.
 - 2. Maintain fire watch during and for at least four hours after flame cutting operations.
 - 3. Maintain adequate ventilation when using cutting torches.
 - 4. Locate building and structure demolition equipment and remove debris and materials so as not to impose excessive loads on supporting foundations, walls, floors, decks, or framing.
 - 5. In general, demolish buildings and structures top down.

- B. Engineering Surveys: During demolition, perform weekly surveys by a Professional Engineer registered in the Commonwealth of Massachusetts to detect hazards that may result from building demolition activities.
- C. Site Access and Temporary Controls: Conduct building and structure demolition and debris-removal operations to ensure minimum interference with roads, streets, walks, walkways, and other adjacent occupied and used facilities.
 - 1. Do not close or obstruct streets, walks, walkways, or other adjacent occupied or used facilities without permission from the Authority and authorities having jurisdiction. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.
 - 2. Use water mist and other suitable methods to limit spread of dust and dirt. Comply with governing environmental-protection regulations. Do not use water when it may damage adjacent construction or create hazardous or objectionable conditions, such as ice, flooding, and pollution.
- D. Explosives: Use of explosives is not permitted.

3.5 DEMOLITION BY MECHANICAL MEANS

- A. Proceed with demolition of structural framing members systematically, from higher to lower level. Complete building and structure demolition operations above each floor or tier before disturbing supporting members on the next lower level.
- B. Remove debris from elevated portions of the building or structure by chute, hoist, or other device that will convey debris to grade level in a controlled descent.
 - 1. Remove structural framing members and lower to ground by method suitable to minimize ground impact and dust generation. Where indicated to salvage structural framing members, disassemble connections via mechanical means and not via thermal cutting. Members to be salvaged shall be dismantled into the largest section possible for shipping and reuse.
- C. Salvage: Items to be salvaged include but are not limited to granite blocks with rock face finishes, existing Lechmere Viaduct structural steel Bents 570 & 571 along with the adjacent structural steel of existing spans 569, 570 and 571 and other items as indicated on Drawings.
- D. Below-Grade Construction: Demolish foundation walls and other below-grade construction that are within footprint of new construction and extending 5 feet outside footprint indicated for new construction. Abandon below-grade construction outside this area.
 - 1. Remove below-grade construction, including basements, foundation walls, footings and piles.
- E. Existing Utilities: Abandon existing utilities and below-grade utility structures. Cut utilities a minimum of 5'-0" below grade, unless indicated otherwise.
- F. Pipe or conduit greater than 15 inch in diameter shall be completely filled with Controlled Density Fill Type I or Type 1E in accordance with Commonwealth of Massachusetts, Massachusetts Department of Transportation (MassDOT) unless otherwise noted on the drawings: Standard Specifications for Highways and Bridges (Latest Edition).

3.6 SITE RESTORATION

- A. Below-Grade Areas: Rough grade below-grade areas ready for further excavation or new construction.

- B. Site Grading: Uniformly rough grade areas of demolished construction to a smooth surface, free from irregular surface changes. Provide a smooth transition between adjacent existing grades and new grades.

3.7 REPAIRS

- A. Promptly repair damage to adjacent buildings, utilities, fences, or other structures or features caused by demolition operations.

3.8 DISPOSAL OF DEMOLISHED MATERIALS

- A. Remove demolition waste materials from Project site and legally recycle or dispose of them in a landfill acceptable to authorities having jurisdiction.
 - 1. Do not allow demolished materials to accumulate on-site.
 - 2. Remove and transport debris in a manner that will prevent spillage on adjacent surfaces and areas.
 - 3. Recycle building materials in accordance with applicable State and Federal Regulations.
- B. Do not burn demolished materials.

3.9 CLEANING

- A. Clean adjacent structures and improvements of dust, dirt, and debris caused by demolition operations. Return adjacent areas to condition existing before demolition operations began.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02223

SEGREGATION OF DEMOLITION DEBRIS AND WASTE TRANSPORTATION AND DISPOSAL

PART 1 - GENERAL

1.1 SUMMARY

- A. This section describes the requirements for the DESIGN-BUILDER and all subcontractors to minimize construction waste and debris and to reuse, salvage, and recycle to the greatest extent feasible.
- B. This Section includes administrative and procedural requirements for the segregation, management, recycling and disposal of demolition debris and project-generated, non-hazardous construction waste.

1.2 RELATED WORK

- A. Other specification sections that relate to the work include but are not limited to the following:
 - 1. Section 01060 - PERMITS AND REGULATORY REQUIREMENTS
 - 2. Section 01560 – TEMPORARY CONTROLS
 - 3. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 4. Section 02080 – ASBESTOS REMOVAL
 - 5. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
 - 6. Section 02090 – LEAD ABATEMENT
 - 7. Section 02091 – REMOVAL OF CONTAMINATED FIXTURES
 - 8. Section 02092 – PCB BULK PRODUCT WASTE ABATEMENT
 - 9. Section 02221 – DEMOLITION

1.3 DEFINITIONS

- A. Asphalt Pavement, Brick, and Concrete (ABC) Rubble: Rubble that contains only weathered (cured) asphalt pavement, clay bricks and attached mortar normally used in construction, or concrete that may contain rebar, reinforcing steel and related accessories. The rubble shall not be mixed with, or contaminated by, another waste or building debris.
- B. Demolition Waste: Building and site improvement materials resulting from demolition or selective demolition operations.
- C. Disposal: Removal off-site of demolition waste and subsequent sale, recycling, reuse, or deposit in landfill or incinerator acceptable to authorities having jurisdiction.
- D. Fixed and Movable Assets: Items that can be removed intact during pre-demolition or demolition with the potential to be re-used or recycled. Examples of such items include, but are not limited to, windows and doors, casework, cabinetry, bathroom fixtures, and kitchen appliances and other items specified in this Section.

- E. Recycle: Recovery of demolition or construction waste for subsequent processing in preparation for reuse.
- F. Salvage: Recovery of demolition or construction waste and subsequent sale or reuse in another facility.
- G. Salvage and Reuse: Recovery of demolition or construction waste and subsequent incorporation into the Work.

1.4 PERFORMANCE REQUIREMENTS

- A. General: DESIGN-BUILDER to develop a waste management plan that results in End-of-Project rates for salvage/recycling of 90 percent by weight of total waste generated by the Work, excluding asbestos containing materials and hazardous materials.
- B. DESIGN-BUILDER shall sample demolition debris suspected to contain hazardous materials to verify prior to segregation as either a recyclable material or a waste.
- C. Salvage/Recycle Requirements: DESIGN-BUILDER shall salvage and recycle all non-hazardous demolition and construction waste including, but not limited to the following materials:
 - 1. Asphaltic concrete paving.
 - 2. Concrete, concrete block, concrete masonry units (CMU), slump stone (decorative concrete block), and rocks.
 - 3. Concrete reinforcing steel.
 - 4. Brick.
 - 5. Coated brick, concrete, and concrete masonry units. Coatings shall include, but not be limited to: paint, stucco applications, and plaster.
 - 6. Paper, including bond, newsprint, cardboard, mixed paper, packing materials, and packaging.
 - 7. Land clearing debris such as cut trees and shrubs.
 - 8. Carpet and Pad.
 - 9. Wood studs, wood joists, plywood, oriented strand board, paneling and trim.
 - 10. Structural steel, miscellaneous steel and rough hardware.
 - 11. Roofing.
 - 12. Doors, door frames, and door hardware.
 - 13. Windows, glass, plastic, and glazing.
 - 14. Metal (ferrous and non-ferrous) including, but not limited to, stud trim, ductwork, piping, reinforcing steel (rebar), roofing, other trim, steel, iron, galvanized sheet steel, stainless steel, aluminum, copper, zinc, lead, brass, and bronze.
 - 15. Equipment.
 - 16. Plumbing fixtures, piping, supports, hangers, valves, and sprinklers.
 - 17. Mechanical equipment and refrigerants.
 - 18. Electrical conduit, copper wiring, lighting fixtures, lamps, and ballasts.

- 19. Electrical devices, switchgear, panel boards, and transformers.
- D. In the event the DESIGN-BUILDER encounters previously unidentified material that is reasonably believed to be hazardous, asbestos containing, coated with lead-based paint, or oily debris, the DESIGN-BUILDER shall immediately stop work in the affected area and report the condition to the AUTHORITY.
- E. The DESIGN-BUILDER should be aware that the Commonwealth of Massachusetts has banned certain waste streams from solid waste management facilities, including incinerators and landfills (ref. 310 CMR 19.017). The list of banned materials has periodically expanded over time and currently includes the following materials:
 - 1. Lead-Acid Batteries
 - 2. Leaves and Yard Waste
 - 3. Whole Tires (banned from landfills only; shredded tires are acceptable)
 - 4. White Goods (large appliances)
 - 5. Cathode Ray Tubes (CRTs), including computer monitors
 - 6. Metal and Glass Containers
 - 7. Single Resin Narrow-Necked Plastics
 - 8. Recyclable Paper, Cardboard and Paperboard
 - 9. Asphalt Pavement, Brick and Concrete
 - 10. Ferrous and Non-Ferrous Metals
 - 11. Treated and Untreated Wood and Wood Waste (banned from landfills only)
 - 12. Clean Gypsum Wallboard
 - 13. Commercial Organic Material (effective October 1, 2014)

The DESIGN-BUILDER should refer to the current MassDEP regulations and guidance to ensure compliance with the waste bans.

1.5 SUBMITTALS

- A. Demolition Waste Management Plan (DWMP): Submit for approval within 21 calendar days of date established for the Notice to Proceed a DWMP as specified in section 1.7. Submit periodic updates to the DWMP whenever substantial changes to waste management procedures are implemented. The plan shall also include minimum worker training and communication plans.
- B. Locations of all designated temporary waste segregation and storage areas, with the naming conventions for waste types, and security measures to prevent unauthorized dumping.
- C. Results of characterization testing of potentially recyclable materials suspected to contain hazardous materials.
- D. Types and capacity of containers to be used for source separation or co-mingled collection.
- E. Distribution Channel: Submit qualifications of organization designated to reuse/recycle fixed and movable assets for AUTHORITY's approval. Include a list of recent projects where items have been

reused/recycled and locations where fixed and movable assets have been delivered. Include name of person assigned to this Project Facility Permitting Information:

1. For disposal and incinerator facilities provide a copy of the facility's current solid waste management facility permit in accordance with 310 CMR 19.000, prior to the start of construction.
 2. Facility Permitting Information: For off-site ABC rubble crushing and/or recycling facilities, provide a statement, prior to construction, from the facility that references its specific exemption from the solid waste regulations (per 310 CMR 16.05 (3) (e)) or provide a copy of the facility's current solid waste management facility permit in accordance with 310 CMR 19.000.
- F. Copies of logs of weekly inspections of each designated waste storage area. Provide written updates to waste management procedures after inspections to improve labeling, storage, dust control, prevention of improper disposal, and cross-mixing controls.
- G. Record Keeping for Recycling and Landfill and/or Incinerator Disposal: Documentation to be submitted by the DESIGN-BUILDER shall include the following:
1. Recycling and Processing Facility Records: Indicate receipt and acceptance of recyclable waste by recycling and processing facilities licensed to accept them. Include manifests, weight tickets, and/or receipts.
 2. Landfill and Incinerator Disposal Records: Indicate receipt and acceptance of waste by landfills and incinerator facilities licensed to accept them. Include manifests, weight tickets, and/or receipts.
 3. List of Fixed and Movable Assets to Be Reused/Recycled: Inventory site and provide preliminary list of materials that can be reused/recycled, including quantities and any costs or savings to the project budget. After consultation with ENGINEER, provide final list of fixed and movable assets to be reused/recycled. Provide tracking and reporting forms.
- H. Records of Donations: Indicate receipt and acceptance of salvageable waste donated to individuals and organizations. Indicate whether organization is tax exempt.
- I. Records of Sales: Indicate receipt and acceptance of salvageable waste sold to individuals and organizations. Indicate whether organization is tax exempt.
- J. At the Project Completion, submit a Final Report of the Management of Demolition Debris, to include at a minimum:
1. Material category.
 2. Generation point of waste.
 3. Total quantity of waste in tons.
 4. Quantity of waste salvaged, both estimated and actual in tons.
 5. Quantity of waste recycled, both estimated and actual in tons.
 6. Total quantity of waste recovered (salvaged plus recycled) in tons.
 7. Total quantity of waste recovered (salvaged plus recycled) as a percentage of total waste.
 8. Analytical testing results of recycled materials, if any.

1.6 QUALITY ASSURANCE

- A. Regulatory Requirements: Comply with hauling and disposal regulations of authorities having jurisdiction, including but not limited to, Massachusetts solid waste regulations contained in 310 CMR 16.00 and 310 CMR 19.000.

1.7 DEMOLITION WASTE MANAGEMENT PLAN

- A. General: The DESIGN-BUILDER is required to recover, store, and recycle/reuse all project waste, including demolition materials, in lieu of disposal if the material is of acceptable physical quality and chemical quality, and the DESIGN-BUILDER can identify a facility willing and permitted to accept the material.
- B. Develop and submit plan for approval, consisting of waste source identification, and waste reduction, storage, handling, testing, and transportation and recycling/disposal procedures. Include separate sections in plan for recycling and disposal of demolition waste. Indicate quantities by weight throughout waste management plan.
- C. Waste Identification: Indicate anticipated types and quantities of demolition and site-clearing waste generated by the Work. Include estimated quantities and assumptions for estimates.
- D. Waste Minimization and Diversion Plan: Describe the specific procedures for reducing waste generated by the project, including minimizing material packaging, recovering recyclable materials (paper, cardboard, metal, wood, etc.) and document plans for tracking the diversion of 90% of recyclable wastes from landfill disposal and compliance with MassDEP's solid waste bans (ref. 310 CMR 19.017).
- E. Waste Reduction Program: List each type of waste and whether it will be recycled, or disposed of in landfill or incinerator. Include points of waste generation, total quantity of each type of waste, quantity for each means of recovery any applicable sampling and analytical procedures, including TCLP if required, of materials to be recycled, and handling and transportation procedures.
 - 1. Recycled Materials: Include list of local receivers and processors and type of recycled materials each will accept, and any required testing of materials prior to acceptance. Include names, addresses, and telephone numbers.
 - 2. Disposed Materials: Indicate how and where materials will be disposed. Include name, address, and telephone number of each landfill and incinerator facility.
 - 3. Salvaged Materials for Sale: For materials that will be sold to individuals and organizations, include list of their names, addresses and telephone numbers.
- F. Handling and Transportation Procedures: Include methods that will be used for separating recyclable waste including sizes of containers, container labeling, and restrictions on waste mingling, and designated location on Project site where materials separation will be located.
- G. Waste Management Coordinator: Identify DESIGN-BUILDER employee who will be the Waste Management Coordinator for the project. The Waste Management Coordinator will be responsible for implementing, monitoring, and reporting status of waste management work plan.

PART 2- PRODUCTS

Not Used.

PART 3 – EXECUTION

3.1 DEMOLITION WASTE MANAGEMENT PLAN IMPLEMENTATION

- A. General: Implement approved Demolition Waste Management Plan (DWMP). Provide containers, storage, signage, transportation, and other items as required to implement DWMP for the entire duration of the Project.
- B. The DESIGN-BUILDER shall conduct a Demolition Waste Management Meeting at the Site. The DESIGN-BUILDER shall review methods and procedures related to waste management including, but not limited to, the following:
 - 1. Distribute approved DWMP to everyone concerned within three days of approved submittal return.
 - 2. Clearly identify the Waste Management Coordinator and explain the Coordinator's responsibilities.
 - 3. Review DWMP with each trade when they first begin work on-site. Review plan procedures and locations established for recycling and disposal.
 - 4. Review and finalize procedures for material separation and verify availability of containers and bins needed to maintain production.
 - 5. Review the weekly inspection procedures and chain of command for corrective measures to maintain compliance with the DWMP.
 - 6. Review procedures for periodic waste collection and transportation to recycling and disposal facilities.
 - 7. Provide recycling educational literature for all workers, subcontractors and suppliers engaged in on-site activities.
 - 8. Provide appropriate recycling signage for containers and workspaces.
- C. Site Access and Temporary Controls: DESIGN-BUILDER shall conduct waste management operations to ensure minimum interference with roads, streets, walkways, and other adjacent occupied and used facilities.
 - 1. Designate and label specific areas on project site necessary for separating materials that are to be salvaged, recycled, reused, donated, sold, and disposed.
 - 2. Comply with project requirements for controlling dust and dirt, pest management, environmental protection, and noise control.
 - 3. Conduct and document in logs the weekly inspections of waste management areas with recommendations for improvements.

3.2 SALVAGING DEMOLITION WASTE

- A. Salvaged Items for Sale and Donation: Sale activities are not permitted on project site.

3.3 RECYCLING WASTE FROM WORK-SITE

- A. General: These wastes include recycled paper, cardboard packaging, plastics, and beverage containers used by on-site workers.
- B. Procedures: DESIGN-BUILDER shall separate recyclable waste from other waste materials, trash, and debris, to the maximum extent practical. For waste which cannot be separated at project site, co-mingle only with waste which is to be separated later at a recycling facility. Contamination of recycling containers with trash or other contaminants or banned items will be addressed by the DESIGN-BUILDER and who will be solely responsible for payment of all fines and penalties.
 - 1. Provide appropriately labeled and marked containers or bins for controlling recyclable waste until they are removed from project site. Include list of acceptable and unacceptable materials at each container and bin. Inspect containers and bins at least weekly for contamination and remove contaminated materials if found.
 - 2. Stockpile processed recycled materials on-site without intermixing with other materials. Place, grade, and shape stockpiles to drain surface water. Cover with polyethylene sheeting to prevent windblown dust.
 - 3. Stockpile recycled materials away from construction area. Do not store any materials within 200 feet of residences, or within 30 feet of trees that are scheduled to remain.
 - 4. Store recycled equipment and components off the ground and protect from the weather.
 - 5. Remove recyclable waste that is generated from project site within 30 days of generation, and transport to recycling receiver or processor.

3.4 RECYCLING DEMOLITION WASTE

- A. On-site crushing of non-coated asphalt pavement, brick, and concrete (ABC) rubble as described in 310 CMR 16.05, is allowed, provided performed in accordance with 310 CMR 16.05. Coated ABC must be transported off-site to an asphalt batching plant or to an ABC crushing or recycling operation that is either conditionally exempt from 310 CMR 16.00 or has been sited and permitted in accordance with 310 CMR 16.00 and 310 CMR 19.000, respectively.
- B. Coated ABC must be tested for characterization prior to recycling, which may include laboratory analysis by Toxicity Characteristic Leaching Procedure (TCLP). The analysis and analytical documentation shall meet the MassDEP Compendium of Analytical Methods requirements. The DESIGN-BUILDER shall include the results of all materials testing in the Final Report of the Management of Demolition Debris in accordance with Section 1.5 Submittals.
- C. Asphaltic Concrete Paving: With the exception of paving debris to be crushed on-site, break up and transport paving to an asphalt-recycling facility.
- D. Concrete: With the exception of concrete debris to be crushed on-site, deposit all debris in designated container to be transported to an approved aggregate recycling facility to be crushed and screened for use as satisfactory soil for fill or sub-base.
- E. Masonry: With the exception of masonry debris to be crushed on-site for reuse, deposit all masonry debris in designated container to be transported to an approved aggregate recycling facility to be crushed and screened for use as satisfactory soil for general fill or satisfactory soil for fill or sub-base. Clean and stack undamaged whole masonry units on wood pallets for reuse.

- F. Wood Materials: Sort and stack salvageable members according to size, type, and length. Separate lumber/untreated wood debris and yard waste and deposit into appropriate container. Separate engineered wood products, panel products, and treated wood materials into designated containers.
- G. Metals: Separate metals by material type if practical. Stack salvageable structural steel members according to size, type of member, and length.
- H. Asphalt Shingle Roofing: Organic and glass-fiber asphalt shingles and felts shall be recycled at a facility permitted by Massachusetts Department of Environmental Protection (DEP) to process post-consumer (used) asphalt shingles. Recycle nails, staples acceptable, flashing trim and accessories as metals.
- I. Glass: Deposit glass debris into designated containers to be transported to an approved glass recycling facility.
- J. Plastics: Deposit plastic containers and debris into designated containers to be transported to an approved plastic recycling facility.
- K. Clean Gypsum WallBoard: Deposit scraps of clean gypsum wallboard into designated container protected from weather and transport to an appropriate gypsum recycling facility to be processed into soil amendment.
- L. Acoustical Ceiling Panels and Tile: Deposit pulp-able mineral fiber panels into designated container protected from weather and prepare for transport, as directed by manufacturer, to an appropriate recycling facility to be processed into new acoustic ceiling panels. Separate suspension system, trim, and other metals from panels and tile and sort with other metals.
- M. Equipment: Drain tanks, piping, and fixtures. Seal openings with caps or plugs. Protect equipment from exposure to weather.
- N. Plumbing Fixtures: Separate by type and size fixtures suitable for reuse. Deposit all other fixtures into designated containers by material type to be transported to an approved recycling facility.
- O. Piping: Separate piping materials by material composition. Deposit in designated containers. Separate supports, hangers, valves, sprinklers, and other components by material type and deposit in designated containers for transport to an approved recycling facility.
- P. Lighting Fixtures: Separate lamps by type and protect from breakage.
- Q. Electrical Devices: Separate switches, receptacles, switchgear, transformers, meters, panelboards, circuit breakers, and other devices by type.
- R. Conduit: Deposit conduit and fittings into designated container.
- S. Fixed and Removable Assets
 - 1. Unless specifically prohibited by the AUTHORITY, all fixed and removable assets specified below shall be removed intact and shall be distributed by sale or donation to parties who are capable of assuring their reuse.
 - 2. Materials: Fixed and movable assets to be removed for reuse may include but not limited to:
 - a. Windows (sash only)
 - b. Doors (including frames)
 - c. Wood millwork, paneling, wainscoting, and other similar interior finishing
 - d. Marble flooring
 - e. Wood flooring

- f. Bathroom plumbing fixtures (toilets and sinks)
 - g. Bathroom stall partitions
 - h. Mirrors
 - i. Kitchen cabinets and countertops
 - j. Kitchen sinks (in-counter and freestanding)
 - k. Kitchen food preparation tables
 - l. Kitchen appliances (ovens, free-standing and walk-in refrigerators, chillers, etc.)
3. Provide tools and manpower qualified to remove specified materials intact and in a condition that they may be reused.
 4. Remove specified materials intact and in condition suitable for reuse and set aside in a location and in such a manner that they will not be damaged by other site operations.
 5. Track and report the disposition of all fixed and movable assets, including organizations to which assets are distributed. Tracking and reporting may be by piece count or by weight, as appropriate to the materials and their distribution.

3.5 DISPOSAL OF WASTE

- A. General: Except for items or materials to be salvaged, recycled, or otherwise reused, DESIGN-BUILDER shall remove waste materials from project site and legally dispose in a landfill or incinerator acceptable to authorities having jurisdiction.
 1. Except as otherwise specified, do not allow waste materials that are to be disposed of accumulate on-site. Burning of wastes is prohibited.
 2. Remove and transport debris in a manner that will prevent spillage on adjacent surfaces and areas.
 3. For solid waste disposal facilities located in the Commonwealth of Massachusetts, dispose of materials only in facilities which currently comply with applicable state regulations, including requirements of 310 CMR 16.00 {Site Assignment for Solid Waste Facilities} and 310 CMR 19.000 {Solid Waste Management}, and local bylaws.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02240

DEWATERING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. **Work Included:** This Section includes permitting, design, installation and operation of dewatering systems to facilitate subsurface construction.
- B. **Related Work:** Other specification sections that relate to the work of this section include, but are not limited to, the following:
 - 1. Volume 2 Technical Provisions Exhibit 2I – “Additional Project Requirements”
 - 2. Section 02015 – GEOTECHNICAL INSTRUMENTATION
 - 3. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 - 4. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 - 5. Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
 - 6. Section 02300 – EARTHWORK

1.2 PERFORMANCE REQUIREMENTS

- A. **Dewatering Performance:** Design, furnish, install, test, operate, monitor, and maintain dewatering system of sufficient scope, size, and capacity to control groundwater flow into excavations and permit construction to proceed on dry, stable sub-grades.
 - 1. Maintain dewatering operations to ensure erosion control, stability of excavations and constructed slopes, that excavation does not flood, and that damage to sub-grades and permanent structures is prevented.
 - 2. Prevent surface water from entering excavations by grading, dikes, or other means.
 - 3. Accomplish dewatering without damaging existing buildings adjacent to excavation.
 - 4. Remove dewatering system when no longer needed.
 - 5. Provide for legal and suitable disposal of groundwater including obtaining permits for discharge of water.
 - 6. Evaluate existing soil conditions and propose equipment and techniques to dewater both non-cohesive and cohesive soils.

1.3 SUBMITTALS

- A. **Shop Drawings:** For dewatering system show arrangement, locations, and details of monitoring wells and well points; pumps, locations of headers and discharge lines; and means of discharge and disposal of water.
 - 1. Dewatering plan and details stamped and signed by a Registered Professional Engineer of the Commonwealth of Massachusetts. This shall include a list of assumptions for design of

dewatering including groundwater levels, soil profile permeabilities, and duration of pumping and or recharge.

2. Include layouts of observation wells, piezometers and flow-measuring devices for monitoring performance of dewatering system and impacts to adjacent structures.
 3. Include a written report outlining control procedures to be adopted if dewatering problems arise, such as boils, loss of fines, or softening of the ground.
- B. Qualification Data: For Installer and professional engineer.
- C. Photographs or videotape of existing conditions of adjacent structures and site work that might be misconstrued as damage caused by dewatering operations. These photographs or videotape records are supplement to the Pre-Construction Survey documentation as specified in Section Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements"..
- D. Record drawings at Project closeout identifying and locating capped utilities and other subsurface structural, electrical, or mechanical conditions performed during dewatering.
1. Indicate locations and capping depth of wells and well points.
- E. Field Test Reports: Before starting excavation, submit test results and computations demonstrating that dewatering system is capable of meeting performance requirements.
- F. Adjacent Foundations Report and Analysis: Record subsurface foundation systems of adjacent structures and evaluate impacts of groundwater removal.
- G. The Design-Builder shall dewater for the length of time necessary to complete the specified sub-surface improvements. Any requirements to remove portions of the dewatering system will be noted on the Drawings.

1.4 QUALITY ASSURANCE

- A. Provide in accordance with Volume 1 DB Contract Terms and Conditions, Section 4, Quality Control and Quality Assurance, and Volume 2 Technical Provisions, Subsection 2.5, Quality Management..
- B. Regulatory Requirements: Comply with water disposal requirements of authorities having jurisdiction.
- C. Professional Engineer: Engage a professional engineer registered in the Commonwealth of Massachusetts to design and certify dewatering systems. Professional engineer shall have a minimum of 5 years experience with type of dewatering systems similar to those proposed for use.
- D. Retain the services of a field representative having a minimum of 5 years of experience in installation of well points, deep wells, recharge systems, or equal systems.

1.5 PROJECT CONDITIONS

- A. Existing Utilities: Do not interrupt utilities serving facilities occupied by MBTA or others unless permitted in writing by MBTA and then only after arranging to provide temporary utility services according to requirements indicated.

- B. Project-Site Information: Subsurface information collected at the project site is presented in the Geotechnical Data Reports, provided within Appendix 2E. MBTA will not be responsible for interpretations or conclusions drawn from this data.
1. The Design-Builder may elect to perform additional subsurface explorations and/or tests to confirm requirements for dewatering.
- C. Survey adjacent structures and improvements, employing a professional engineer or land surveyor, establishing elevations at fixed points to act as benchmarks. Identify benchmarks and record existing elevations.
1. During dewatering, regularly resurvey benchmarks, maintaining an accurate log of surveyed elevations for comparison with original elevations. Promptly notify MBTA if changes in elevations occur or if cracks, sags, or other damage is evident in adjacent structures.
 2. Notify the MBTA immediately if any settlement or movement is detected on structures. If the settlement or movement is deemed by the MBTA to be related to the dewatering, take actions to protect the adjacent structures and submit a modified dewatering plan to the MBTA within 24 hours. Implement the modified plan and repair any damage incurred to the adjacent structures.
 3. If subgrade soils are disturbed or become unstable due to dewatering operation or an inadequate dewatering system, notify the MBTA, stabilize the subgrade, and modify system to perform as specified.
 4. If oil and/or other hazardous materials are encountered after dewatering begins, immediately notify the MBTA. Handling of contaminated groundwater shall be in accordance with Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER.

PART 2 - PRODUCTS

NOT USED.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Execution of earth excavation, installing earth retention systems, and dewatering shall not commence until the related submittals have been reviewed by the MBTA with all the MBTA's comments satisfactorily addressed and the geotechnical instrumentation has been installed.
- B. Protect structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by dewatering operations.
1. Prevent surface water and subsurface or groundwater from entering excavations, from ponding on prepared sub-grades, and from flooding site and surrounding area.
 2. Protect sub-grades and foundation soils from softening and damage by rain or water accumulation.

- C. Install dewatering system to ensure no interference with roads, streets, walks, and other adjacent occupied and used facilities.
 - 1. Do not close or obstruct streets, walks, or other adjacent occupied or used facilities without permission from Authority and authorities having jurisdiction. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.

3.2 INSTALLATION

- A. Install dewatering system utilizing wells, well points, or similar methods complete with pump equipment, standby power and pumps, filter material gradation, valves, appurtenances, water disposal, and surface-water controls.
- B. Before excavating below ground-water level, place system into operation to lower water to specified levels. Operate system continuously until drains, sewers, and structures have been constructed and fill materials have been placed, or until dewatering is no longer required. Dewatering operations shall be stopped based on a mutual decision between the Design-Builder and the MBTA.
- C. Provide an adequate system to lower and control groundwater to permit excavation, construction of structures, and placement of fill materials on dry sub-grades. Install sufficient dewatering equipment to drain water-bearing strata above and below bottom of foundations, drains, sewers, and other excavations.
 - 1. Do not perform open-sump pumping that leads to loss of fines, soil piping, sub-grade softening, and slope instability.
- D. Reduce hydrostatic head in water-bearing strata below sub-grade elevations of foundations, drains, sewers, and other excavations.
 - 1. Unless otherwise indicated maintain piezometric water level a minimum of 24 inches below bottom surface of excavation.
- E. Dispose of water removed by dewatering in compliance with applicable Local, State and Federal regulations in a manner that avoids negative impacts on abutters, endangering public health, property, and portions of work under construction or completed. Dispose of water in a manner that avoids inconvenience to others. Provide sumps, sedimentation tanks, and other flow-control devices as required by authorities having jurisdiction.
- F. Provide standby equipment and power source on-site, installed and available for immediate operation, to maintain dewatering on continuous basis if any part of system becomes inadequate or fails. If dewatering requirements are not satisfied due to inadequacy or failure of dewatering system, restore damaged structures and foundation soils at no additional expense to the MBTA.

Damages: Promptly repair damages to adjacent facilities caused by dewatering operations.

3.3 OBSERVATION WELLS

- A. Provide, take measurements, and maintain observation wells or piezometers indicated on the approved dewatering plan and additional observation wells as may be required by authorities having jurisdiction.
- B. Observe and record daily elevation of ground water and piezometric water levels in observation wells.

- C. Repair or replace, within 24 hours, observation wells that become inactive, damaged, or destroyed. Suspend construction activities in areas where observation wells are not functioning properly until reliable observations can be made. Add or remove water from observation-well risers to demonstrate that observation wells are functioning properly.

3.4 REMOVAL

- A. Do not remove dewatering system without written approval from the MBTA.
- B. Backfill and compact sumps or ditches with screened gravel or crushed stone wrapped with geotextile fabric in accordance with Section 02300 – EARTHWORK and Section 02196 – GEOTEXTILE MATERIALS.
- C. Dewatering wells shall be abandoned upon completion of the work, and completely backfilled with cement grout.
- D. Cut off and cap monitoring wells and piezometers a minimum of 48 inches below grade or overlying construction.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02250

STORM WATER POLLUTION PREVENTION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The work specified in this Section includes the preparation, implementation, and termination of a Storm Water Pollution Prevention Plan (SWPPP) required by the U.S. Environmental Protection Agency (EPA) under the National Pollutant Discharge Elimination System (NPDES) *General Permit for Discharges from Construction Activities* (CGP).
- B. Pursuant to the Federal Clean Water Act, effective June 30, 2008, construction activities which disturb one acre or more are required to apply to EPA for coverage under the NPDES CGP. On February 16, 2012 (Federal Register/Vol. 77, No. 40/ pp. 12286 - 12293), EPA published the final NPDES *General Permit for Stormwater Discharges From Construction Activity*. The 2012 CGP will expire on February 16, 2017.
- C. Related work:
 - 1. Volume 2 Technical Provisions Exhibit 21 "Additional Project Requirements".
 - 2. Section 02060 EROSION AND SEDIMENTATION CONTROL
 - 3. Section 02100 SITE PREPARATION
 - 4. Section 02240 DEWATERING
 - 5. Section 02270 SLOPE PROTECTION
 - 6. Section 02283 HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
 - 7. Section 02300 EARTHWORK

1.2 SUBMITTALS

- A. Design-Builder shall refer to Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements". for submittal procedures.
- B. Submit the SWPPP in accordance with the requirements of Article 1.4 of this Section. Resubmit as appropriate during the progress of the Work to reflect proposed revisions and changed conditions, as well as after rainfall events exceeding one-inch. Appendices need not be included with these resubmittals. However, the Design-Builder is advised that submittal of selected items contained therein, or copies of same, are required to be submitted by other provisions of this Section or other Sections of these Contract Documents. At completion of the Work, and before final payment is made, Design-Builder shall submit one electronic copy of the final SWPPP, including all Appendices.

1.3 NPDES NOTICE OF INTENT

- A. The NPDES CGP requires the submission of a Notice of Intent (NOI) to the U.S. EPA prior to the

start of construction (defined as any activity which disturbs land, including clearing and grubbing). There is a fourteen (14) day review period commencing from the date on which EPA enters the Notice into their database. The Design-Builder is advised that, based on the review of the NOI, EPA may require additional information, including but not limited to, the submission of the SWPPP for review. Work may not commence on the project until final authorization has been granted by EPA. The scheduling requirements of the process should be anticipated by the Design-Builder. Any additional time required by EPA for review of submittals will not constitute a basis for claim of delay.

- B. The operator of the construction site, the Design-Builder, must submit the NOI. The Design-Builder is required to file a Notice of Intent form using EPA's electronic NOI (eNOI system) at: <https://www.epa.gov/npdes/electronic-notice-intent-enoi>.

1.4 STORM WATER POLLUTION PREVENTION PLAN

- A. The CGP also requires the preparation and implementation of a SWPPP in accordance with the aforementioned statutes and regulations. The SWPPP will include the CGP conditions and detailed descriptions of controls of erosion and sedimentation to be implemented during construction. It is the responsibility of the Design-Builder to prepare the SWPPP to meet the requirements of the most recently issued CGP, including but not limited to the requirements of the U.S. EPA's Developing Your Pollution Prevention Plan A Guide for Construction Sites (Office of Water/EPA 833-R-06-004/May 2007), and the requirements of this Section. The EPA's template for a Construction SWPPP is available at: <https://www.epa.gov/npdes/developing-stormwater-pollution-prevention-plan-swppp>.

The Design-Builder shall submit the SWPPP to the MBTA for approval at least four weeks prior to any site activities. It is the responsibility of the Design-Builder to be familiar with the CGP conditions and the conditions of all Massachusetts Wetlands Protection Act permits, the MassDEP Chapter 91 License, the U.S. Army Corps of Engineers Section 404 Permit, and other environmental permits applicable to this project, and to include in the SWPPP the methods and means necessary to comply with applicable conditions of said permits.

- B. It is the responsibility of the Design-Builder to complete the SWPPP in accordance with the EPA CGP, provide all information required, and obtain any and all certifications as required by the CGP. Any amendments to the SWPPP required by site conditions, schedule changes, revised work, construction methodologies, and the like are the responsibility of the Design-Builder. Amendments will require the approval of the MBTA prior to implementation.
- C. Included in the CGP conditions is the requirement for inspection of all erosion controls and site conditions on a weekly basis, or once every 14 calendar days and within 24-hours of the occurrence of a storm event exceeding 0.25 inches in twenty-four hours. The Design-Builder shall choose a qualified individual who will be on-site during construction to perform these inspections. The name and qualifications of the inspector shall be submitted to the MBTA for approval in accordance with Design-Builder approval requirements. In addition, if the MBTA determines at any time that the inspector's performance is inadequate, the Design-Builder shall provide an alternate inspector. Written weekly inspection forms, storm event inspection forms, and Monthly Summary Reports must be completed and provided to the MBTA. Monthly Summary Reports must include a summary of construction activities undertaken during the reporting period, general site conditions, erosion control maintenance and corrective actions taken, the anticipated schedule of construction activities for the next reporting period, any SWPPP amendments, and representative photographs. The inspector qualifications, inspection reports and monthly reports shall also conform to the requirements of the Wetlands Order of Conditions issued by any Conservation Commissions with jurisdiction over the

Work.

- D. The Design-Builder is responsible for preparation of the SWPPP, including all certifications, inspections, reports and any corrective actions necessary to comply with the provisions of the CGP. This Item addresses acceptable completion of the SWPPP, any revisions/amendments required during construction, inspection reports and preparation of monthly reports. In addition, any erosion controls beyond those specified in bid items elsewhere in this contract which are selected by the Design-Builder to facilitate and/or address the Design-Builder's schedule, methods and prosecution of the Work shall be considered incidental to this item.

1.5 NPDES NOTICE OF TERMINATION OF SWPPP

- A. The CGP requires the submission of a Notice of Termination (NOT) from all operators when final stabilization has been achieved. Approval of final stabilization by the MBTA and confirmation of submission of the NOT by the Design-Builder will be required prior to submission of the MBTA's Final Estimate.
- B. Upon submission of the NOT, Design-Builder to provide MBTA with all working documents and forms associated with the SWPPP as the MBTA will be deemed the "Operator" from that point forward.

1.6 PENALTIES

- A. Failure to comply with provisions of the NPDES permitting program and the SWPPP may result in penalties assessed by EPA, the costs of which would be borne by the Design-Builder.

PART 2 - PRODUCTS

Not Used.

PART 3 - EXECUTION

3.1 IMPLEMENTATION OF THE STORM WATER POLLUTION PREVENTION PLAN

- A. The SWPPP, developed in accordance with Paragraph 1.4 of this Section, shall be implemented and adhered to during all phases of construction. The Design-Builder shall retain an up-to-date copy of his SWPPP and all Appendices at an on-site construction project office. The SWPPP, including all Appendices, shall be available for inspection during normal working hours by the MBTA, and all duly-authorized Federal, State, and local officials, from the date of initial SWPPP submittal until the final copy is submitted upon completion of the Work, in accordance with the requirements of Paragraph 1.2 B.
- B. The Design-Builder shall develop appropriate plans, figures, related sketches, etc. as necessary to illustrate the SWPPP. Such items shall be maintained in an Appendix to the SWPPP as they are developed by the Design-Builder. At a minimum, such drawings shall address the following three elements for the site: (1) Existing Site Conditions; (2) Site Plans (illustrating slopes after grading, areas of disturbance, drainage pattern, etc.); and (3) Site Controls (illustrating erosion and sediment control

measures, project construction waters management, oil and hazardous materials (OHM) management, etc.). Each element shall be separately addressed on its own drawing or series of drawings.

- C. The following inspection and maintenance practices shall be used to maintain erosion and sediment controls:
1. All control measures identified in the SWPPP shall be inspected by a Design-Builder-designated individual as specified in Section 1.4 C.
 2. All measures shall be maintained in good working order; if a repair is necessary, it shall be initiated within 48 hours of deficiency identification.
 3. An Inspection and Maintenance Report shall be completed for each inspection by the individual who performed the inspection. Completed Inspection and Maintenance Reports shall be maintained in an Appendix to the SWPPP. The Design-Builder-developed report form to be completed by the Design-Builder's inspector shall be submitted to the MBTA for approval, and shall address the control measures identified in the SWPPP. A sample Inspection and Maintenance Report form is presented in: *Office of Water/EPA 833-R-06-004/May 2007*. The Design-Builder shall further develop this form as necessary to list the specific control measures to be inspected and to provide additional detail based on his proposed work. Inspection activities performed by the Design-Builder shall in no way limit the MBTA from conducting their own inspections and identifying deficiencies to the Design-Builder for correction.
- D. The Design-Builder shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) to achieve compliance with the conditions of the NPDES CGP and with the requirements of the SWPPP.
- E. The Design-Builder shall maintain records of dates when major grading activities occur, dates of temporary or permanent cessation of construction, and dates of initiation of stabilization measures in an Appendix to the SWPPP.
- F. Oil and Hazardous Materials Management and Spill Control
1. For practices not more specifically addressed by federal, state, and local laws and implementing regulations or these Specifications, all oil and hazardous materials and all spills shall be managed in accordance with the OHM Management and Spill Control Program presented in the SWPPP.
 2. Spills
 - a. The NPDES CGP does not relieve the Design-Builder of the reporting requirements of the Massachusetts Contingency Plan, 40 CFR Part 117, or 40 CFR Part 302. Where a release containing a hazardous substance in an amount equal to or in excess of a reporting quantity established under the Massachusetts Contingency Plan, 40 CFR Part 117, or 40 CFR Part 302 occurs, the Design-Builder is required to comply with the requirements of the aforementioned regulations. Spills of oil or hazardous material by the Design-Builder shall be reported to the Massachusetts Department of Environmental Protection and/or the National Response Center as appropriate, if the reportable quantity is exceeded. All spills of OHM by the Design-Builder, in any quantity shall be reported to the MBTA within 24-hours.
 - b. A spill report shall be prepared by the Design-Builder following each occurrence. The spill report shall present a description of the release, including quantity and type of material, date of spill, circumstances leading to the release, location of spill, response actions and personnel,

documentation of notifications, and corrective measures implemented to prevent reoccurrence. Such reports shall be maintained in an Appendix to the SWPPP.

- c. The Design-Builder shall identify an appropriately trained site employee involved with day-to-day site operations to be the spill prevention and cleanup coordinator. The name(s) of responsible spill personnel shall be posted in the material storage area and in the office trailer on site. Each employee shall be instructed that all spills are to be reported to the spill prevention and cleanup coordinator.

- G. The Design-Builder shall be required to amend the SWPPP whenever there is a change in design, construction, operation, or maintenance, which has a significant effect on the potential for the discharge of pollutants to waters, including the addition of or change in location of storm water discharge points, or if the SWPPP proves to be ineffective in eliminating or significantly minimizing pollutants in storm water discharges or in otherwise achieving the general objectives of the SWPPP. Also, where warranted based on the results of an inspection by the Design-Builder or others, the site description, procedures, or other elements of the SWPPP shall be revised as appropriate; modifications called for by the inspection and resultant changes to the SWPPP shall be implemented within 7 calendar days following the inspection. In addition, the SWPPP shall be amended to identify any new subDesign-Builder that will implement a measure of the SWPPP. Finally, the SWPPP shall be amended to incorporate specific revisions if so directed by the MBTA, or any duly-authorized Federal, State, or local official at any time during the performance of the Work under this Contract.

- H. The Work specified in this Section for preparing, implementing, monitoring, and maintaining the SWPPP shall include development and implementation of activities and measures to properly handle OHM and to prevent storm water pollution; as such the Work shall also include installation, operation, maintenance, and removal of all facilities for the collection, containment, diversion, and disposal of surface and ground water as required for compliance with the SWPPP, including all supervision, labor, materials, and equipment not specifically included but necessary for proper completion of the Work.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection with the work are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02260

EXCAVATION SUPPORT AND PROTECTION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. **Work Included:** This Section specifies temporary soils excavation support and protection systems.
- B. **Related Work:** Other specification section that relate to work of this section include, but are not limited to, the following:
 - 1. Volume 2 Technical Provisions Exhibit 2I – “Additional Project Requirements”
 - 2. Section 02015 – GEOTECHNICAL INSTRUMENTATION
 - 3. Section 02240 – DEWATERING
 - 4. Section 02300 – EARTHWORK
 - 5. Section 03300 – CAST-IN-PLACE CONCRETE
 - 6. Section 03371 – SHOTCRETE
 - 7. The construction of excavation support systems shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design-Builder at no additional cost to the MBTA.
 - 8. Adjacent structures shall be monitored and protected as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
 - 9. Vibration monitoring for installation of excavation support systems will be performed by the Design-Builder’s Geotechnical Instrumentation Engineer as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
 - 10. Construction operations not to exceed specified noise limits in accordance with Volume 2 Technical Provisions Exhibit 2I, “Additional Project Requirements”.

1.1 PERFORMANCE REQUIREMENTS

- A. Design, furnish, install, monitor, and maintain excavation support and protection systems capable of supporting excavation sidewalls and of resisting soil and hydrostatic pressure and superimposed loads, and protect from damage existing and proposed improvements including, but not limited to, pipelines, utilities, structures, roadways, railroads and other facilities.
 - 1. Provide professional engineering services needed to assume engineering responsibility, including preparation of a design submittal, Shop Drawings and a comprehensive engineering analysis.
 - 2. Prevent surface water from entering excavations by grading, dikes, or other means.

3. Install excavation support and protection systems without damaging existing buildings, pavements, and other improvements or facilities adjacent to excavation.
 4. Provide vibration monitoring, and other geotechnical instrumentation, as needed, to prevent impacts on adjacent structures and utilities.
- B. Construction of the temporary excavation support systems shall not disturb the existing structures or the completed proposed structures. Damage to such structures shall be repaired by the Design-Builder at no additional cost to the MBTA.
- C. The Design-Builder shall bear the entire cost and responsibility of correcting any failure, damages, subsidence, upheaval, or cave-ins as a result of improper installation, maintenance, or design of the temporary excavation support systems. The Design-Builder shall pay for all claims, costs, and damages that arise as a result of the work performed at no additional cost to the MBTA.

1.2 SUBMITTALS

- A. Shop Drawings: Prepared by or under the supervision of a qualified professional engineer for excavation support and protection systems.
1. Include Shop Drawings signed and sealed by the qualified professional engineer responsible for their preparation.
 2. Show proposed temporary excavation support system(s), details, location, layout, depths, extent of different types of support relative to existing features and the permanent structures to be constructed, and methods and sequence of installation and removal.
 3. Provide a list of all design assumptions, including safety factors used for the temporary excavation support system(s) and all lateral pressures used for each system.
 4. If utilizing a tieback system, include tieback installation procedures and criteria for acceptance of tiebacks for performance and proof tests. Submit the tieback testing results to the MBTA for information only.
 5. Show requirements of dewatering during the construction.
 6. Show the minimum lateral distance from the edge of the excavation support system for use for vehicles, construction equipment, and stockpiled construction and excavated materials.
 7. Provide a list of equipment used for installing the excavation support systems.
 8. Provide a monitoring schedule, installation procedures, and location plans for vibration/noise monitoring, geotechnical instrumentation including deformation monitoring points, inclinometers, and observation wells/piezometers to monitor ground, excavation support system, adjacent structures, and groundwater fluctuation during the entire construction period.
- B. Qualification Data: For Installer and professional engineer currently registered in the Commonwealth of Massachusetts.
- C. Photographs or videotape, sufficiently detailed, of existing conditions of adjoining construction and site improvements that might be misconstrued as damage caused by the absence of, the installation of, or the performance of excavation support and protection systems. These photographs or videotape

records are supplemental to the Pre-Construction Survey documentation as specified in Volume 2 Technical Provisions Exhibit 2I, "Additional Project Requirements".

- D. Monitoring data from vibration and noise recording equipment, observation wells, deformation monitoring points, and offset lines in accordance with Section 02015 – GEOTECHNICAL INSTRUMENTATION. The data provided will be used by the MBTA only for the information of the MBTA and third parties. The Design-Builder shall remain responsible for the interpretation of the data as it relates to the protection of structures and the adequacy and safety of the means, methods, and sequencing of construction.
- E. For excavation support systems left in place, submit the following as-built information prior to backfilling and covering the excavation support systems:
 - 1. Survey locations of the temporary excavation support systems, including coordinates of the endpoints or change in direction.
 - 2. Type of the temporary excavation support system.
 - 3. Elevations of top and bottom of the excavation support systems left in place.

1.3 PROJECT CONDITIONS

- A. Existing Utilities: Do not interrupt utilities serving facilities occupied by MBTA or others unless permitted in writing by MBTA and then only after arranging to provide temporary utility services according to requirements indicated.
- B. Project-Site Information: A Geotechnical Data Report has been prepared for this Project and is available for information only. The report shall not be interpreted as a warranty of subsurface conditions whether interpreted from written text, boring logs, or other data. The Design-Builder shall assume that subsurface conditions between subsurface explorations could differ from conditions shown on the boring logs. MBTA will not be responsible for interpretations or conclusions drawn from this data.
 - 1. Make additional test borings and conduct other exploratory operations necessary for excavation support and protection.
- C. Survey adjacent structures and improvements, employing a qualified professional engineer or land surveyor; establish exact elevations at fixed points to act as benchmarks. Clearly identify benchmarks and record existing elevations.
 - 1. During installation of excavation support and protection systems, regularly resurvey benchmarks, maintaining an accurate log of surveyed elevations and positions for comparison with original elevations and positions. Promptly notify MBTA if changes in elevations or positions occur or if cracks, sags, or other damage is evident in adjacent construction.

1.4 QUALITY ASSURANCE

- A. Have a registered engineer approve and inspect all excavation support areas on a periodic basis.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. General: Provide materials that are either new or in serviceable condition.
- B. Structural Steel: ASTM A 36/A 36M, ASTM A 690/A 690M, or ASTM A 992/A 992M.
- C. Steel Sheet Piling: ASTM A 328/A 328M, ASTM A 572/A 572M, or ASTM A 690/A 690M; with continuous interlocks.
- D. Cast-in-Place Concrete: ACI 301, of compressive strength required for application.
- E. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.
- F. Timber Piling: ASTM D 25, species listed in AWPA C3, pressure-treated in accordance with AWPA C3.
- G. Seven Wire Strand: ASTM A 416, Grade 250 or 270, uncoated seven-wire, low-relaxation strand.
- H. Grout: Suitable for application, minimum 4,000 psi.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Protect structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards that could develop during excavation support and protection system operations.
 - 1. Shore, support, and protect utilities encountered.
- B. Install excavation support and protection systems to ensure minimum interference with roads, streets, walks, and other adjacent facilities.
 - 1. Do not close or obstruct streets, walks, or other adjacent occupied or used facilities without permission from MBTA and authorities having jurisdiction. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.
- C. Locate excavation support and protection systems clear of permanent construction.
- D. Monitor excavation support and protection systems daily during excavation progress and for as long as excavation remains open. Promptly correct bulges, breakage, or other evidence of movement to ensure that excavation support and protection systems remain stable.
- E. Promptly repair damages to adjacent facilities caused by installing excavation support and protection systems.

3.2 SOLDIER BEAMS AND LAGGING

- A. Install vertical steel soldier beams before starting excavation at element spacings and design depths indicated on the approved shop drawings. Space soldier beams at regular intervals not to exceed allowable flexural strength of lagging. Accurately align exposed faces of flanges to vary not more than 2 inches from a horizontal line and not more than 1:120 out of vertical alignment.
- B. Install wales horizontally at spacing indicated on the approved shop drawings and secure to soldier beams.

3.3 SHEET PILING

- A. Before starting excavation, install one-piece sheet piling lengths and tightly interlock to form a continuous barrier. Limit vertical offset of adjacent sheet piling to 60 inches. Accurately align exposed faces of sheet piling to vary not more than 2 inches from a horizontal line and not more than 1:120 out of vertical alignment. Cut tops of sheet piling to uniform elevation at top of excavation.

3.4 TIEBACKS

- A. Tiebacks: Drill for, install, grout, and tension tiebacks into position. Test load-carrying capacity of each tieback and replace and retest deficient tiebacks.
 - 1. Test loading as specified in the Shop Drawing submittal shall be observed by a qualified professional engineer responsible for design of excavation support and protection system.
 - 2. Maintain tiebacks in place until permanent construction is able to withstand lateral earth and hydrostatic pressures.
 - 3. Inspect tiebacks periodically to confirm anchors exhibit no movement.

3.5 BRACING

- A. Bracing: Locate bracing to clear columns, floor framing construction, and other permanent work. If necessary to move brace, install new bracing before removing original brace.
 - 1. Do not place bracing on permanent concrete work or where it will be cast into or included in permanent concrete work, unless otherwise approved by MBTA.
 - 2. Install internal bracing, if required, to prevent spreading or distortion of braced frames.
 - 3. Maintain bracing until structural elements are supported by other bracing or until permanent construction is able to withstand lateral earth and hydrostatic pressures.

3.6 REMOVAL AND REPAIRS

- A. Remove excavation support and protection systems when construction has progressed sufficiently to support excavation and bear soil and hydrostatic pressures. Remove in stages to avoid disturbing underlying soils or damaging structures, pavements, facilities, and utilities.

1. Remove excavation support and protection systems to a minimum depth of 48 inches below overlying construction and abandon remainder.
 2. Repair or replace, as approved by MBTA, adjacent work damaged or displaced by removing excavation support and protection systems.
- B. When tiebacks are used, release tension in tiebacks as the excavation is backfilled. Do not leave tensioned tieback in place at the completion of the work.

3.7 MONITORING TRACK MOVEMENT

- A. Before the start of excavation support work, establish elevations along Top of Rail of nearest track, each rail, spaced approximately every 20 feet in the vicinity of the work.
- B. Perform two baseline elevation surveys of the Top of Rail before the start of excavation support installation. Survey both vertical and lateral (into excavation) positions.
- C. Perform weekly survey of settlement monitoring points from the beginning of excavation support installation until the structure is completely in place and fully backfilled.

PART 4 - MEASUREMENT AND PAYMENT

4.2 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02270

SLOPE PROTECTION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following types of slope protection.
1. Type 1, Dumped Riprap: angular shaped stones dumped in place to form a well-graded mass with a minimum of voids.
 2. Type 2, Slope Paving: angular shaped stones, each having one flat face, carefully placed on slopes.
 3. Type 3, Special Slope Paving under Bridges:
 - a. Type 3A: Quarry stone, not grouted.
 - b. Type 3B: Quarry stone, grouted.
 - c. Type 3C: Precast concrete block.
 - d. Type 3D: Portland cement concrete.
 4. Type 4, Channel Paving: Nearly rectangular stones placed along the slopes around culvert inlets or outlets, around foundations, bridge berms and dikes.
 - a. Type 4A: not grouted.
 - b. Type 4B: grouted.
 5. Type 5, Stone Protected Slopes (Modified Rock Fill): to be used at detention basin on 2 to 1 side slope, at Lechmere Station Lot A Bus Access Road 1.5 to 1 side slope and the infiltration basin spillway as shown on the Drawings.
 6. Type 6, Gravel Slopes for Access Driveways: Red Bridge Pump Station
 7. Type 7, Grass Protected Slopes at detention basin
- B. Alternates: Not Applicable.
- C. Items to Be Installed Only: Not Applicable.
- D. Items to Be Furnished Only: Not Applicable.
- E. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
1. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 2. Section 02300 – EARTHWORK
 3. Section 03300 - CAST-IN-PLACE CONCRETE.
 4. Section 02920 - SEEDED LAWN

1.2 REFERENCES

- A. American Society for Testing and Materials, ASTM C-139, Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes
- B. American Society for Testing and Materials, ASTM C-140, Standard Test Methods for Sampling and Testing.

1.3 QUALITY ASSURANCE

- A. Control of gradation of stone for Type 1 slope protection shall be by visual inspection. Provide at the construction site and at the quarry a mass of rock of at least five tons meeting the specified gradation. The sample at the construction site may be a part of the finished riprap covering. These samples will be used as a reference for judging the gradation of riprap supplied.
- B. **JOB CONDITIONS**
 - 1. Do not grout slope or channel paving or place concrete slope paving on frozen ground nor when the temperature falls below 50 degree F. During cold weather, provide protective coverings for the work.
 - 2. Should any work be exposed to temperatures of 40 degrees F or below, within four days after grouting or concrete placement, cover the work with a one-foot thick layer of straw, hay or mulch; then cover with a weighted cover of canvas or plastic sheet.

PART 2 - PRODUCTS

2.1 TYPE 1, DUMPED RIPRAP

- A. Stone: hard, durable, angular in shape; resistant to weathering; free from overburden, spoil, shale and organic materials; neither breadth nor thickness of a stone shall be less than one third its length.
- B. Gradation

SIZE OF STONE SMALLER THAN	MAXIMUM PERCENT OF TOTAL WEIGHT
400 pounds	100
300 pounds	80
200 pounds	50
25 pounds	10

Maximum percent passing a two-inch sieve: 5 percent

- C. Filter Fabric (Geotextile) below riprap:
 - 1. Shall meet the physical requirements set forth in the MassDOT Standard Specifications M9.50.0 Type I geotextile fabrics.

2.2 TYPE 2, SLOPE PAVING

- A. Stone: sound, angular in shape, free from structural defects; each stone having one reasonably flat face, a thickness perpendicular to the face of not less than six inches and no dimension less than six inches.
- B. Gradation: approximately 60 percent, two to three cubic feet each in volume; the remainder, one to two cubic feet each in volume.
- C. Filter Fabric (Geotextile) below riprap:
 - 1. Shall meet the physical requirements set forth in the MassDOT Standard Specifications M9.50.0 Type I geotextile fabrics.

2.3 TYPE 3, SPECIAL SLOPE PAVING UNDER BRIDGES

- A. Quarry Stone: granite or other similar durable stone; rectangular exposed surface with split or quarry face finish; uniform in color; 12 to 28 inches long, 10 to 14 inches wide, 3 to 6 inches thick.
- B. Precast Concrete Block: ASTM C-139, 4 inches by 12 inches by 16 inches, sampled and tested in accordance with ASTM C-140.
- C. Grout: Portland cement, sand and water mixture with a minimum 28 day compressive strength of 3,000 psi.
- D. Concrete: Section 03310, Class 3000 - 1-1/2.

2.4 TYPE 4, CHANNEL PAVING

- A. Stone: sound, durable, angular blocks, as nearly rectangular as practicable; rounded stones or thin slabs will not be acceptable.
- B. Gradation: minimum 75 percent, at least 200 pounds; the remainder graded to produce a compact mass when placed with the larger stones.
- C. Grout: As specified in paragraph 2.03.C above.

2.5 TYPE 5, STONE PROTECTED SLOPES (MODIFIED ROCK FILL)

- A. Stone: sound, durable, angular shaped stones which are the product of primary crushing of a stone crusher; rounded stone, boulders, sandstone and similar soft stone or thin slabs will not be acceptable.
- B. Gradation: for rock fill slope, per MassDOT Standard Specifications M2.02.4, except that 95 to 100 percent passing stone size shall be 12-inch. At inlet and outlet structures in detention basin, minimum 50 percent passing stone size shall be 12-inch.

2.6 TYPE 6, GRAVEL SLOPES FOR ACCESS DRIVEWAYS

- A. Dense graded crushed stone shall meet the requirements per MassDOT Standard Specifications M2.01.7

2.7 TYPE 7, GRASS SLOPES

- A. Seed mixture, soil conditioning materials and fertilizers: shall meet the requirements set forth in MassDOT Standard Specifications M6.03.

2.8 GRAVEL BORROW OR CRUSHED STONE BASE: Section 02300 - EARTHWORK.

PART 3 - EXECUTION

3.1 TYPE 1, DUMPED RIPRAP

- A. Riprap shall be installed in accordance with construction methods for MassDOT Standard Specifications.
- B. A minimum 2-foot deep riprap key shall be installed to a depth below the final grade at the toe of the riprap. Filter fabric shall be wrapped around the riprap stone above at the toe of slope.

3.2 TYPE 2, SLOPE PAVING

- A. Slope paving shall be installed in accordance with construction methods for MassDOT Standard Specifications.
- B. A minimum 2-foot deep riprap key shall be installed to a depth below the final grade at the toe of the riprap. Filter fabric shall be wrapped around the riprap stone above at the toe of slope.

3.3 TYPE 3, SPECIAL SLOPE PAVING UNDER BRIDGES

- A. General: Place special slope paving under bridges on a six-inch gravel borrow or crushed stone base. Construct the paving to a continuous surface of uniform appearance, approximately parallel to and within three inches of the slope shown on the plans.
- B. Type 3A, Quarry Stone, not Grouted; Type 3B, Quarry Stone, Grouted and Type 3C, Precast Concrete Block: shall be installed in accordance with construction methods for MassDOT Standard Specifications.
- C. Type 3D, Portland Cement Concrete: Section 03300 CAST-IN-PLACE CONCRETE.

3.4 TYPE 4, CHANNELING PAVING

- A. Channeling shall be installed in accordance with construction methods for MassDOT Standard Specifications.

3.5 TYPE 5, STONE PROTECTED SLOPES (MODIFIED ROCK FILL)

- A. Stone shall be installed in accordance with construction methods for MassDOT Standard Specifications Section 983.
- B. A minimum 2-foot deep riprap key shall be installed to a depth below the final grade at the toe of the riprap.

3.6 TYPE 6, GRAVEL SLOPES FOR ACCESS DRIVEWAY

- A. Installation shall be in accordance with the MassDOT Standard Specification Section 401.
- B. Gravel course shall be installed to a depth of 8-inch.

3.7 TYPE 7, GRASS SLOPES

- A. Installation shall be in accordance with the MassDOT Standard Specification Section 765.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02282

HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the procedures used for field screening; soil sampling, stockpile management, reuse, transportation, and disposal of excavated materials.
- B. This section includes furnishing all labor, equipment, appliances and materials, and performing all operations in connection with the handling, segregating, testing, treating, stockpiling, transporting, and disposal and/or re-use of soil (defined hereinafter as including stone ballast, sediments and track bed for the purposes of this Section) and associated fill and waste material resulting from the construction operations as specified.
- C. Related Work: The following items are not included in this Section and will be performed under but may not be limited to the following designated Sections:
1. Section 01568 – CONSTRUCTION SAFETY
 2. Section 02300 – EARTHWORK
 3. Section 02221 – DEMOLITION
 4. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 5. Section 02080 – ASBESTOS REMOVAL
 6. Section 02369 – DRILLED MINI-PILES
 7. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 8. Section 02402 – STORMWATER TREATMENT AND DISPOSAL SYSTEMS
- D. For the purpose of this section the AUTHORITY will be the Generator and will sign all disposal facility waste profiles, Hazardous Waste Manifests (manifest), Material Shipping Records (MSR), and MCP Bills of Lading (BOL) as the Generator. The AUTHORITY's License Site Professional (LSP) will sign all BOL as the LSP and MSRs as the Environmental Professional. Except for soil that requires transport under a manifest, all soil shall be transported under BOL or MSR whichever is applicable, based on the results of the laboratory chemical analysis of soils. BOL shall be utilized for soils classified as containing chemical concentrations \geq Reportable Concentration (RCS-1) soils; MSR shall be utilized for all soils classified as containing chemical concentrations \leq RCS-1 soils.
- E. Furnish all labor, materials, equipment, and incidentals necessary to properly sample, classify, segregate, handle/manage, load, transport, and dispose of excavated materials located from within the Limit of Work. Work covered by this Section shall include furnishing, operating, and maintaining soil stockpile/staging areas and equipment decontamination stations for the duration of excavation activities and dismantling, disposing of decontamination stations, and stockpile/staging areas at project completion. Decontamination stations shall be capable of eliminating the dispersion of dust and mud caused by vehicles exiting the site.

1.2 RESPONSIBILITIES

- A. The DESIGN-BUILDER shall employ the services of an Environmental Consultant to assist in the activities listed below. DESIGN-BUILDER's Responsibilities:

1. The DESIGN-BUILDER shall employ the services of an Environmental Consultant to perform the soil screening, soil sampling, dust control measures, management coordination, and support compliance efforts associated with all references listed in this Section. The Environmental Consultant shall include at least one professional experienced in soil sampling and dust control measures and a Licensed Site Professional (LSP) registered with the Massachusetts LSP Board. Proof of current licensure and professional experience on projects of similar nature and complexity shall be provided to the Engineer with the Excavated Materials Management Plan (EMMP).
2. The DESIGN-BUILDER shall field-screen excavated material for the presence of volatile organic compounds (VOCs) with a photo ionization detector (PID) calibrated to a benzene standard. The DESIGN-BUILDER shall perform field screening of excavated material exhibiting olfactory and/or visual evidence of oil or hazardous materials at a frequency of no less than every 100 cubic yards of material or fraction thereof, or as directed by Engineer. Excavated materials not exhibiting such characteristics shall be screened upon initial excavation; additional screening shall be conducted if characteristics are inconsistent during subsequent excavation.
3. The DESIGN-BUILDER shall, as deemed appropriate by DESIGN-BUILDER'S LSP and AUTHORITY'S LSP, utilize x-ray fluorescence (XRF) for initial soil screening and segregation purposes. The DESIGN-BUILDER shall perform field screening of excavated material exhibiting olfactory and/or visual evidence of oil or hazardous materials at a frequency of no less than every 100 cubic yards of material or fraction thereof, or as directed by Engineer. Excavated materials not exhibiting such characteristics shall be screened upon initial excavation; additional screening shall be conducted if characteristics are inconsistent during subsequent excavation.
4. The DESIGN-BUILDER shall segregate excavated soils into stockpiles based upon the results of on-site screening.
5. The DESIGN-BUILDER shall be responsible for submitting to the Engineer the daily logs summarizing field screening and excavating activities. The logs shall include the soil screening classification, volume and a sketch showing the origin and on-site location of each excavated soil stockpile.
6. The DESIGN-BUILDER shall identify and propose locations for construction staging of both on or offsite temporary soil stockpiles and miscellaneous materials, soil/waste treatment technologies and treatment areas (on-site or offsite), disposal, recycling and treatment facilities, facilities for the beneficial re-use of excavated materials including but not limited to soil, debris, or other miscellaneous materials, temporary storage facilities, landfills, soil recycling and hazardous waste treatment, storage and disposal facilities for all excavated material.
7. The DESIGN-BUILDER shall be responsible for transporting excavated material to the approved construction storage location/stockpile area and disposal, recycling, treatment facilities and facilities for beneficial re-use.
8. The DESIGN-BUILDER shall furnish, operate and maintain equipment decontamination stations for the duration of excavation and soil disposal work.
9. The DESIGN-BUILDER shall develop and implement site-specific emergency response and health and safety protocols and procedures.

10. For each shipment of material transported to a disposal facility, the DESIGN-BUILDER shall demonstrate to the Engineer that the least costly means of disposal has been selected. This demonstration shall be made prior to shipment.
11. The DESIGN-BUILDER shall be responsible for submitting completed Bills of Lading, MSR, manifests and other shipping documents to the Engineer within two weeks of shipment to a storage or disposal/recycling facility. The DESIGN-BUILDER is responsible for up-loading these BOLs onto the MassDEP electronic filing system (eDEP). The AUTHORITY's LSP will sign and stamp BOLs. The receiving facility shall provide electronic attestation of receipt of soils within five days of receiving notification from the LSP of the availability of the BOL for that purpose on eDEP.
12. The DESIGN-BUILDER shall advise the Engineer at least three working days in advance of the schedule for off-site disposal of excavated material. No off-site shipments or on-site re-use will occur without the approval of the Engineer.
13. The DESIGN-BUILDER shall advise the Engineer at least three working days in advance of the collection of soil samples and any other environmental sampling. The DESIGN-BUILDER shall collect, analyze and characterize samples of excavated material prior to off-site recycling and/or disposal.
14. The DESIGN-BUILDER shall prepare the necessary documents to transport and dispose of excavated material for review and signing by the Authority's LSP. These documents include, but are not limited to waste profiles, BOLs, MSR and manifests, and any supporting documents required by the disposal facility.
15. The DESIGN-BUILDER shall submit the executed transportation and disposal documents to the appropriate local, state and federal agencies as well as the Engineer.
16. The DESIGN-BUILDER shall provide an environmental field technician to oversee the loading of excavated material into transport vehicles for off-site disposal/recycling.
17. The DESIGN-BUILDER shall develop an excavated soil tracking/management system and keep records, including daily logs and photographs, of all waste streams, stockpiles, and excavated materials for the purposes of tracking points of origin and final disposition. DESIGN-BUILDER's soil tracking/management system shall be compatible with ENGINEER's GIS-based soil management system.
18. The DESIGN-BUILDER shall develop and implement dust control measures.

B. AUTHORITY's Responsibilities:

1. The AUTHORITY will review and approve the proposed facilities selection of off-site recycling, reuse or disposal facilities.
2. The AUTHORITY will be the designated Generator for excavated material identified for off-site reuse, recycling and/or disposal.
3. The AUTHORITY's LSP will review and approve all paperwork, manifests, and Bills of Lading prior to soil disposal.
4. The AUTHORITY'S LSP will review and sign all shipping documentation as LSP-of-Record.

1.3 QUALITY ASSURANCE AND QUALITY CONTROL

- A. The DESIGN-BUILDER shall be responsible for the collection and analysis of soil samples from all areas of the site. Sampling frequency shall be conducted as to meet the requirements of the DESIGN-BUILDER's disposal facility. For the purpose of disposal, TPH data is acceptable. However, MCP notification will be based upon VPH and/or EPH MADEP Method 1.0 analysis. The analysis and analytical documentation shall meet the MassDEP Compendium of Analytical Methods requirements. The DESIGN-BUILDER shall include the result of all soil testing in the Excavated Materials Management Plan in accordance with Section 1.4 Submittals.

1.4 SUBMITTALS

- A. The DESIGN-BUILDER shall prepare an Excavated Materials Management Plan (EMMP) that describes the work to be performed under this Specification. The EMMP shall be submitted within fourteen days after the issuance of the Notice to Proceed. The EMMP shall be accepted before excavated soil is disposed of off-site or re-used. At a minimum the EMMP shall address the following:
 - 1. The Plan shall include the name and current licensure of the DESIGN-BUILDER's Environmental Consultant.
 - 2. The procedures that shall be used for field screening of the excavated soils.
 - 3. The procedures for the collection of soil samples for laboratory chemical analysis. The plan shall list the proposed laboratory analytical parameters.
 - 4. A plan (in accordance with Section 3.4 Temporary Stockpiling of Excavated Materials) for the on-site or off-site contaminated soil staging/stockpiling for each active construction area.
 - 5. A material management system plan to track the excavated materials from generation through final disposition. Plan shall be updated monthly and include at a minimum the following:
 - a. Provisions for the tracking of the excavated materials from the "point of excavation" to the location of the stockpile material in the storage/staging area to the final disposition of the stockpiled material including all proposed daily log sheets.
 - b. A description of the tracking methodology that shall be implemented to identify the source excavation area(s) and the final disposition of the excavated soil from each area of excavation.
 - c. Person(s) responsible for maintaining the tracking system, and the plan to provide the Authority with electronic access to the material management system and its updates.
 - 6. The means and methods for decontaminating all equipment and personnel, including provisions for installing equipment decontamination pad(s) within the work zone.
 - 7. The means and method for on-site treatment of soil requiring off-site disposal determined through TCLP analysis to be characteristically hazardous pursuant to RCRA (310 CMR 30.00 et. seq.).
 - 8. The DESIGN-BUILDER shall identify each waste stream and propose an appropriate disposal facility that will accept the excavated material as classified. The DESIGN-BUILDER shall submit approvals or letters of intent and facility information for each facility proposed. For each facility, the DESIGN-BUILDER shall submit the following information:
 - a. General Information

- 1) Facility Name
 - 2) Facility Address
 - 3) Name of Contract Person
 - 4) Title of Contact Person
 - 5) Telephone Number of Contact Person
 - 6) Permit Number
- b. The facility shall specify the volume of material that can be accepted from the site on a weekly and a total basis.
 - c. The facility shall provide written confirmation that they are permitted to accept and will accept the classified material of the general quality and quantity described by these Specifications.
 - d. The facility shall provide a listing of all current and valid permits, licenses, letters of approval, and other authorizations to operate that they hold, pertaining to the receipt and management of the soils or materials specified in this contract.
 - e. The DESIGN-BUILDER shall submit a complete list of the disposal facility's permitted allowable contaminant levels and physical characteristic requirements for excavated material, and list any required regulatory approvals for individual waste streams.
9. A plan for dust monitoring on-site during any earthwork activities.
 10. The plan shall be amended as necessary.
- B. Laboratory results for all samples collected and/or analyzed by the DESIGN-BUILDER shall be tabulated and compared to applicable MCP standards by the DESIGN-BUILDER's Environmental Consultant and subsequently submitted to the Engineer within two days of receipt. The results shall include all Chain-of-Custody forms and all documentation provided by the laboratory.
- C. All data shall be provided as Electronic data deliverables (EDDs) formatted for upload to EQUIS™ software. Tabulated analytical results shall be provided in Excel table format, compared to applicable regulatory standards. Final laboratory analytical reports shall be provided in PDF format.
- D. The DESIGN-BUILDER shall submit soil disposal documentation.
1. Pre-disposal documentation shall be prepared and submitted to the Engineer at least 5 business days prior to transportation and disposal. Each documentation submittal shall be assigned a unique identification referenced to the area of excavation, stockpile and sample name.
 - a. Completed MSR, BOL, or manifest signed by the AUTHORITY and AUTHORITY's LSP as required.
 - b. Completed and signed profiles as required by the receiving facility.
 - c. Analytical data report provided by the analytical laboratory.
 - d. Sketch plan showing sampling location.
 - e. Summary of soil source location; site history; sampling methods and data comparison to facility criteria and MCP reporting criteria.
 - f. Written approval from the disposal facility that the material has been accepted.
 - g. Receiving facility–required checklist of requirements.

2. Post disposal documentation shall be prepared and submitted following disposal and referenced to the pre-disposal documentation by name.
 - a. Load sheets completed and signed by the hauler and the receiving facility.
 - b. Certified weight slips from the receiving facility.
 - c. For BOLs only, the facility and AUTHORITY attestations of shipment and receipt.
 3. All soil disposal documentation shall be compiled and re-submitted at the completion of the disposal activities. The submittal shall consist of one or more PDF-Searchable electronic files contained on a CD. The final submittal shall be organized by the uniquely identified MSR, BOL, or manifest.
- E. All elements of the EMMP shall be submitted as a final close-out document within four weeks after the completion of all excavation and disposal activities. The final submittal shall consist of one or more PDF-searchable electronic files on a CD. Previous submittals of one or more of the elements described herein or previous eDEP filings shall not modify the requirements of the final submittal. The final submittal shall contain the supporting documentation identified in 1.4 (A) through (C).
- F. The DESIGN-BUILDER shall submit their work zone air quality monitoring program for review prior to commencement of site activities.

1.5 REFERENCES

- A. All regulations cited and those of other governing agencies in their most recent version are applicable. This Section refers to many requirements found in these references, but is in no way intended to cite or reiterate all provisions therein or elsewhere. It is the DESIGN-BUILDER's responsibility to know, understand, and abide by all such regulations and common practices. Other provisions contained in these references may from time to time during the execution of this Contract be enforced by the Engineer. In the event of a conflict, the most stringent regulations shall govern.

The following documents and/or publications are made part of this Section by reference herein:

1. Massachusetts Contingency Plan (MCP), 310 CMR 40.0000.
2. Massachusetts Hazardous Waste Regulations, 310 CMR 30.00.
3. Solid Waste Management Facility Regulations, 310 CMR 19.00.
4. Site Assignment Regulation for Solid Waste Facilities, 310 CMR 16.000.
5. Interim Remediation Waste Management Policy for Petroleum Contaminated Soils, DEP Bureau of Waste Site Cleanup Policy No. WSC-94-400.
6. "Hazardous Waste Operations and Emergency Response", Federal Occupational Safety and Health Act (OSHA), 29 CFR 1910.120.
7. "General Regulations for Hazardous Waste Management", EPA, 40 CFR 260.
8. "Regulations for Identifying Hazardous Waste, Hazardous Waste Generators and Hazardous Waste Transporters", EPA, 40 CFR 261, 262 and 263.
9. "Standards for Management of Specific Hazardous Wastes and Facilities", EPA, 40 CFR 266.
10. "Construction of Buildings in Contaminated Areas," DEP, Bureau of Waste Site Cleanup Policy #WSC-00-425, dated January 2000.
11. Massachusetts DEP Policy #COMM-97-001.

12. Local regulations governing dust control, soil handling, and health and safety (see Section 01567 – HEALTH AND SAFETY).
13. Compendium of Quality Assurance and Quality Control Requirements and Performance Standards (CAM) DEP WSC #02320.
14. MassDEP Technical Update Background Levels of Polycyclic Aromatic Hydrocarbons and metals in soils.
15. MassDEP Similar Soils Provision Guidance (WSC#-13-500).
16. Interim Remediation Waste Management Policy for Petroleum Contaminated Soils Attachment II, Jar headspace analytical Screening Procedure. MassDEP Policy No. WSC-94-900.
17. All other applicable Federal, State, or local requirements

1.6 DEFINITIONS

- A. Area of Excavation: For the purpose of reusing soil/fill on site the limit of excavation is considered to be the approximate area in which the soil/fill was removed provided that area is consistent in soil strata, color, texture, geotechnical properties, and has substantially similar visual and olfactory characteristic as accepted by the AUTHORITY’s Engineer. Soil/fill returned to the limit of excavation shall be placed approximately in the same location from which it originated.
- B. Background: Any soil or fill material which meets the regulatory definition of “background” as defined in 310 CMR 40.0006 may be reused as common fill/ordinary borrow provided it also meets the physical requirements as specified herein and as specified in Section 02210 – Earth Excavation, Backfill, and Grading – or the environmental requirements as specified in Part 3.6. Excess soil that meets the definition of background shall be transported under a Material Shipping Record (MSR) or BOL.
- C. Contaminated Material/Soil: Any excavated material found to contain oil or hazardous material (OHM) at concentrations equal to or exceeding applicable MCP Method 1 standards (310 CMR 40.0300), reportable concentrations (310 CMR 40.1600), or regulated background levels (as defined in the MADEP Technical Update Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil and 310 CMR 40.00006) or other applicable State or Federal Regulations.
- D. Excavated Material: All soil, sediment, and/or debris excavated from within the Limit of Excavation.
- E. Generator: The AUTHORITY will be the generator, with the exception of materials contaminated by releases from the DESIGN-BUILDER’s vehicles, equipment, or supplies.
- F. Hazardous Material/Waste: A waste material or combination of waste material, that because of its quantity, concentration, physical, chemical, or infectious characteristics may cause or significantly contribute to an increase in a serious irreversible or incapacitating reversible illness, or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of or otherwise managed. This definition also includes but is not limited to materials regulated under TSCA, M.G.L., Chapter 21E, RCRA (40 CFR 239-282), Massachusetts Hazardous Waste regulations (310CMR 30.00), and the MCP (310 CMR 40.00), and any applicable Federal regulations. Where applicable, consideration shall be given to MSDS in determining if a material could be potentially hazardous.
- G. Historic Fill: Also referred to as “urban fill.” Generally acknowledged as fill material from non-specific sources. Historic fill typically are observed to contain mixtures of ash, coal, glass, brick, wood, and/or miscellaneous building debris. OHM attributable to a source or sources or to a specific

industrial process is excluded from this definition regardless of the physical soil constituents. Historic fill material typically contains elevated concentrations of polycyclic aromatic hydrocarbons, metals, and/or petroleum hydrocarbons. Historic fill shall not include boulders, ledge, consolidated rock, asphalt, concrete, railroad timbers, rail, cobblestones, or any other abandoned building materials, which would preclude the disposal of the material as daily cover at a landfill.

- H. Investigation-Derived Waste: Any potentially-contaminated material generated as a result of sampling potentially-contaminated media, such as soil, sediment, surface water or groundwater.
- I. Managed Fill Site: A site that can accept for re-use reclamation soils, <RCS-1 soils, or <RCS-2 soils, as applicable for that location.
- J. Natural soils: Unconsolidated sand gravel silt clay and organic materials which has become a part of the unconsolidated soil matrix.
- K. Reclamation Soil: Natural soil or soil containing only low levels of oil or hazardous material such that MassDEP would not require notification, further investigation or cleanup at the original location.
- L. Special Waste: Any solid waste that is determined not to be hazardous waste and that exist in such quantities or in such chemical or physical state or any combination thereof so that a particular management controls are required to prevent an adverse impact from the collection, transport, transfer storage processing, treatment or disposal of the solid waste. Asbestos and PCB contaminated soils/fill are examples of special waste.
- M. Soil: Any unconsolidated mineral and organic matter, including any fill, overlying bedrock that has been subjected to and influenced by geologic and other environmental factors.
- N. Stockpiled Materials: Any excavated soil/fill and/or debris (which include ABC material or other construction/demolition waste) which are stored prior to re-use, disposal, recycling, or treatment.

1.7 PERMIT REQUIREMENTS

- A. The DESIGN-BUILDER shall obtain all Federal, State, and local permits required for the transport and disposal of excavated material. The DESIGN-BUILDER shall adhere to all permit requirements.
- B. The DESIGN-BUILDER shall verify that the disposal facilities, recycling/treatment facilities proposed have all certifications and permits as required by Federal, State, and local regulatory agencies to receive and dispose of the excavated material.
- C. The DESIGN-BUILDER shall submit and/or amend all documentation of the permit requirements as stated in this subsection in accordance to the requirements of the EMMP (Section 1.4).

PART 2 - PRODUCTS

2.1 GENERAL

- A. All DESIGN-BUILDER personnel shall wear personal protective equipment and protective clothing consistent with the levels of protection for this Work as indicated in Section 01568 – CONSTRUCTION SAFETY.
- B. The containers must be approved by and labeled in accordance with the US Department of Transportation (DOT). The containers shall have a secure cover which will prevent a release of material during transportation.

2.2 STORAGE LABELS

- A. Signage must comply with Section 01580– PROJECT IDENTIFICATION AND SIGNS.
- B. Provide signage to label all stockpiles. Labels shall be of 6 in. by 12 in. weatherproof material, such as plastic, affixed to 1 in. x 3 in. wood straps, 3 ft long. The labels shall be clearly marked with indelible ink marker. Markings shall be as agreed upon between AUTHORITY and DESIGN-BUILDER.

2.3 STOCKPILE SHEETING

- A. Stockpile Sheeting: Provide nylon-reinforced polyethylene (NRPE) sheeting as follows:
 - 1. The membrane shall be manufactured of new, first quality product designed and manufactured specifically for the intended use.
 - 2. The material shall be 10 mil polyethylene reinforced with a non-woven grid of high-strength nylon cord.
 - 3. The material shall be ultra-violet resistant and cold crack resistant to -40°F.
 - 4. The materials shall be manufactured in a minimum 12 ft seamless width. Labels on the roll shall identify the thickness, length width and manufacturer’s mark number.

2.4 DUST MONITORING EQUIPMENT

- A. Air monitoring shall include total dust testing using MIE, INC. Miniram PDM-3 Dust Monitors or approved equal.

2.5 EQUIPMENT AND VEHICLE DECONTAMINATION PAD

- A. A decontamination pad shall be constructed of reinforced concrete or bituminous concrete. The decontamination pad shall be of minimum length to accommodate one eighteen-wheel dump truck, and a minimum area to accommodate the largest piece of equipment to be used in the excavation. The pad shall have a 6 in. containment berm and provisions for collection, storage, and disposal of decontamination water.
- B. If space restrictions exist, the DESIGN-BUILDER shall submit an alternative vehicle decontamination plan for Engineer’s approval.

PART 3 - EXECUTION

3.1 GENERAL

- A. The DESIGN-BUILDER shall handle and convey all materials to perform site work described in these Contract documents.
- B. The DESIGN-BUILDER shall perform all disposal characterization sampling and analytical testing of the excavated material as required by the DESIGN-BUILDER’S permitted disposal facility.
- C. Based upon all analytical results, DESIGN-BUILDER shall load, transport, and dispose of the excavated material as specified herein.
- D. The AUTHORITY shall have final approval over all disposal options.

- E. DESIGN-BUILDER shall immediately notify the Engineer of visible stains or unnatural odor of any excavated material, or if potentially contaminated and/or hazardous material including asbestos piping is encountered. Work shall not be allowed to continue in this area until approved by the Engineer.

3.2 FIELD SCREENING EXCAVATED MATERIAL

- A. The DESIGN-BUILDER shall screen excavated materials for the presence of oil and hazardous materials as excavation proceeds for preliminary waste profiling using visual, olfactory and field sample analysis.
- B. The DESIGN-BUILDER shall perform VOC field screening evaluation in accordance with Department of Environmental Protection Policy No. WSC-94-900, "Interim Remediation Waste Management Policy for Petroleum Contaminated Soils, Attachment II, Jar Headspace Analytical Screening Procedure."
- C. The DESIGN-BUILDER shall perform field screening of soils for metals by XRF as appropriate on a site-specific basis.
- D. Field screening equipment shall be provided by the DESIGN-BUILDER and maintained and calibrated according to the manufacturer's recommendations.
- E. The DESIGN-BUILDER shall use the following field screening classification system in order to segregate excavated material:

FIELD SCREENING & SEGREGATION - CLASSIFICATION SYSTEM

MEDIA	VISUAL/ODOR	JAR HEADSPACE ANALYSIS	SCREENING CLASSIFICATION
Material	Light or No Staining	<10 ppm	Presumed Reusable/ within project limit, temporarily store on-site
Material	Staining/Odor or Unnatural Colors	>10 ppm	Presumed not suitable for project re-use, stockpile for disposal testing

3.3 DISPOSAL CHARACTERIZATION SAMPLING

- A. The DESIGN-BUILDER shall be responsible for sampling and characterizing the excavated material to determine appropriate off-site disposal and/or re-use opportunities. The DESIGN-BUILDER is responsible for final waste characterization and shall determine if any additional waste characterization is required at no additional cost to the AUTHORITY.
- B. Stockpiled soils: Soil stockpiles shall be limited in size to a maximum of 500 cu yd. A minimum of one grab sample (for VOC analysis) and a composite sample (generated by collection of at least eight (8) random grab samples from across the stockpile) shall be collected from each stockpile. The sample will be collected at a minimum depth of 1 foot from the stockpile surface.
- C. For in-situ soils: Soil samples shall be collected at a frequency of a minimum of one five-point composite sample per 500 cubic yards of material and one grab sample for VOCs.
- D. Test pit sampling: Test pit samples shall be collected from the excavation pit or, if infeasible, from the excavator bucket. Samples shall be composited from the excavation bottom and the sidewalls so as to form a sample representative of the test pit soils. If samples are collected from the excavator bucket or from a stockpile generated from the test pit excavation, the collection method described in Section 3.3(B) shall apply.

- E. Should the Disposal Facility require additional samples the DESIGN-BUILDER shall collect a sufficient number of samples that will satisfy the requirements of the disposal facility. No separate payment will be made for sampling conducted by the DESIGN-BUILDER, the DESIGN-BUILDER's Environmental Consultant, or any agent/personnel acting on behalf of the DESIGN-BUILDER or the DESIGN-BUILDER's Environmental Consultant.
- F. Samples shall be collected in such a manner as not to result in cross-contamination. All sampling equipment shall be decontaminated between uses. Disposable sampling equipment shall not be used for collection of more than one sample.
- G. The collected samples shall be submitted, at a minimum, for the following chemical analyses: total petroleum hydrocarbons (TPH) using modified EPA Method 8100, acid/base/neutrals (A/B/Ns) using EPA Method 8270, volatile organic compounds (VOCs) using EPA Method 8260, polychlorinated biphenyls using EPA Method 8082, RCRA 8 metals (arsenic, barium, cadmium, mercury, selenium and silver) using Method 6010/7471, reactive cyanide and sulfide using EPA Method sw-846, Ignitability using modified EPA Method 1010, Corrosivity using EPA Method 9045, and Conductivity using EPA Method 120.1. Any sample found to contain contaminant concentrations equal to or greater than "20 times" their hazardous waste toxicity threshold (i.e., the twenty-times rule) shall be analyzed for toxicity characteristic leachate procedure (TCLP).
- H. All analyses shall be performed by a laboratory certified for such analyses by the Commonwealth of Massachusetts.

3.4 TEMPORARY STOCKPILING OF EXCAVATED MATERIALS

- A. Unless otherwise directed by the AUTHORITY, excavated material shall be reused on-site or transported for off-site re-use or disposal within forty-five days of excavation.
- B. When it is necessary to temporarily stockpile excavated material, it shall be stockpiled in a secure manner to prevent exposure to humans and the environment.
- C. The stockpiling or consolidating of excavated material near sensitive human health receptors such as public and private water supply wells or sensitive environmental receptors such as wetlands, surface water bodies, or marine environments shall be strictly prohibited.
- D. Excavated material to be stockpiled shall be placed entirely on intact pavement or on a polyethylene liner, shall be covered at the end of each day's work and at all times when earthwork is not taking place on site, with the same material or so as to minimize the infiltration of precipitation, volatilization of contaminants and erosion of the stockpile. Any cover material used shall be properly secured and replaced if damaged.
- E. Excavated material that has not been characterized and which exhibit odor staining and/or constituents which indicate the potential for OHM or which have been determined to be impacted by OHM at or above RCS-1 concentrations shall be completely covered with a minimum 10 mil thick layer of plastic tarp at the end of each working day and secured with ropes, ties, anchors or equivalent materials. The covered system shall be capable of resisting actual wind gust at the site, with a minimum wind capacity of 40 miles per hour.
- F. Excavated material not previously classified in accordance with the field screening classification, final characterization, or as otherwise directed by the Engineer shall be stockpiled separately based on type of suspected waste material. DESIGN-BUILDER shall maintain these materials separately and securely until classified by testing.
- G. Stockpiles are to be segregated based on a review of pre-characterization data, visual and olfactory conditions, and field screening results obtained during excavation. Stockpiles shall be no greater than

500 cu yds. Similar material may be stockpiled together; however, effort will be made to keep each stockpile separate. Each stockpile must be clearly marked from adjacent stockpiles.

- H. Stockpiles shall include berms around the edges to minimize infiltration of storm water or exfiltration of leachate.
- I. Any failure of materials or procedures used in employing the base layer or cover layer shall be immediately repaired, replaced or re-secured so as to minimize precipitation infiltration, volatilization and erosion/runoff of the excavated material.
- J. Movement and/or aeration of excavated material shall be limited to those activities that are necessary to manage such stockpiles. Land farming of excavated soils that are subject to MCP regulations is prohibited.
- K. Disposal of material that is contaminated as a result of careless handling, cross contamination or use of unauthorized procedures shall be at the DESIGN-BUILDER expense. Delays of Work resulting from temporary storage of excavated material, regardless of the classification, shall be at no additional cost to the AUTHORITY.
- L. The stockpiles shall be clearly labeled and securely barricaded from contact with workers and the general public.

3.5 DEBRIS MANAGEMENT

- A. The DESIGN-BUILDER shall be responsible for decontaminating debris. The decontamination means and methods shall be amended to the EMMP.
- B. The DESIGN-BUILDER is required to recycle/reuse any other recovered materials in lieu of disposal if the material is of acceptable physical quality and chemical quality, and the DESIGN-BUILDER can identify a facility willing and permitted to accept the material.

3.6 ON-SITE AND OFF-SITE SOIL REUSE AND DISPOSAL

- A. Excavated material found to be suitable for on-site or off-site reuse or disposal shall conform to the following:
 - 1. Soils shall comply with the geotechnical requirements and shall be suitable for the intended use as described in Section 02300 – Earthworks.
 - 2. Soils not exhibiting visual or olfactory evidence of OHM or elevated VOC or metal concentration as identified by PID or XRF screening may be reused within the area of excavation without first performing laboratory analysis. Soil/fill material that is not re-used within the area of excavation must be characterized prior to off-site re-use.
 - 3. Any soil which exhibits a petroleum odor or has a chemical odor or visual indications of OHM or VOCs identified by PID, or elevated metals as identified by XRF shall be handled as potentially contaminated soils. Soil exhibiting visual or olfactory evidence of OHM shall not be reused on-site without prior confirmation that the OHM concentration shall not pose a significant risk under current or future use scenarios.
 - 4. Excavated material which has been characterized may be re-used within the limits of work provided the proposed re-use area has been characterized and determined to meet MassDEP regulations and Similar Soils guidance. Soil reuse shall also comply with MassDEP Policy #WSC-00-425, “Construction of Buildings in Contaminated Areas.”

5. Excavated material that has been sampled and found to contain OHM concentrations less than MCP RCS-1 limits or regulated background (as defined in the Technical Update Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soils) as applicable and subject to geotechnical requirements and is deemed suitable for use as described in Section 02300 – Earthworks – shall be considered suitable for on-site or off-site reuse.
6. If re-used off site, the DESIGN-BUILDER shall be responsible for conducting adequate testing and documenting that excavated material that is designated for off-site reuse shall contain OHM concentrations equal to or less than OHM concentrations at the designated reuse location (in accordance with the MCP’s “Similar Soils” policy) and in accordance with the facility permitted acceptance limits. The AUTHORITY shall have final approval over all proposed reuse locations.
7. Excavated material that has been sampled and determined to contain OHM in concentrations at or exceeding RCS-1 Reportable Concentrations or regulated background levels (as defined in the Technical Update Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soils) whichever applicable, may be suitable for on-site re-use if a risk assessment determines that this soil does not pose a significant risk to human health and the environment at the proposed location(s) with associated current and anticipated future uses(s) and do not violate MassDEP policies or requirements.

3.7 MCP NOTIFICATION REQUIREMENTS

- A. Notification to the MassDEP shall be the sole responsibility of the AUTHORITY.
- B. The DESIGN-BUILDER shall be familiar with the MCP definitions of “two hour”, “72 hour” and “120 day” reportable conditions.
- C. The DESIGN-BUILDER shall immediately notify the Engineer of any 2 hour, 72 hour and 120-day reporting conditions.
- D. MCP notification for petroleum shall be based upon VPH/EPH MassDEP Method 1.0 analysis. Notification shall not be based upon Total Petroleum Hydrocarbon concentrations.
- E. Depending upon the nature of the reportable conditions, the MCP may require the cessation of work, implementing a Limited Removal Action (prior to notification), developing / implementing an “Immediate Response Action Plan” or a “Release Abatement Measure Plan” prior to continuing work or other actions which could delay certain aspects the site work.
- F. The AUTHORITY’s LSP shall prepare electronic eDEP MCP filings required during construction, including but not limited to Release Notification Forms (RNF), Release Abatement Measures (RAM), Utility-related Abatement Measures (URAM), and subsequent associated status reports or any other required MCP filings.
- G. DESIGN-BUILDER shall prepare all soil management documentation in support of those eDEP filings.

3.8 ENVIRONMENTAL FIELD MONITORING/DUST CONTROL

- A. During excavation and construction, the DESIGN-BUILDER shall monitor the air quality where construction activities involve soil handling such as excavation, relocation, staging, loading, or grading of soil/waste materials. All personnel shall be made aware of potential hazards and be informed of air monitoring information.

- B. The air monitoring program is to be designed to protect public health and the environment from the potential generation of dust and OHM contaminant releases during the Work.
- C. The DESIGN-BUILDER shall keep accurate documentation of all air monitoring which will be made available to the Engineer upon request.
- D. The DESIGN-BUILDER's Site Health and Safety Officer and Superintendent shall be responsible for ensuring that monitoring is conducted in an appropriate manner and that work practices, engineering controls and/or personal protective equipment are proper for the conditions.
- E. When there is a potential for visible dust being generated during periods of site activity, air monitoring shall include, at a minimum, daily monitoring and documentation of one upwind and two downwind conditions. Dust monitoring activities may be limited to visual assessment and documentation, subject to the approval of the AUTHORITY.
- F. The air monitoring information including air monitoring in the vicinity of the site activities shall also be utilized for establishing levels of personal protection measures in the DESIGN-BUILDER's Site Specific Health and Safety Plan.
- G. Air monitoring shall involve appropriate techniques capable of providing real-time indications of air contaminants to protect on-site personnel and the local population.
- H. If there are indications of OHM contamination, the frequency of air monitoring shall be determined by the DESIGN-BUILDER's Industrial Hygienist or competent health professional in consultation with the AUTHORITY's LSP.
- I. Dust shall be controlled during excavation of soil/fill material to limit potential spread of contaminants and potential exposure of contaminants to workers and the public.
- J. Nuisance dust levels shall be reduced by pre-wetting the surface soils and by establishing and maintaining clean access roads. The DESIGN-BUILDER's Dust, Vapor and Odor Control Plan shall describe the procedures and materials to minimize dust. At a minimum, the DESIGN-BUILDER shall provide clean water, free from salt, oil and other deleterious materials.
- K. Prior to excavation, areas of exposed earth shall be lightly sprayed with water before excavation if there is potential for nuisance dust generation. Additional water spray may be utilized only when any indication of excessive dust is observed. To the extent feasible, the DESIGN-BUILDER shall minimize the use of water within the limits of excavation.
- L. When feasible, access roads shall be sprayed with water on a regular basis to minimize the generation of dust.
- M. All containers and stockpiles shall be covered at all times except as necessary to place or remove materials from the containers or stockpiles. The DESIGN-BUILDER shall monitor the covers daily to ensure the covers are in place and effectively eliminating the generation of dust.

3.9 VAPOR AND ODOR CONTROL

- A. The DESIGN-BUILDER shall provide the materials and labor to control objectionable vapors and odor in accordance with the DESIGN-BUILDER's Dust, Vapor and Odor Control Plan. The DESIGN-BUILDER shall limit the exposure area and shall cover the exposure area with synthetic reusable covers, lime, foam suppressants or other methods to reduce off-site odors to acceptable levels. The DESIGN-BUILDER shall not use soil suitable for on-site re-use as a cover to control vapor and odors.

3.10 RE-USE/DISPOSAL FACILITY CLASSIFICATION/CATEGORIES

- A. The DESIGN-BUILDER shall transport excavated materials for off-site reuse, recycling, or disposal at a permitted facility based on the following categories:
1. **Managed Fill Site:** Compliant with the Similar Soils Provision Guidance (WSC#-13-500) and other DEP regulations and guidance. Accepts excavated materials that contain oil or hazardous materials at concentrations less than RCS-1 or RCS-2, as applicable to that facility, but less than applicable release notification thresholds established by 310 CMR 40.0300 and 40.1600.
 2. **In-State Unlined Landfill Facility:** Accepts excavated material that meets MassDEP criteria for reuse at in-state unlined landfills, to be used as daily cover, intermediate cover, and pre-cap contouring material. The material must not exceed the contaminant levels listed in DEP Policy #COMM-97-001. This category also includes excavated material and solid waste that meets Massachusetts DEP Solid Waste criteria and regulations and the facility's operating permit for reuse or disposal in the Massachusetts landfill per COMM 97-001. Sediments may not be reused at an in-state unlined landfill.
 3. **In-State Lined Landfill Facility:** Accepts excavated material that meets MassDEP criteria for reuse at in-state lined landfills, to be used as daily cover, intermediate cover, and pre-cap contouring material. The material must not exceed the contaminant levels listed in DEP Policy #COMM-97-001. This category also includes excavated material and solid waste that meets Massachusetts DEP Solid Waste criteria and regulations and the facility's operating permit for reuse or disposal in the Massachusetts landfill.
 4. **Asphalt Batch Recycling Facility:** Accepts excavated materials that meet the criteria set forth in MassDEP policy WSC-94-400 and the receiving facility's operating permit(s) for recycling at a licensed asphalt batch facility.
 5. **Regional Thermal Treatment Facility:** Accepts soil and fill that contains contaminants that exceed in-state lined and unlined landfill reuse criteria as well as in-state recycling acceptance criteria but meets the criteria for regional thermal treatment facilities or out-of-state recycling facilities and are not classified as a RCRA Hazardous Waste.
 6. **NON-RCRA Out-of-State Lined Landfill:** Accepts excavated material that contains concentrations of OHM that require removal to a regional disposal facility (ies), are not classified as a RCRA Hazardous Waste and meets the destination state's solid and hazardous waste regulations and the receiving facility's operating permit(s). This includes material designated as a "special waste.
 7. **Hazardous Waste:** Materials determined to contain TSCA PCB Remediation Waste or RCRA Listed or Characteristic Hazardous Waste at concentrations requiring management and disposal as a Hazardous Waste.
 8. **Other Legal Disposal and/or Recycling Facilities not mentioned above:** Accepts excavated materials in accordance with the valid state or federal operating permit(s).
- B. With the exception of Managed Fill and RCRA Landfill Materials, soil shall be transported using a Bill of Lading (BOL). If hazardous wastes are to be disposed of, the RCRA Landfill Material shall be transported under a Uniform Hazardous Waste Manifest (Manifest). Managed Fill soils shall be transported using a Material Shipping Record (MSR). Closed-out attested BOLs, Manifests and copies of MSRs will be appended to the electronic searchable PDF version of the EMMP.

- C. Treatment of Soil Prior to Disposal/Re-use: Materials determined through testing to be characteristically hazardous waste through TCLP analysis shall be treated on-site to render the material characteristically non-hazardous.
- D. Material shipped to any recycling/disposal facility must meet the selected facility's chemical and physical acceptance criteria. Selected facilities must be established, fully operational, appropriately insured, and be operating in compliance with all applicable local, state, and federal regulations.

3.11 WASTE PROFILES AND SHIPPING DOCUMENTS

- A. The DESIGN-BUILDER shall provide certified tare and gross weight slips for each load received at the accepted facility and these shall be attached to each returned shipping document.
- B. The DESIGN-BUILDER shall prepare and submit to the AUTHORITY for review all completed waste profile applications and questionnaires, and coordinate with disposal facilities and all Federal and State Environmental Agencies.
- C. The DESIGN-BUILDER shall prepare all draft Hazardous Waste Manifests, Bills of Lading, and material shipping records for review and use by AUTHORITY's LSP with all applicable analytical backup, notification, and control forms. Final copies of Bills of Lading shall be signed by the AUTHORITY as generator and by the AUTHORITY's LSP following approvals of draft Bills of Lading.
- D. The DESIGN-BUILDER shall furnish all generator copies of the Hazardous Waste Manifest to the AUTHORITY for submittal to the appropriate regulatory agencies and to retain for the AUTHORITY's records.

3.12 TRANSPORT OF EXCAVATED MATERIAL

- A. The DESIGN-BUILDER shall not be permitted to transport materials off-site until all storage, disposal, or recycling facility documentation has been received, reviewed, and approved by the AUTHORITY.
- B. The DESIGN-BUILDER shall transport materials from the site to the storage, disposal, reuse or recycling facility in accordance with all United State Department of Transportation (DOT), USEPA, MassDEP, and applicable state and local regulations.
- C. The Hauler(s) shall be licensed in all states affected by transport.
- D. The DESIGN-BUILDER shall be responsible for ensuring that free liquid is properly transported. "Wet soils" shall not be loaded for transport. The DESIGN-BUILDER shall dewater "wet soils", and properly dispose of free liquid in accordance with local, state, and federal regulations. The DESIGN-BUILDER shall dispose of any free liquids that may result during transportation at no additional cost to the AUTHORITY.
- E. All excavated material transported upon public roadways shall be covered to minimize fugitive dust, and where necessary truck tire and undercarriage decontamination shall be employed to minimize tracking of soils onto public roadways.

3.13 RE-USE/DISPOSAL

- A. DESIGN-BUILDER shall dispose of all excavated materials at a facility(ies) approved to accept them, in accordance with all federal, state and local regulations.

- B. The DESIGN-BUILDER shall perform analyses on the material as necessary to fulfill any disposal testing requirements of any approved Facility.
 - 1. The DESIGN-BUILDER shall bear all costs incurred in sampling and analyses for those tests required by any facility.
 - 2. The DESIGN-BUILDER shall submit a copy of all sampling analyses to the AUTHORITY within two days of receipt of the laboratory report.
- C. The DESIGN-BUILDER shall provide to the AUTHORITY copies of all weight slips; both tare and gross, for every load weighed and disposed of at the approved facility. The slips shall be tracked by the original shipping document number that was assigned by the DESIGN-BUILDER in accordance with its material management system.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02283

HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies requirements applicable to the handling and disposal of groundwater contaminated with oil or hazardous materials [as defined in 310 CMR 40.0000, the Massachusetts Contingency Plan (MCP)] encountered prior to or during the course of excavation in areas suspected or confirmed as containing contaminated soils or groundwater.
- B. The DESIGN-BUILDER shall coordinate the work outlined in this section with the work outlined throughout the specifications, and shall perform the work as specified in the project drawings.

1.2 RELATED WORK

- A. Other specification sections that relate to the work include but are not limited to the following:
 - 1. Section 01060 – PERMITS AND REGULATORY REQUIREMENTS
 - 2. Section 01560 – TEMPORARY CONTROLS
 - 3. Section 02221 – DEMOLITION
 - 4. Section 02240 – DEWATERING
 - 5. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 - 6. Section 02300 – EARTHWORK

1.3 RESPONSIBILITIES

- A. The DESIGN-BUILDER shall retain an Environmental Consultant which will include, at a minimum, a Licensed Site Professional (LSP) and a qualified Health and Safety Professional. The duties of the DESIGN-BUILDER's Environmental Consultant shall include preparation of a Groundwater Pre-characterization Sampling Plan and a Groundwater Management Plan.
- B. The DESIGN-BUILDER shall perform in-situ groundwater testing prior to the start of excavation in contaminated areas, and collect samples for laboratory analysis in accordance with the criteria contained herein and the Groundwater Pre-characterization Sampling Plan to be prepared by the DESIGN-BUILDER's Environmental Consultant.
- C. The DESIGN-BUILDER shall coordinate all work performed in contaminated areas with the AUTHORITY's LSP of Record.
- D. The DESIGN-BUILDER shall extract, handle, store, treat, and properly discharge or dispose of on or off-site, liquid waste and residual material according to the criteria contained herein and in the Groundwater Management Plan to be prepared by the DESIGN-BUILDER's Environmental Consultant. For each liquid waste stream and residual material, the DESIGN-BUILDER shall demonstrate to the Engineer that the least costly means of treatment and discharge, or disposal has been selected. This demonstration shall be made prior to treatment or shipment.
- E. The DESIGN-BUILDER shall provide compliance monitoring required by groundwater or surface water discharge permits including sampling, laboratory testing, and reporting. The DESIGN-BUILDER shall obtain all permits and approvals necessary for the discharge of groundwater generated from construction dewatering.

- F. The DESIGN-BUILDER shall select an appropriate destination facility, obtain approval for acceptance of the material, and contract directly with the facility for off-site reuse/disposal/treatment.
- G. The DESIGN-BUILDER shall obtain all discharge permits, be responsible for all fees, and adhere to permit conditions related to treatment, storage, and discharge of extracted groundwater.
- H. The DESIGN-BUILDER shall pump, handle, store, test, treat and dispose of dewatered groundwater from the excavation according to the procedures outlined herein and in the Groundwater Management Plan to be prepared by the DESIGN-BUILDER's Environmental Consultant.
- I. The DESIGN-BUILDER shall implement measures to prevent the flow of storm water runoff into open excavations.
- J. The DESIGN-BUILDER shall collect and dispose of non-aqueous phase liquids (NAPLs) and sediments encountered or generated from dewatering activities according to the procedures outlined herein and in the Groundwater Management Plan to be prepared by the DESIGN-BUILDER's Environmental Consultant.
- K. The DESIGN-BUILDER shall manage contaminated materials (sediments, oil, and liquid waste) generated by the work under this section in a manner that ensures the protection of health, safety, public welfare, and the environment. The DESIGN-BUILDER shall handle, store, transport, treat, recycle, reuse, dispose, or discharge contaminated materials in compliance with the provisions of 310 CMR 40.0000 and all other applicable federal, state, and local laws and regulations and bylaws.
- L. The DESIGN-BUILDER shall manage and treat dewatered groundwater in compliance with the applicable provisions of 310 CMR 30.00, 310 CMR 40.00, 314 CMR 7.00, 314 CMR 5.00, 314 CMR 40.00 and all other applicable federal, state, and local laws and regulations or bylaws.
- M. The DESIGN-BUILDER shall prepare and implement a DESIGN-BUILDER's Health and Safety Plan for all workers engaged in intrusive activity or other work where exposure to contaminated dewatering sediments or groundwater is possible during the performance of the work. The Plan shall include procedures for, without limitation, the following:
 - 1. Measures to protect human populations from exposure to oil or hazardous material from any source within the limits of work;
 - 2. The institution of air monitoring activities to protect the public from exposure to gases and airborne particulates;
 - 3. Measures that may be necessary to contain oil and/or hazardous material during the performance of the work, including:
 - a. Measures to decontaminate vehicles and equipment to minimize the spread of contaminated groundwater from the work area;
 - b. Discontinuance of work where necessary to protect public health and safety.

1.4 REFERENCES

- A. The DESIGN-BUILDER shall be responsible for adhering to regulations, specifications, and recognized standard practices related to contaminated groundwater treatment, management, and disposal during excavation activities. The AUTHORITY will not be responsible at any time for the DESIGN-BUILDER's violation of pertinent state or federal regulations or endangerment of laborers and others. Applicable regulations include, but are not limited to, the most recent versions of the following:
 - 1. MA Department of Environmental Protection (DEP) Policy WSC-94-400, Interim Remediation Waste Management Policy for Petroleum Contaminated Soils
 - 2. Massachusetts DEP, 310 CMR 40.0000, The Massachusetts Contingency Plan.

3. Massachusetts DEP, 310 CMR 30.0000, Hazardous Waste Regulations.
4. 314 CMR 3.00, "Massachusetts Surface Water Quality Permit Program."
5. 314 CMR 5.00, "Ground Water Discharge Permit Program."
6. U.S. Environmental Protection Agency, Requirements under the National Pollution Discharge Elimination System.
7. NIOSH/OSHA/USCG/EPA: "Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities," DHHS/NIOSH Pub. 85-115.
8. OSHA 29 CFR 1910: Safety and Health Regulations for General Industry, OSHA, as amended 10/86, and HAZWOPER: OSHA Regulations 29 CFR 1910.120.
9. 29 CFR 1926: Safety and Health Regulations for Construction, OSHA, as amended.
10. Protection of Health and Safety at Hazardous Waste Sites: An Overview, USEPA, 9/85 EPA/625/9-85/006.
11. 105 CMR 670.000 and 441 CMR 21.00 (Right to Know).

1.5 SUBMITTALS PRIOR TO START OF WORK

- A. Within 21 days of the DESIGN-BUILDER receiving a Notice To Proceed, the DESIGN-BUILDER shall prepare and submit a Groundwater Pre-characterization Sampling Plan for the pre-testing of groundwater for contaminants. The groundwater investigations shall be required in areas of known or suspected groundwater contamination and/or within the limits of MCP Disposal Sites and where excavation dewatering is anticipated based on project design drawings and available information on depths to groundwater. DESIGN-BUILDER shall not begin dewatering until the submittal relevant to that dewatering location and permit has been accepted and required Permit(s) have been obtained.
- B. The DESIGN-BUILDER'S Groundwater Pre-characterization Sampling Plan is to be submitted for approval by the DESIGN-BUILDER's Environmental Consultant, and include at a minimum:
 1. Locations of existing and proposed groundwater monitoring wells to be sampled for the purpose of precharacterization sample collection. DESIGN-BUILDER shall install and sample an adequate number of wells at appropriate depths to adequately characterize groundwater in areas where dewatering will be required.
 2. Field screening and sample collection method(s) to be used, including a description of sample compositing techniques to obtain a vertical representation of the groundwater quality at each sample location.
 3. A scaled engineering drawing showing proposed sampling locations, known subsurface utilities, and other major site features.
 4. Number of samples to be collected from each location, sample preservation, and the laboratory methods for which the samples will be submitted for analysis.
- C. Within 21 days following the completion of groundwater testing, the DESIGN-BUILDER shall submit a Groundwater Management Plan for approval, prepared by the DESIGN-BUILDER's Environmental Consultant, based upon the results of pre-characterization testing and containing, at a minimum:
 1. Conceptual schematics of anticipated treatment methodologies based on available data. As detailed designs are developed for specific areas, DESIGN-BUILDER shall provide drafts of all applicable groundwater discharge Permits for review by AUTHORITY prior to submittal to

relevant agency. DESIGN-BUILDER shall allow a minimum of two weeks review period by the AUTHORITY.

2. Prior to start of dewatering at each location or separate treatment system location, DESIGN-BUILDER shall provide groundwater treatment design details, including but not limited to storage, treatment equipment and methods, sampling procedures, discharge or off-site disposal locations (including liquid waste, NAPL, and contaminated sediments), and treatment and dilution calculations.
 3. A scaled drawing of the work site(s) showing approximate limits of each area of contaminated groundwater identified in the Groundwater Management Plan, the related MassDEP release tracking numbers, and the locations where groundwater treatment systems are anticipated to be temporarily located during excavation in those areas. This portion of the Groundwater Management Plan shall be updated as applicable during construction.
 4. Anticipated locations of effluent discharge.
 5. A plan showing location of proposed temporary off-site storage areas, if needed.
 6. An Emergency Response Plan for addressing oil and/or hazardous materials released by the DESIGN-BUILDER or encountered during the work.
 7. Name and address of proposed Hauler licensed to transport Hazardous Waste material.
 8. Field screening and sample collection method(s) to be used, including a description of sample compositing techniques to obtain an adequate representation of the groundwater quality, in any areas where precharacterization testing is not performed.
 9. Sample preservation methods and the laboratory methods for which the samples will be submitted for analysis, in any areas where precharacterization testing is not performed.
 10. Evidence that the DESIGN-BUILDER's analytical laboratory is currently certified to perform these analyses in Massachusetts, if precharacterization testing is not performed.
 11. Tabulated results of all pre-characterization testing performed, compared with regulatory criteria in 310 CMR 40.0932 for the appropriate groundwater category. This data shall be provided as developed. All data shall be submitted as Electronic data deliverables (EDDs) formatted for upload to EQuIS™ software. Tabulated analytical results shall be provided in Excel table format, compared to applicable regulatory standards. Final laboratory analytical reports shall be provided in PDF format.
- D. Based upon the groundwater sampling results, the DESIGN-BUILDER shall prepare and submit a Health and Safety Plan (H&SP) prepared by a qualified Health and Safety Professional experienced in working in contaminated environments. The H&SP must be submitted prior to the health and safety coordination meeting. The DESIGN-BUILDER shall schedule the health and safety coordination meeting, to be held at least three (3) days prior to commencement of excavation work, to discuss issues relating to possible exposure to groundwater contamination and the provisions of the H&SP. The DESIGN-BUILDER shall provide written notice of this meeting to all interested parties, including the AUTHORITY, the AUTHORITY's LSP, and any subcontractors retained by the DESIGN-BUILDER. Health and safety training of DESIGN-BUILDER's workers and subcontractors shall be provided by the DESIGN-BUILDER.
- E. The DESIGN-BUILDER shall obtain and submit a copy of each discharge permit, and a map showing the approved groundwater extraction area and discharge location represented by each permit. Permit information shall be updated as applicable during construction.

1.6 ADDITIONAL SUBMITTALS

- A. The DESIGN-BUILDER shall submit the following to the AUTHORITY's LSP within one (1) week of receipt:
1. Approval letters from the receiving facility indicating their acceptance of the material and a complete list of their acceptance criteria.
 2. Copies of disposal or treatment facility weight slips and manifests, and certifications of disposal or recycling.
 3. Copies of field screening data and monitoring observations of the DESIGN-BUILDER's Environmental Consultant during work in contaminated areas.
 4. Copies of all permits obtained by the DESIGN-BUILDER for the work described herein, and all compliance and/or monitoring documents submitted, including completion reports, for these permits.
 5. Copies of laboratory reports showing a summary of analytical methods, analytical results, a QA/QC statement and Chain-of-Custody log. Tabulated results of all testing performed, compared with regulatory criteria in 310 CMR 40.0932 for the appropriate groundwater category.

1.7 ENVIRONMENTAL SITE CONDITIONS

- A. A complete assessment of the potential and existing sources of groundwater contamination in excavation areas has not been performed for this contract. The DESIGN-BUILDER shall conduct pre-characterization soil and/or groundwater sampling in the work areas and obtain representative data necessary to obtain approval from off-site disposal or treatment facilities or to design and operate on-site treatment facilities prior to extraction of groundwater, and obtain information on the potential health hazards to be encountered during the performance of the work.
- B. The nature of the materials which may be encountered in excavation areas may require use of special protective clothing, use of engineering controls, and the possible use of respiratory protective equipment which is intended to minimize worker exposure to known or suspected site hazards. During dewatering activities in areas of contaminated groundwater, DESIGN-BUILDER shall ensure that workers are not exposed to contaminants in excess of the permissible exposure limits (PEL). If exposure cannot be reduced to or below the PEL through the use of engineering controls or revised work practices, the DESIGN-BUILDER shall provide personal protective equipment including, but not limited to, respiratory and dermal protection.
- C. The DESIGN-BUILDER shall adequately characterize the groundwater for disposal based on the criteria established by the DESIGN-BUILDER's discharge permits or disposal facility.
- D. The DESIGN-BUILDER shall be responsible for determining the level of Personal Protection required based on the criteria outlined in the DESIGN-BUILDER's Health and Safety Plan. In the event that the DESIGN-BUILDER determines that a level of protection higher than Level D is required, and this condition has not been previously identified as potentially present, work shall be suspended in the contaminated area until the DESIGN-BUILDER is equipped to continue the work.

PART 2 – PRODUCTS

Not Used.

PART 3 – EXECUTION

3.1 CHARACTERIZATION REQUIREMENTS FOR EXTRACTED GROUNDWATER

- A. The DESIGN-BUILDER shall review existing soil and groundwater data and complete additional sampling as needed to determine the means and methods to treat, store, manage or discharge or dispose of contaminated groundwater extracted from the excavation areas.
- B. The DESIGN-BUILDER's Environmental Consultant shall conduct sampling in accordance with permit requirements and appropriate DEP policy, and submit all samples to a DEP-approved testing laboratory for analysis by EPA and DEP methods.
- C. The detection limits for all chemical tests shall be low enough to allow material classified according to the criteria specified herein with a statistical significance at a ninety percent confidence level and this detection shall be acceptable to the discharge permit issuer or the operator of the selected disposal facility to allow analysis within the parameters of the discharge permit or the facility's permit.
- D. The DESIGN-BUILDER shall determine the disposition of the material based on the laboratory test data and the estimated quantities for each disposition and arrange for the on-site treatment or transportation of the material to the appropriate facility. The AUTHORITY's LSP will review the laboratory test data and DESIGN-BUILDERS estimated quantity for each disposition prior to transport.
- E. The AUTHORITY's LSP will review and obtain the signature of an authorized representative of the AUTHORITY on the Hazardous Waste Manifests on behalf of the AUTHORITY, which will be designated as the Generator, for all liquids transported off-site.

3.2 GENERAL REQUIREMENTS FOR EXCAVATION IN CONTAMINATED AREAS

- A. The DESIGN-BUILDER shall design and implement support of excavation or other methods to minimize inflow of groundwater into excavations where contaminated groundwater is present.
- B. The DESIGN-BUILDER shall limit excavation activities and related dewatering in contaminated areas to only those actions that are necessary for completion of the construction.
- C. The DESIGN-BUILDER shall excavate material using methods which will permit observation of exposed subsurface soils to identify and segregate any contaminated soils/wastes and to reduce the potential for contaminating groundwater beyond the contaminated areas.
- D. The DESIGN-BUILDER shall not exacerbate contamination at the site as a result of performing the work or as a result of placing structures within the contaminated area.
- E. The DESIGN-BUILDER shall protect construction workers, surrounding human populations and environmental receptors from exposure to oil or hazardous material during construction activities.
- F. The DESIGN-BUILDER shall manage contaminated groundwater, and other Remediation Wastes removed from the construction area in compliance with the provisions of 310 CMR 40.0040 and all applicable Federal, State, and local laws. The DESIGN-BUILDER shall obtain a NPDES Remediation General Permit for dewatering in areas of known or suspected groundwater contamination in a timely manner so as to not impact the construction schedule.
- G. While conducting the work, if conditions are encountered which, in accordance with 310 CMR 40.0311 through 40.0314, requires DEP notification within 2 hours or 72 hours, as applicable, the DESIGN-BUILDER shall suspend construction in the affected area and coordinate with the AUTHORITY's LSP and DEP to implement an Immediate Response Action (IRA) in accordance with 310 CMR 40.0410.

3.3 GROUNDWATER CLASSIFICATION CRITERIA

- A. The DESIGN-BUILDER shall become familiar with the areas where contaminated soil and/or groundwater has been identified, and plan for and manage the groundwater extraction, treatment, and discharge requirements for each work zone based on the results of soil and groundwater testing.
- B. Excavated soils within contaminated areas shall be monitored by the DESIGN-BUILDER's Environmental Consultant. The DESIGN-BUILDER's Environmental Consultant will confirm by visual and olfactory observation whether precharacterization soil and/or groundwater testing adequately represents localized groundwater conditions and the types of contaminants present.
- C. If the presence of localized releases of oil and/or hazardous materials affecting groundwater are identified in areas not previously suspected or known to be contaminated, DESIGN-BUILDER shall stop work and immediately notify Engineer and AUTHORITY'S LSP. Work will not continue until new conditions are evaluated by the AUTHORITY'S LSP.

3.4 GROUNDWATER TREATMENT UNIT STORAGE

- A. The DESIGN-BUILDER shall operate and manage groundwater treatment systems outside of any active public way, and/or transport the material to a temporary off-site treatment and storage areas owned or operated by the DESIGN-BUILDER, or to the approved disposal facility.
- B. The DESIGN-BUILDER shall operate and manage contaminated groundwater treatment systems and the sediments generated in a manner that is protective of health, safety, public welfare and the environment.
- C. The DESIGN-BUILDER's Environmental Consultant shall collect and submit all analytical samples necessary for proper off-site reuse, disposal or treatment of the material. The DESIGN-BUILDER shall obtain preapproval for off-site reuse, disposal or treatment and discharge of extracted groundwater prior to dewatering in designated areas.

3.5 REQUIREMENTS FOR DISPOSITION OF TREATED GROUNDWATER

- A. The DESIGN-BUILDER shall perform testing of treated groundwater to confirm it meets the discharge permit requirements. The number of samples which must be collected and the analytical methods required are permit-specific.
- B. Non-aqueous waste liquids that are generated as a result of treatment of groundwater, such as oil, grease, or sediments shall be containerized for transportation and disposal as Special Waste Liquids.
- C. All data shall be submitted as Electronic data deliverables (EDDs) formatted for upload to EQUIS™ software. Tabulated analytical results shall be provided in Excel table format, compared to applicable regulatory standards. Final laboratory analytical reports shall be provided in PDF format.

3.6 TRANSPORTATION AND DISPOSAL OF CONTAMINATED MATERIAL

- A. The DESIGN-BUILDER shall be responsible for extracting, storing, treating, managing, and disposing of treated groundwater.
- B. Contaminated materials transported by the DESIGN-BUILDER shall be loaded into properly licensed and permitted vehicles and transported directly to the destination facility in watertight containers.
- C. Transportation of Special Waste Liquid material shall be conducted by the DESIGN-BUILDER's licensed hazardous-waste hauler. The hauler shall be licensed in all states necessary for proper disposal of Special Waste Liquid materials.

3.7 DEWATERING/SEDIMENTATION CONTROL

- A. All contaminated water collected during dewatering under this Specification will require, at a minimum, sedimentation removal and oil/water separation, and temporary storage.
- B. The DESIGN-BUILDER shall obtain all required local, state, and federal permits necessary for discharge of pumped groundwater. The DESIGN-BUILDER is responsible for compliance with the permit conditions and is responsible for any fines levied for permit violations.
- C. The DESIGN-BUILDER shall design and furnish the sedimentation control system to reduce the concentration of sediments to less than 100 ppm Total Suspended Solids (TSS) or in accordance with the criteria given in the DESIGN-BUILDER's discharge permit and install and operate the system according to the approved shop drawings.
- D. The DESIGN-BUILDER shall perform laboratory testing of the discharge water in accordance with the permit requirements and report the results to the permitting agency and the AUTHORITY's LSP. The DESIGN-BUILDER shall not discharge treated water without verifying compliance with permit limits by laboratory testing.
- E. The DESIGN-BUILDER shall remove NAPL and sediments from pumped water using an oil/water separator, sedimentation devices and/or oil absorbent materials. The DESIGN-BUILDER shall be responsible for proper handling, characterization and disposal of collected oil, oily water and sediments as Special Waste Liquids.

3.8 CONTINGENCIES

- A. The DESIGN-BUILDER is required to notify their workers of the history of the site area and contaminants that may be present, and to be alert for the potential discovery or evidence of contaminated materials.
- B. Should any sudden, continuous or intermittent release of oil or hazardous material occur during the course of the work, the DESIGN-BUILDER shall notify the AUTHORITY's LSP immediately and shall immediately begin actions to contain or abate the release. If such release of oil or hazardous material is the responsibility of the DESIGN-BUILDER, then the cost of complying with this provision shall be borne by the DESIGN-BUILDER.

PART 4 - MEASUREMENT AND PAYMENT

4.1 MEASUREMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02296

TRAFFIC DECKING

PART 1 - GENERAL

1.1 GENERAL

- A. Temporary traffic decking over excavated areas shall consist of steel plates which span the incomplete work.
- B. Traffic controls are specified in Volume 2 Technical Provisions Exhibit 21 “Additional Project Requirements”.
- C. All steel plates must be identified with the name of the Design-Builder and a 24-hour phone number on both sides.
- D. The Design-Builder is required to comply with all requirements of 520 CMR 14.00: *Excavation and Trench Safety*, which has established standards to prevent unauthorized access to the unattended trenches.
- E. The Design-Builder shall contact local DPW prior to potential snow storms to coordinate the use of steel plates in roadways.
- F. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 02052 - MAINTENANCE OF TRAFFIC THROUGH WORK AREAS
 - 2. Section 02298 - TEMPORARY PEDESTRIAN FACILITIES
 - 3. Section 02360 - DRIVEN PILES
 - 4. Section 02400 - DRAINAGE AND SEWER SYSTEMS

1.2 SUBMITTALS

- A. Submit shop drawings to show methods and sequence of installation and construction of decking and supporting members, including details of girders, beams, piles other than those forming a part of the excavation support system, accessories, surface materials, openings, ramps, guard rails, curbs, signs, and access hatches. Roadways shall conform to existing roadway elevations and grades where possible.
- B. Include engineering calculations supporting the design and selection of materials and methods stamped by a registered engineer in the Commonwealth of Massachusetts.
- C. Show methods and proposed sequence of removing decking and restoring the roadway.

1.3 QUALITY ASSURANCE

- A. Design Criteria: The Design-Builder shall be responsible for the design of decking. Comply with Contract Drawings and the following criteria.
 - 1. Design for AASHTO HS20-44 Wheel loading, indicated earth pressures, utility loads, and other applicable live and dead loads, including construction equipment.
 - 2. Design structural steel in accordance with industry standards.
 - 3. Design decking to include the following:
 - a. Wheel guards, railings, barricades, and safety construction.
 - b. Access hatches for utilities and for fire hydrants and valves.
 - c. Clearance for existing and relocated utilities.
 - 4. Select timber and lumber species and grade in accordance with ASTM D2555 to meet the design unit stresses.
 - 5. Select anti-skid material of a type which, after installation, has a skid number at 30 mph or not less than 35 when tested in accordance with ASTM E274.
 - 6. Maximum grade for vehicular ramps: five percent.
 - 7. Maximum grade for pedestrian ramps: seven and half percent and design with appropriate allowances for construction tolerances.
 - 8. Provide minimum 12-inch high wheel guards of an accepted type securely installed around perimeter of openings in the decking.

1.4 PROJECT CONDITIONS

- A. Ventilation. Provide ventilation as required to prevent the accumulation of gases below decking.
- B. Illumination and Access. Provide illumination, galleries, walkways, and access facilities as necessary to enable inspection of the supporting system, lagging, bracing, and utilities maintained in place. Provide these facilities for the full length of decking where excavation is deeper than 20 feet. Provide suitable openings and flush covers for access to utility services located below the decking and for fire fighting access.

PART 2 - PRODUCTS

2.1 STEEL PLATES

- A. Steel plates spanning across excavations shall be designed and constructed to HS20-44 Wheel Loading.
- B. Steel shall be ASTM A36 with a minimum yield stress of 36 KSI. The steel plates shall have sufficient thickness for supporting the intended traffic load with a maximum allowable deflection of (3/4") three-quarter inch.
- C. Decking materials may be either new or used. Used materials shall be sound and free of damage or defects, which would impair their suitability. Prior to installation of decking material the MBTA will inspect used material and may require that certain items of decking material be removed from the work.

PART 3 - EXECUTION

3.1 INSTALLATION OF STEEL PLATES

- A. Install decking in accordance with the approved Shop Drawings and conform the decking system to existing roadway elevations and grades. Securely fasten surface members to prevent movement under traffic conditions. Bed transition members, plates, and ramps to existing pavement to prevent movement and noise under traffic conditions.
- B. The plates shall be set with a maximum vertical lip of ¼-inch, which may be accomplished by recessing the plate or providing for the transition area. Plates shall be pinned or welded together to prevent lateral movement, noise, or vibration.
- C. Apply anti-skid material at ramps, vehicular traffic intersections, and on traffic lanes approaching traffic intersections and pedestrian crossings for a distance of 150 feet, in accordance with the manufacturer's instructions.
- D. Install decking within plus or minus one inch of the elevations indicated on the approved Shop Drawings; except, install and maintain surface elevations at abutting elements within 1/2 inch of each other.

3.2 INSPECTION OF STEEL PLATES

- A. It is the responsibility of the Design-Builder to inspect and monitor the condition of active steel plates and to make the necessary adjustments to protect the public safety.

3.3 MAINTENANCE

- A. Immediately replace or repair broken or chipped pieces, bent or loose plates and deck members and protruding fasteners. Patch adjacent paving as potholes develop using bituminous concrete. Immediately adjust, re-secure, and bed loose transition members, plates, and ramps to the existing pavement.
- B. Replace anti-skid materials when the MBTA determines the material is no longer effective. Maintain the surfaces of the decking, transitions, and ramps in vehicular and pedestrian traffic lanes and intersections free of dirt, snow, and ice and other deleterious materials.
- C. Maintain the decking in an acceptable condition at all times.

3.4 REMOVAL

- A. Coordinate with other work of the project to accomplish a smooth transition from temporary facilities to permanent facilities.
- B. When no longer required, remove the decking and all temporary supporting members and dispose of them off the project site.

- C. Cut off interior support members at the elevation shown on the approved Shop Drawings.
- D. Remove exterior support members either to a level ten feet below finish ground level or to the top of the adjacent MBTA subway structures, whichever elevation is higher.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02298

TEMPORARY PEDESTRIAN FACILITIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This section specifies requirements for furnishing, installing, operating and maintaining temporary pedestrian facilities. Temporary pedestrian facilities shall be provided for all construction work zones.
- B. Except for the materials shown on the Drawings to be left in place, all materials provided by the Contract under this section shall be removed by the Design-Builder when no longer required.
- C. Related Work:
 - 1. Volume 2 Technical Provisions Exhibit 21 "Additional Project Requirements".
 - 2. Section 02052 – MAINTENANCE OF TRAFFIC THROUGH WORK AREAS
 - 3. Section 02296 - TRAFFIC DECKING

1.2 SUBMITTALS

- A. Submit shop drawings of temporary pedestrian facilities for each phase of construction at least 30 days prior to implementation of that portion of the Work.
 - 1. Indicate construction zones, laydown areas, storage areas, and location of construction field offices. Indicate access locations for each zone.
 - 2. Indicate pedestrian routes and detours through and around each construction zone.
 - 3. Indicate all existing and temporary crosswalks.
 - 4. Indicate the extent and type of all proposed temporary pedestrian facilities.
 - 5. Indicate all directional signage and directional arrows.
 - 6. Indicate the proposed surface improvements in the areas of temporary pedestrian facilities.
 - 7. Indicate a sequence of construction and a sequence of removal such that at no time is there any unsafe condition.

1.3 QUALITY ASSURANCE

- A. Structural loads shall be calculated according to the Massachusetts Building Code.
- B. Electrical components shall conform to the Massachusetts Electrical Code.
- C. Temporary pedestrian facilities shall conform with:
 - 1. Americans With Disabilities Act, Accessibility Guidelines for Buildings and Facilities

2. Rules and Regulations of the Massachusetts Architectural Access Board
3. Massachusetts Building Code
4. Manual on Uniform Traffic Control Devices
5. Occupational Health and Safety, Code 1926
6. Local municipality Traffic Department Guidelines

1.4 PROJECT CONDITIONS

- A. Coordination will be required with the work requirements to install permanent paved walks, and curbs.

PART 2 - PRODUCTS

2.1 CONCRETE

- A. Precast concrete barriers meeting the Massachusetts Highway Department Standard Specification 629. Precast barriers are the only acceptable barrier where pedestrians are being protected from vehicular traffic.

2.2 METALS

- A. Chain-link fence meeting the Specification 02444 – CHAIN-LINK FENCE AND GATES.
- B. Hot galvanized pipe, ASTM A53 Type E, Grade B coated with zinc inside and outside. Brackets, plates, anchoring elements, and miscellaneous components shall be hot-dip galvanized.
- C. Welding shall conform with AWS D1.1 Structural Welding Code-Steel and AWS D1.3 Structural Welding Code-Sheet Metal.

2.3 WOOD

- A. Wood and Timber Members: Suitable for service, sized to limit deflection under full construction loading.
- B. Plywood flooring shall be Sturdifloor Exposure-1, exterior adhesive type, ¾ inch thick with non-skid epoxy resin and aggregate coat on exposed surfaces.
- C. Plywood shall be ¾ inch, exterior Medium Density Overlay

2.4 ELECTRICAL

- A. Fluorescent light fixtures shall be vandal resistance, UL listed, and suitable for wet and outdoor installations. Light housing shall be 20 gauge steel seamless with white corrosion resistant finish of baked enamel, epoxy or porcelain. Lamp shall be rapid start and energy saving type. Ballast shall be 120 V, Class P, thermally protected, high power factor.

- B. Electrical components shall be grounded. Metal frames shall be bonded to the electrical system grounding conductor as well as to a locally driven rod. Final installation of grounding system shall ensure that no point in the metal framing shall have a resistance measurement to, local earth ground exceeding 25 ohms.
- C. Conduit shall be UL listed with corrosion resistant coating for all electrical system wiring, with all fittings meeting the Massachusetts Electrical Code for outdoor installations.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. For each work area where temporary pedestrian facilities are used, perform on-site assembly expeditiously to minimize interference with the walking public and vehicular traffic. Complete and place in service all required temporary pedestrian facilities prior to the start of the construction work in the area.
- B. Prepare substrate surfaces to support barriers and fences with slopes not to exceed 5% in the direction of the traveling path, and does not exceed 2% across the traveling path.
- C. Firmly secure temporary pedestrian facilities to substrates as required to resist all wind, snow, dead, and live loads.

3.2 MAINTENANCE

- A. The Design-Builder is responsible to repair all temporary pedestrian facilities until they can be removed following construction
- B. The Design-Builder shall remove snow and ice, apply salt, broom clean, and make all necessary repairs. Snow, ice, sweepings, and other material generated by maintenance activities will be disposed of off the project site.
- C. The Design-Builder shall inspect all temporary facilities daily and make all necessary repairs to maintain the structural integrity of the system and allow safe passage by the walking public and vehicular traffic.
- D. Maintain the decking in an acceptable condition at all times.

3.3 REMOVAL

- A. Coordinate with other work of the project to accomplish a smooth transition from temporary facilities to permanent facilities.
- B. Perform removed work so that at no time is there any unsafe construction.
- C. When no longer required, remove all temporary facilities and dispose of them off the project site.
- D. Obtain permission from the Owner to leave any materials in place.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02300

EARTHWORK

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

A Work Included: This Section specifies the following items.

1. Preparing subgrades for structures and landscaping.
2. Excavating, backfilling and compacting for structures and track bed.
3. Drainage course for slabs-on-grade.
4. Subbase course for bituminous and cement concrete pavements.
5. Subsurface drainage backfill for walls and trenches.
6. Excavating, backfilling and compacting for utility trenches.
7. Excavating, backfilling and compacting for test pits.
8. Placement and compaction of structural backfill.
9. Placement of Ordinary Borrow for fill and embankment areas.
10. Placement of Gravel for base courses.
11. Crushed stone shall be installed only in areas directed by the Owner.

B Related Work: The following items are not included in this Section and will be performed under the designated Sections:

1. Section 02100 - SITE PREPARATION
2. Section 02221 - DEMOLITION
3. Section 02240 - DEWATERING
4. Section 02260 - EXCAVATION SUPPORT AND PROTECTION
5. Section 02282 - HANDLING, TRANSPORTATION AND DISPOSAL OF EXCAVATED MATERIALS
6. Section 02357 – CAST IN PLACE CONCRETE RETAINING WALLS
7. Section 02358 – SOIL NAIL RETAINING WALLS
8. Section 02359 – MODULAR PRECAST BLOCK RETAINING WALLS
9. Section 02370 – DRILLED SHAFTS
10. Section 02400 – DRAINAGE AND SEWER SYSTEMS
11. Section 02402 – STORMWATER TREATMENT AND DISPOSAL SYSTEMS
12. Section 02450 – SECONDARY CONTAINMENT SYSTEM WITH GEOSYNTHETIC BARRIERS
13. Section 02470 – SITE IMPROVEMENTS
14. Section 02509 – PAVEMENT BASE COURSES
15. Section 02513 – BITUMINOUS CONCRETE PAVEMENT
16. Section 02524 – CURBS, GUTTERS, AND WALKS
17. Section 02650 – EXISTING SITE UTILITIES
18. Section 02713 – EXTERIOR WATER DISTRIBUTION SYSTEMS
19. Section 02800 – EXTERIOR CONDUIT SYSTEMS
20. Section 02920 – SEEDED LAWNS
21. Section 03300 - CAST-IN-PLACE CONCRETE
22. Division 2 Sections for installing underground mechanical and electrical utilities and buried mechanical and electrical structures.

- C Geotechnical reports have been prepared for the retaining walls and bridges associated with this project and are provided for information only. The opinions expressed in these reports are those of the geotechnical engineers and represent interpretations of subsoil conditions, tests, and results of analyses conducted by geotechnical engineers. Authority will not be responsible for interpretations or conclusions drawn from this data.
- D Design-Builder shall perform a minimum of 8 additional test borings and conduct other exploratory operations as deemed necessary to verify subsurface conditions for earthwork and for design of support of excavation and dewatering systems. The location and depth of explorations shall be determined by the Design-Builder.

1.2 DEFINITIONS

- A Backfill: Soil and/or fill material and/or controlled low-strength material used to fill an excavation.
 - 1. Initial Backfill: Backfill placed beside the pipe from the springline to the crown of the pipe or utility and 12-in over pipe or utility in a trench unless otherwise noted, including haunches to support sides of pipe.
 - 2. Final Backfill: Backfill placed over initial backfill to the gravel sub-base layer to fill a trench.
- B Bedding Course: Granular material placed under structures or utilities to a depth of 12-in unless otherwise noted and to the springline of the pipe or utility or to the base of the structure.
- C Borrow: Geotechnically and analytically satisfactory soil imported from off-site for use as fill or backfill.
- D Drainage Course: Course supporting the slab-on-grade that also minimizes upward capillary flow of pore water.
- E Excavation: Removal of material encountered above subgrade elevations and to lines and dimensions indicated.
 - 1. Authorized Additional Excavation: Excavation below subgrade elevations or beyond indicated lines and dimensions as directed by the Owner for the removal of unsuitable material or for other reasons.
 - 2. Bulk Excavation: Excavation more than 10 feet in width and more than 30 feet in length.
 - 3. Unauthorized Excavation: Excavation below subgrade elevations or beyond indicated lines and dimensions without direction by Owner. Unauthorized excavation, as well as remedial work directed by Owner, shall be without additional compensation.
- F Fill: Soil materials used to raise existing grades.
- G Fill (Urban Fill): In-situ material known as Fill, also known as urban fill or miscellaneous fill, is defined as a mixture of soil and other materials which have been located in the area through man-made processes primarily for the purpose of grading, backfilling or filling in low areas. Material commonly associated with urban fill includes, but are not limited to; glass, brick, ash, wood fragments and other similar granular materials. Urban fill as defined herein shall not include boulders, ledge, consolidated rock, asphalt, concrete, railroad timbers, rail, cobblestones or any other abandoned building materials which would preclude the disposal of the urban fill as daily cover at a landfill. Material containing less than 10%, by volume, solid waste/debris, as determined by the Owner, shall be classified as urban fill. Material that contains 10% or more solid waste/debris by volume, as determined by the Owner, shall be classified as solid waste.

- H Soil (Natural Soils): Soil, otherwise known as natural soil, is defined for the purposes of the Contract as unconsolidated sand, gravel, silt and clay, and the organic material which has become part of the unconsolidated soil matrix.
- I Rock: Rock material in beds, ledges, unstratified masses, conglomerate deposits, and boulders of rock material that exceed 1 cu. yd. for bulk excavation or 3/4 cu. yd. for trench, and pit excavation that cannot be removed by rock excavating equipment equivalent to the following: (Bulk Excavation - Rock material that cannot be excavated with a heavy duty track-type tractor, rated at not less than 300 hp flywheel power and equipped with a single shank hydraulic ripper, capable of exerting not less than 50,000 lbs breakout force (Caterpillar D8R or equivalent); Trench Excavation – Rock material that cannot be excavated with a track-type hydraulic excavator, equipped with a 36-inch wide short-tip radius rock bucket, rated at not less than 138 hp flywheel power with bucket-curling force of not less than 29,000 lbs and stick-crowd force of not less than 26,000 lbs (Caterpillar 320DL or equivalent)).
- J Structures: Buildings, footings, foundations, retaining walls, slabs, rail tracks, tanks, curbs, mechanical and electrical appurtenances, manholes, catch basins or other man-made stationary features constructed above or below the ground surface.
- K Subbase Course: Course placed between the final backfill and the bituminous or cement concrete pavement.
- L Subgrade: Surface or elevation remaining after completing excavation, or top surface of a fill or backfill immediately below subbase, drainage fill, or topsoil materials.
- M Utilities: On-site underground pipes, conduits, ducts, and cables, as well as underground services within buildings.
- N Fine Grading and Compaction: Grading, shaping, and compacting those portions of excavations, backfills, embankments, and original ground, upon which pavement, structures, surfacing, ballast, subballast, base, or subbases are to be placed.
- O Unsuitable Material: Unsuitable material shall be material determined by the Owner to be unsuitable in its natural location and condition as a foundation material, as a sub-base, or as a part of the finished site work. Unsuitable material may include, but is not limited to, clays, silts, very wet material, very plastic material, peat, muck, logs, stumps, roots, grass, sod, highly organic material, refuse, ashes, and other types of unsuitable material.

1.3 QUALITY ASSURANCE

- A The Authority reserves the right to perform inspections and testing at any time during the execution of work.
- B When rework or replacement of soils are required to achieve compaction, the Authority may conduct confirmatory testing.
- C The Owner may require Design-Builder to perform additional tests to determine compliance with these specifications.

1.4 QUALITY CONTROL

- A The Design-Builder shall assume full responsibility for quality control inspection and testing and give sufficient notice to the Owner to permit the witnessing of the inspections or tests.
- B The Design-Builder shall engage a qualified, independent testing agency to perform quality control testing and inspections.
- C Source of supply. No earthwork materials will be accepted on the jobsite without written approval from the Owner. The Design-Builder shall perform sufficient tests and inspections necessary to determine the acceptability of the source of supply. A Certified Testing and Inspection Agency may be used to perform such test and inspections. The qualifications of the person or agency performing these tests and inspections shall be forwarded to the Owner for approval. Subsequent to this approval, test results showing the acceptability of the source of supply, shall be forwarded to the Owner for approval.
- D The Owner reserves the right to perform inspections and tests at any time during the execution of the work.
- E Notification Point: The Design-Builder shall give the Owner 2 days notice in advance of quality control tests and inspections.

1.5 SUBMITTALS

- A Product Data: For the following:
 - 1. Geotextile
 - 2. Controlled low-strength material, including design mixture.
- B Material Test Reports: From a qualified testing agency indicating and interpreting test results for compliance of the following with requirements indicated:
 - 1. Classification according to ASTM D 2487 and moisture content according to ASTM D 2216 of each on-site and borrow soil and/or fill material proposed for fill and backfill.
 - 2. Laboratory compaction curve according to ASTM D 1557 for each onsite and borrow soil and/or fill material proposed for fill and backfill.
 - 3. During Construction, submit written confirmation of fill lift thickness, in-place soil moisture content, and percentage of compaction to the Owner before placing the next lift or constructing foundations or structures.
- C Qualifications for Approving Source: Prior to earthwork operations, submit the qualifications of the persons or Agency approving the source of supply of materials and quality control testing and inspection.
- D Hold Point-Earthwork Operations: Submit, prior to commencing earthwork activities, a plan describing the earthwork operations including the frequency and locations of tests and inspections. No work shall be performed until this plan has been approved by the Owner.
- E Hold Point-Supply and Quality Control Inspection Results: Submit the results of all sources of supply and quality control inspections and tests. Submittals reviewed beyond the second rejection (or required submittal) shall be provided at no cost to the Authority and shall be reviewed by the Owner

at the Design-Builder's expense. No work shall be performed until the Owner has approved the source of supply.

- F Hold Point-Material Handling: At least two weeks prior to the start of any excavation activity submit, in writing, the following for review and Design-Builder shall not start excavation activity until the entire submittal is acceptable to the Owner.
1. Description of the method of dewatering excavated material and control of effluent water quality.
 2. Identification of a licensed hauler and disposal facility for possible vacuum collection, trucking and disposal of contaminated aqueous liquids.
 3. Locations and methods of excavating, handling, and stockpiling (if applicable) excavated material, including drainage, as specified in this Section. Describe methods to keep materials from various sources separated during stockpiling operations (if applicable).
- G Pre-excavation Photographs and Videotape: Refer to Section 01545.
- H Backfill Materials: Submit a 20 lb. sample, grain size analysis, moisture content determination, and moisture density curve performed in accordance with ASTM D422, ASTM D2216 and compaction test results (ASTM D1557 Procedure C) for each proposed source of backfill, imported material and on-site material to be reused, for review by the Owner at least, one (1) week prior to use of the material. The grain size analysis shall indicate that the backfill material conforms to the gradation requirements specified. Provide Atterberg Limits test results in accordance with ASTM D4318 for samples with greater than 5 percent fines.
- I In addition, a certification statement and analytical results shall accompany each physical sample of earth materials to be imported onto the site, including but not limited to crushed stone, loam, bedding sand, gravel sub-base, common fill and structural backfill. At a minimum the certification shall state the point of origin and that the material is free of contaminants. The certification shall include representative sample analysis from each point of origin of backfill to be used on the site. The sample(s) shall be analyzed by a certified laboratory for total metals (MCP 14 metals), volatile organic compounds (EPA Method 8260), semi-volatile organic compounds (EPA Method 8270), petroleum hydrocarbons (EPA Method 8100), and Total PCBs and pesticides (EPA Method 8081 and 8082). On-site soils defined as suitable for reuse in this Section and in Section 02282 – HANDLING, TRANSPORTATION AND DISPOSAL OF EXCAVATED MATERIAL can be used as backfill without providing the certification required above.
- J All sampling of soils for chemical testing shall be performed by a person experienced in sample collection and shall be either: 1) a Licensed Site Professional registered in the Commonwealth of Massachusetts or 2) an authorized representative of the Licensed Site Professional. Samples of each material shall be submitted to a chemical analytical laboratory, certified by the Massachusetts Department of Environmental Protection.
- K Submit additional samples and geotechnical and analytical test data and certifications for every 1000 cubic yards (every 200 cubic yards for moisture density curves) of material imported or anytime consistency of material changes in the opinion of the Owner. Submit associated chemical laboratory data on the imported materials throughout the course of the Work, if requested by the Owner, to evaluate the consistency of the source or process, at no additional cost to the Owner.

1.6 PROJECT CONDITIONS

- A Existing Utilities: Do not interrupt utilities serving facilities occupied by the Authority or others unless permitted in writing by Owner and then only after arranging to provide temporary utility services according to requirements indicated.
 - 1. Notify the Owner not less than two days in advance of proposed utility interruptions.
 - 2. Do not proceed with utility interruptions without the Owner's written permission.
 - 3. Contact utility-locator service for area where Project is located before excavating.
- B Demolish and completely remove from site existing underground utilities indicated to be removed. Coordinate with utility companies to shut off services if lines are active.

PART 2 - PRODUCTS

2.1 SOIL MATERIALS

- A Soil, Fill and Borrow Materials:
 - 1. Ordinary Borrow: Shall be in accordance with the Massachusetts Department of Transportation (MassDOT) Standard Specifications section M1.01.0 which uses soil groups A-1, A-2-4, and A-3 gradation limits under AASHTO M145 to define Ordinary Borrow.
 - 2. Gravel Borrow: Shall be used below retaining wall foundations and as backfill behind retaining walls and shall consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings, and deleterious material with the following gradation requirement.

<u>Sieve Size</u>	<u>Percent Passing by Weight</u>
3-inch (76.2 mm)	100
1/2 inch (12.5 mm)	50-85
No. 4	40-75
No. 50	8-28
No. 200	0-5

- 3. Processed Gravel for Subbase: Shall be in accordance with MassDOT Standard Specifications section M1.03.1.
- 4. Sand Borrow: Sand borrow shall be used as pipe bedding for all pipe, unless shown or directed otherwise, with the exception of Reinforced Concrete Pipe and Ductile Iron Pipe, placed between 6 inches below pipe invert to 6 inches above pipe crown and shall be in accordance with MassDOT Standard Specifications section M1.04.0.
- 5. Sand Borrow for Subdrains: Shall be in accordance with MassDOT Standard Specifications section M1.04.1.
- 6. Controlled Density Fill (CDF) Type 2E: CDF Type 2E shall consist of a cementitious hard excavatable mixture of aggregate, Portland Cement, air entraining admixtures and water. The material shall be of the type specified in MassDOT 1995 Standard Specifications for Highway and Bridges and 2012 Supplemental Specifications, Type 2E. Controlled density fill shall be used as trench backfill material around structures (not including manholes and catch basins) as

directed by the Owner. Controlled density fill shall also be used around the excavation support systems as directed by the Owner.

7. Controlled Density Fill (CDF) Type 1: CDF Type 1 shall be used to fill abandoned utilities, as specified in Section 02221 – DEMOLITION.
8. Controlled Density Fill Type 2: CDF Type 2 shall consist of a cementitious hard non-excavatable mixture of aggregate, Portland Cement, air entraining admixtures and water. The material shall be of the type specified as Type 2 in MassDOT 1995 Standard Specifications for Highway and Bridges and 2012 Supplemental Specifications. CDF Type 2 shall be used in areas where size and distance do not require the very flowable characteristic and is intended for permanent installations.

B Aggregates and Related Materials:

1. Crushed Stone: Shall be in accordance with MassDOT Standard Specifications section M2.01.4 for ¾-inch crushed stone. Crushed stone shall be used as Ductile Iron Pipe and Reinforced Concrete Pipe bedding between 12 inches below pipe invert to 6 inches above pipe crown and as a working mat or as a filter around perforated drain pipe. Crushed stone shall be wrapped in filter fabric, placed in maximum 6-inch thick layers, loose measure, and compacted with a minimum of four passes of a vibratory plate or roller compactor. The crushed stone shall be uniformly blended.
2. Dense-Graded Crushed Stone: Aggregate base course for concrete pavement over structural slabs shall conform to the requirements of MassDOT, Highway Division, M2.07.1, except that the maximum particle size shall be ¾”.

C Satisfactory Soils: ASTM D 2487 Soil Classification Groups GW, GP, GM, SW, SP, and SM or a combination of these groups; free of rock or gravel larger than 4 inches in any dimension, debris, waste, frozen materials, vegetation, and other deleterious matter.

D Unsatisfactory Soils: Soil Classification Groups GC, SC, CL, ML, OL, CH, MH, OH, and PT according to ASTM D 2487, or a combination of these groups.

1. Unsatisfactory soils also include satisfactory soils not maintained within 2 percent of optimum moisture content at time of compaction.

E Subbase Material: Naturally or artificially graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; with at least 90 percent passing a 1-1/2-inch sieve and not more than 12 percent passing a No. 200 sieve.

F Engineered Fill: Naturally or artificially well graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; with at least 90 percent passing a 1-1/2-inch sieve and not more than 12 percent passing a No. 200 sieve.

G Drainage Course: Narrowly graded mixture of washed crushed stone, or crushed or uncrushed gravel; ASTM D 448; coarse-aggregate grading Size 57; with 100 percent passing a 1-1/2-inch sieve and 0 to 5 percent passing a No. 8 sieve.

H Filter Material: Narrowly graded mixture of natural or crushed gravel, or crushed stone and natural sand; ASTM D 448; coarse-aggregate grading Size 67; with 100 percent passing a 1-inch sieve and 0 to 5 percent passing a No. 8 sieve.

I Sand: ASTM C 33; fine aggregate, natural, or manufactured sand.

- J Impervious Fill: Clayey gravel and sand mixture capable of compacting to a dense state.
- K Ballast Berm: The inner core material shall be a low permeability soil meeting the requirements of item M1.08.1, Impervious Soil Borrow, containing no peats and other organic soils, as per MassDOT Highway Division Standard Specifications for Highways and Bridges.

2.2 GEOTEXTILES

- A Geotextiles shall be of type and properties required for specific application as determined by the Owner.
 - 1. Geotextiles for erosion and sedimentation control are specified in Section 02060 – EROSION AND SEDIMENTATION CONTROL.
 - 2. Geotextile used for marker barrier to separate the clean fill and contaminated soil (site urban fill) shall be constructed of a non-woven high visibility geotextile, TenCate Mirafi Orange Delineation or approved equal. The materials chosen must be of a professional grade, but “landfill quality” products are not needed.

2.3 ACCEPTANCE SAMPLING AND DOCUMENTATION REQUIREMENTS FOR MASSDOT ROADWAY BRIDGES

- A The following samples and documents must be submitted to the Program Manager per MassDOT Research and Materials assurance requirements:
 - 1. For Gravel Borrow: Sampling frequency shall be a minimum of one per 5000 CY or fraction thereof from each source.
 - 2. For Crushed Stone: Sampling frequency shall be a minimum of one test per lot per each source.

PART 3 - EXECUTION

3.1 PREPARATION

- A Protect structures, utilities, sidewalks, pavements, and other facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by earthwork operations.
- B Preparation of subgrade for earthwork operations including removal of vegetation, topsoil, debris, obstructions, and deleterious materials from ground surface is specified in Section 02100 - SITE PREPARATION.
- C Protect and maintain erosion and sedimentation controls, which are specified in Section 02100 - SITE PREPARATION, during earthwork operations.
- D Provide protective insulating materials to protect subgrades and foundation soils against freezing temperatures or frost.

3.2 DEWATERING

- A Comply with requirements of Section 02240 - DEWATERING.

3.3 EXPLOSIVES

- A Explosives: Do not use explosives. Use of explosives is subject to consideration by the Authority only on a case-by-case basis.

3.4 EXCAVATION, GENERAL

- A Unclassified Excavation: Excavate to subgrade elevations regardless of the character of surface and subsurface conditions encountered. Unclassified excavated materials may include bituminous and cement concrete sidewalks and roadways, bricks and cobbles, soil materials, and obstructions. No changes in the Contract Sum or the Contract Time will be authorized for removal of obstructions.

All excavations required by the Contract Documents, except Contaminated Soils, over-excavation of unsuitable materials, and Rock Excavation will be considered to be "Unclassified Excavation." This item does not include excavation for the convenience of the Design-Builder and does not include excavation identified as incidental to the work of other Sections. Excavation for the convenience of the Design-Builder shall conform to the limits acceptable to the Owner and shall be at no additional expense to the Authority.

1. If excavated materials intended for fill and backfill include unsatisfactory soil materials and rock, replace with satisfactory soil materials.
2. Remove rock to lines and grades indicated to permit installation of permanent construction without exceeding the following dimensions:
 - a. 24 inches outside of concrete forms other than at footings.
 - b. 12 inches outside of concrete forms at footings.
 - c. 6 inches outside of minimum required dimensions of concrete cast against grade.
 - d. Outside dimensions of concrete walls indicated to be cast against rock without forms or exterior waterproofing treatments.
 - e. 12 inches beneath bottom of concrete slabs on grade.
 - f. 18 inches beneath pipe in trenches, and the greater of 24 inches wider than pipe or 42 inches wide.
3. Follow a construction procedure that permits visual identification of firm stable ground. In the event that groundwater is encountered, the Owner may require that the size of the open excavation be limited to that which can be handled by the Design-Builder's chosen method of dewatering and allow visual observation of the bottom and backfill in the dry.
4. Exercise extreme caution while excavating so as not to damage existing signal cable and duct lines or disturb other appurtenances and structures and buildings not designated for removal. To avoid adverse impacts on existing buildings on footings, excavation should not intrude the "zone of influence" beneath existing building footings. The Zone of Influence is defined as the section below the footing extending outward and downward at a slope of 1H:1V from 1 foot beyond the outside edges of the existing footings. Any damage caused by the Design-Builder's

operations shall be immediately repaired with materials and methods approved by the Owner at no cost to the Authority.

5. If unsuitable bearing materials are encountered at required subgrade elevations consult Owner for direction. The extent of over-excavation of unsuitable bearing materials and the type of material used to backfill over-excavations will be determined by the Owner.
6. Protect track ballast from fouling by excavated material, transport of backfill, dust, concrete operations, and other construction work.

3.5 EXCAVATION OF GRANITE BLOCK ABUTMENTS AND WINGWALLS

- A. Granite blocks demolished as part of the work shall be removed from the MBTA property and become the property of the Design Builder.

3.6 CONCRETE EXCAVATION

- A. Removal of existing concrete retaining walls and foundations and removal of portions of existing concrete abutments and wingwalls as indicated on the plans. The work to be done under this item shall consist of the removal and disposal of all reinforced and unreinforced concrete portions of the retaining walls, the abutments, wingwalls and foundations as specified on the plans.
 1. The Design-Builder shall not allow debris, tools or incidental equipment of any kind to swing over areas where vehicular or pedestrian traffic exists. Any material that accidentally falls into such areas shall be removed immediately at the Design-Builder's expense.

3.7 EXCAVATION FOR STRUCTURES

- A. Excavate to indicated elevations (i.e. the bottom elevation of proposed footing if no gravel borrow is required under the footing or 2 feet below the bottom elevation of proposed footing if 2 feet minimum gravel borrow is required under the footing) and dimensions within a tolerance of plus or minus 1 inch. Extend excavations a sufficient distance from structures for placing and removing concrete formwork, for installing services and other construction, and for inspections. Notify the Owner when excavations have reached subgrade to perform subgrade inspection per Section 3.9.
 1. Excavations for Footings and Foundations: Do not disturb bottom of excavation. Excavate by hand to final grade just before placing concrete reinforcement. Trim bottoms to required lines and grades to leave solid base to receive other work. If material remaining at bottom of trench is disturbed, recompaction shall be required.
 2. Excavation for Underground Tanks, Basins, and Mechanical or Electrical Utility Structures: Excavate to elevations and dimensions indicated within a tolerance of plus or minus 1 inch. Do not disturb bottom of excavations intended as bearing surfaces. If material remaining at bottom of trench is disturbed, recompaction shall be required.

3.8 EXCAVATION FOR WALKS AND PAVEMENTS

- A. Excavate surfaces under walks and pavements to indicated lines, cross sections, elevations, and subgrades.

B Bituminous Concrete Excavation by Cold Plane

1. This work shall consist of removing bituminous concrete by Cold Planer in designated areas. The Cold Planer must be equipped with an elevating device capable of loading planed material directly into dump trucks while operative. It shall have all necessary safety devices such as reflectors, headlights, taillights, flashing lights, and back up signals so as to operate safely in traffic both day and/or night.
2. The Cold Planer shall be designed and built for planing flexible pavements and possess the ability to plate cement concrete patches when encountered in bituminous pavement. It shall be self-propelled and have the means for planing without tearing or gouging the underlying surface. Variable lacing patterns shall be provided to permit a rough grooved or smooth surface as directed.
3. A three inch cut to predetermine grade or any specified lesser depth may be required in one pass. The minimum width of pavement planed in each pass shall be six feet, except in areas to be trimmed and edged. The machine shall be adjustable as to crown and depth and meet the standards set by the Air Quality Act of noise and air pollution. The milled or planed surface shall conform generally to the grade and cross slope required. The surface shall not be torn, gouged, shoved, broken or excessively grooved. It shall be free of imperfections in workmanship that prevent resurfacing after this operation. Surface texture shall be as specified by the Owner and excess material shall be removed so that the surface is acceptable to traffic if required.

3.9 EXCAVATION FOR UTILITY TRENCHES

A Excavate trenches to indicated gradients, lines, depths, and elevations.

1. Excavate trenches to allow installation of top of pipe below frost line unless otherwise noted. Frost line is defined as 4 feet below the lowest adjacent grade.

B Excavate trenches to uniform widths to provide the following clearance on each side of pipe or conduit. Excavate trench walls vertically from trench bottom to 12 inches higher than top of pipe or conduit, unless otherwise indicated.

1. Clearance: 12 inches each side of pipe or conduit.

C Trench Bottoms: Excavate and shape trench bottoms to provide uniform bearing and support of pipes and conduit. Shape subgrade to provide continuous support for bells, joints, and barrels of pipes and for joints, fittings, and bodies of conduits. Remove projecting stones and sharp objects along trench subgrade.

1. For pipes and conduit less than 6 inches in nominal diameter and flat-bottomed, multiple-duct conduit units, hand-excavate trench bottoms and support pipe and conduit on an undisturbed subgrade. If material remaining at bottom of trench is disturbed, recompaction shall be required.
2. For pipes and conduit 6 inches or larger in nominal diameter, shape bottom of trench to support bottom 90 degrees of pipe circumference. Fill depressions with tamped sand backfill.
3. Excavate trenches 6 inches deeper than elevation required in rock or other unyielding bearing material to allow for bedding course.

4. Soft unsuitable material existing below the required subgrade shall be removed and replaced with thoroughly compacted gravel, or crushed stone.
5. If cross pipes, drains, or other unforeseen obstacles are encountered during the excavation, the proposed line and grade of the conduit trench or foundation may be altered only with prior approval of the Owner.
6. Temporary Sheet piling and Shoring of Trenches:
 - a. When conduit and foundations are being installed in a trench or hole, the Design-Builder shall furnish, place, and maintain such sheet piling and shoring as may be required to support the sides of such excavations and adjacent structures.
 - b. Should the Design-Builder be permitted to slope the sides of such excavations so that sheet piling, shoring, or bracing is not necessary to prevent cave-ins or slides along the excavation, such additional excavation and backfill required because of flattening of slopes shall be done at no additional cost to the Authority.
7. Marker barrier shall be placed on sides and bottom of all utility trenches within the NorthPoint Development before bedded and backfilled.

3.10 SUBGRADE INSPECTION

- A Notification Point - Notify Owner when excavations have reached required subgrade.
- B If Owner determines that unsatisfactory soil is present, continue excavation and replace with backfill of type approved by the Owner.
- C Proof-roll subgrade below wall foundations, slabs, and pavements with heavy pneumatic-tired equipment to identify soft pockets and areas of excess yielding. Do not proof-roll wet or saturated subgrades.
 1. Completely proof-roll subgrade in one direction, repeating proof-rolling in direction perpendicular to first direction. Limit vehicle speed to 3 mph.
 2. Proof-roll with a loaded 10-wheel, tandem-axle dump truck weighing not less than 15 tons.
 3. Excavate soft spots, unsatisfactory soils, and areas of excessive pumping or rutting, as determined by Owner, and replace with backfill of type approved by the Owner.
- D Reconstruct subgrades damaged by freezing temperatures, frost, rain, accumulated water, or construction activities, as directed by Owner, without additional compensation.

3.11 REPLACEMENT OF ADDITIONAL AUTHORIZED EXCAVATION OR UNAUTHORIZED EXCAVATION

- A Fill over-excavation that the Owner authorized and any over-excavation that takes place by accident under foundations or wall footings. Lean concrete fill, with 28-day compressive strength of 2500 psi may be used when approved by Owner.
 1. Fill over-excavation that the Owner authorized and any over-excavation that take place by accident under other construction or utility pipe with backfill of type directed by Owner.

3.12 STORAGE OF SOIL MATERIALS

- A Stockpile borrow soil materials and excavated satisfactory soil materials without intermixing unless as directed by the Owner. Place, grade, and shape stockpiles to drain surface water. Cover to prevent windblown dust.
 - 1. Stockpile soil materials away from edge of excavations. Do not store within drip line of remaining trees.

3.13 BACKFILL

- A Place and compact backfill in excavations promptly, but not before completing the following:
 - 1. Construction below finish grade including, where applicable, subdrainage, dampproofing, waterproofing, and perimeter insulation.
 - 2. Surveying locations of underground utilities for Record Documents.
 - 3. Testing and inspecting underground utilities.
 - 4. Removing concrete formwork.
 - 5. Removing trash and debris.
 - 6. Removing temporary shoring and bracing, and sheeting.
 - 7. Installing permanent or temporary horizontal bracing on horizontally supported walls.
- B Place backfill on subgrades free of mud, frost, snow, or ice.

3.14 UTILITY TRENCH BACKFILL

- A Place backfill on subgrades free of water, mud, frost, snow, or ice.
- B Place and compact bedding course on trench bottoms and where indicated. Shape bedding course to provide continuous support for bells, joints, and barrels of pipes and for joints, fittings, and bodies of conduits. Sand borrow bedding shall be placed by hand shovels, in layers not more than 4-inches thick in loose depth, and each layer shall be thoroughly and evenly compacted by tamping on each side of the pipe to provide uniform support around the pipe, free from voids. Crushed stone bedding material shall be placed in layers not more than 6-inches thick in loose measure, and compacted with at least 4 passes using a vibratory plate or roller compactor.
- C Backfill trenches excavated under footings and within 18 inches of bottom of footings with gravel borrow; backfill remaining depth with concrete to elevation of bottom of footings. Concrete is specified in Section 03300 - CAST-IN-PLACE CONCRETE.
- D Provide 4-inch thick, concrete-base slab support for piping or conduit less than 30 inches below surface of roadways. After installing and testing, completely encase piping or conduit in a minimum of 4 inches of concrete before backfilling or placing roadway subbase. If required by utility owners when their minimum cover requirements cannot be met, install steel plates over ductbanks per their standard procedures.
- E Place and compact initial backfill of material free of particles larger than 1 inch in any dimension, to a height of 12 inches over the utility pipe or conduit.

1. Carefully compact initial backfill under pipe haunches and compact evenly up on both sides and along the full length of utility piping or conduit to avoid damage or displacement of piping or conduit. Coordinate backfilling with utilities testing.
- F Backfill voids with satisfactory soil while installing and removing shoring and bracing.
- G Place and compact final backfill of satisfactory soil to final subgrade elevation in uncompacted layers not to exceed 9 inches.
- H The Design-Builder shall not place backfill against or on structures until they have attained sufficient strength to support the loads (including construction loads) to which they will be subjected, without distortion, cracking or other damage. As soon as practicable after the structures are structurally adequate and other necessary work has been satisfactorily completed, the Design-Builder, as required by the Owner, shall make special leakage tests of the structures. After the satisfactory completion of leakage tests and the satisfactory completion of any other required work in connection with the structures, the backfilling around the structures shall proceed using Controlled Density Fill (CDF) material. Symmetrical backfill loading shall be maintained. Special care shall be taken to prevent any wedging action or eccentric loading upon or against the structures.
- I Install warning tape directly above utilities, no less than 12 inches above the crown of the pipe or utility and no more than 16 inches above the crown of the pipe or utility.

3.15 EMBANKMENT FILL

- A Bench sloped surfaces steeper than 1 vertical to 4 horizontal so fill material will bond with existing material.
- B Place and compact fill material in layers to required elevations as follows:
1. Under grass and planted areas, use satisfactory soil material.
 2. Under walks and pavements, use engineered fill.
 3. Under steps and ramps, use engineered fill.
 4. Under slabs, use engineered fill.
 5. Under footings and foundations, use Gravel Borrow.
 6. Behind retaining walls, use Gravel Borrow.
- C Place fill on subgrades free of mud, frost, snow, or ice.

3.16 SOIL MOISTURE CONTROL

- A Uniformly moisten or aerate subgrade and each subsequent fill or backfill soil layer before compaction to within 2 percent of optimum moisture content.
1. Do not place backfill or fill soil material on surfaces that are muddy, frozen, or contain frost or ice.
 2. Remove and replace, or scarify and air dry otherwise satisfactory soil material that exceeds optimum moisture content by 2 percent and is too wet to compact to specified dry unit weight.

3.17 COMPACTION OF SOIL BACKFILLS AND FILLS

- A Place backfill and fill soil materials in layers not more than 12 inches in loose depth for material compacted by heavy compaction equipment, and not more than 6 inches in loose depth for material compacted by hand-operated tampers.
- B Place backfill and fill soil materials evenly on all sides of structures to required elevations, and uniformly along the full length of each structure.
- C Compact soil materials to not less than the following percentages of maximum dry unit weight according to ASTM D 1557:
 - 1. Under structures, rail ways, slabs, steps, and pavements, compact each layer of backfill or fill soil material at 95 percent minimum at a moisture content within 2% of optimum; and areas behind retaining walls and within 10 feet of structures, building slabs, steps, and pavements at 95 percent minimum.
 - 2. Care should be given to compaction effort used near building walls to not exceed the pressures the wall is designed to resist.
 - 3. Under walkways, compact each layer of backfill or fill soil material at 95 percent minimum.
 - 4. Under lawns, compact each layer of backfill or fill soil material at 90 percent minimum.
 - 5. Under unpaved areas, compact each layer of backfill or fill soil material at 92 percent minimum.
 - 6. For utility trenches, compact each layer of initial and final backfill soil material at 95 percent minimum.
 - 7. For embankments, compact each layer at minimum 92 percent minimum.

3.18 GRADING

- A General: Uniformly grade areas to a smooth surface, free of irregular surface changes. Comply with compaction requirements and grade to cross sections, lines, and elevations indicated.
 - 1. Provide a smooth transition between adjacent existing grades and new grades.
 - 2. Cut out soft spots, fill low spots, and trim high spots to comply with required surface tolerances.
- B Site Grading: Slope grades to direct water away from buildings and to prevent ponding. Finish subgrades to required elevations within the following tolerances:
 - 1. Lawn or Unpaved Areas: Plus or minus 1 inch.
 - 2. Walks: Plus or minus 1 inch.
 - 3. Pavements: Plus or minus 1/2 inch.

3.19 SUBSURFACE DRAINAGE

- A Subdrainage Pipe: Specified in Section 02400 - DRAINAGE AND SEWER SYSTEMS.
- B Subsurface Drain: Place subsurface drainage geotextile around perimeter of subdrainage trench. Place a 6-inch course of filter material on subsurface drainage geotextile to support subdrainage pipe.

Encase subdrainage pipe in a minimum of 12 inches of filter material, placed in compacted layers 6 inches thick, and wrap in subsurface drainage geotextile, overlapping sides and ends at least 6 inches.

1. Compact each filter material layer to 90 percent of maximum dry unit weight according to ASTM D 1557.

C Drainage Backfill: Place and compact filter material over subsurface drain, in width indicated, to within 12 inches of final subgrade, in compacted layers 6 inches thick. Overlay drainage backfill with 1 layer of subsurface drainage geotextile, overlapping sides and ends at least 6 inches.

1. Compact each filter material layer to 90 percent of maximum dry unit weight according to ASTM D 1557.
2. Place and compact impervious fill over drainage backfill in 6-inch-thick compacted layers to final subgrade.

3.20 SUBBASE COURSE

A Place subbase course on subgrades free of water, mud, frost, snow, or ice.

B On prepared subgrade, place subbase course under pavements and walks as follows:

1. Shape subbase course to required crown elevations and cross-slope grades.
2. Place subbase 6 inches or less in compacted thickness in a single layer.
3. Place subbase that exceeds 6 inches in compacted thickness in layers of equal thickness, with no compacted layer more than 6 inches thick or less than 3 inches thick.
4. Compact subbase course at optimum moisture content to required grades, lines, cross sections, and thickness to not less than 95 percent of maximum dry unit weight according to ASTM D 1557.

C Pavement Shoulders: Place shoulders along edges of subbase and base course to prevent lateral movement. Construct shoulders, at least 12 inches wide, of satisfactory soil materials and compact simultaneously with each subbase and base layer to not less than 95 percent of maximum dry unit weight according to ASTM D 1557.

3.21 DRAINAGE COURSE

A Place drainage course on subgrades free of water, mud, frost, snow or ice.

B On prepared subgrade, place and compact drainage course under cast-in-place concrete slabs-on-grade as follows:

1. Install subdrainage geotextile on prepared subgrade according to manufacturer's written instructions, overlapping sides and ends.
2. Compact each layer of drainage course to required cross sections and thicknesses to not less than 90 percent of maximum dry unit weight according to ASTM D 1557.

3.22 FIELD QUALITY CONTROL

- A Testing Agency: The Design-Builder shall engage a qualified independent testing agency to perform field quality-control testing.
- B Allow testing agency to inspect and test subgrades and each fill or backfill layer. Proceed with subsequent earthwork only after test results for previously completed work comply with requirements.
- C Footing Subgrade: If in the opinion of the Design-Builder's independent testing agency unsuitable bearing materials are encountered at required subgrade elevations consult Owner for direction. The extent of over-excavation of unsuitable bearing materials and the type of material used to backfill over-excavations will be determined by the Owner.
- D The Design-Builder's qualified independent testing agency will test compaction of soils in place according to ASTM D 1556, ASTM D 2167, ASTM D 2922, and ASTM D 2937, as applicable. Tests will be performed at the following locations and frequencies:
 - 1. Paved and Slab Areas: At each compacted fill and backfill layer, at least 1 test for every 2000 sq. feet or less of paved area or slab, but in no case fewer than 3 tests.
 - 2. Foundation and Wall Backfill: At each compacted backfill layer, at least 1 test for each 30 feet or less of wall length, but no fewer than 2 tests.
 - 3. Trench Backfill: At each compacted initial and final backfill layer, at least 1 test for each 100 feet or less of trench length per lift, but no fewer than 2 tests.
- E When testing agency reports that subgrades, fills, or backfills have not achieved degree of compaction specified, scarify and moisten or aerate, or remove and replace soil to depth required; recompact and retest until specified compaction is obtained. Authority may conduct confirmatory testing.

3.23 PROTECTION

- A Protecting Graded Areas: Protect newly graded areas from traffic, freezing, and erosion. Keep free of trash and debris.
- B Repair and reestablish grades to specified tolerances where completed or partially completed surfaces become eroded, rutted, settled, or where they lose compaction due to subsequent construction operations or weather conditions.
 - 1. Scarify or remove and replace soil material to depth as directed by Owner; reshape and recompact.
- C Where settling occurs before Project correction period elapses, remove finished surfacing, backfill with additional soil material, compact, and reconstruct surfacing.
 - 1. Restore appearance, quality, and condition of finished surfacing to match adjacent work, and eliminate evidence of restoration to greatest extent possible.

3.24 DISPOSAL OF SURPLUS AND WASTE MATERIALS

- A Disposal as specified in Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS.

3.25 MONITORING OF EXCAVATION

- A If in the opinion of the Owner the integrity of the adjacent railroad tracks, buildings, structures, or paved areas are jeopardized due to movement, the Design-Builder shall immediately discontinue further excavation in the affected area and implement a Plan of Action to mitigate further movement. Mitigating measures shall remain in effect until such time that the Owner evaluates the impact on the structure and may direct the Design-Builder to perform any remedial work. The Design-Builder shall submit proposed remedial measures to the Geotechnical Engineer for review and approval. Submittals shall include methods and names of subDesign-Builders. The Design-Builder shall proceed with remedial work upon acceptance by the Owner. Mitigating measures shall be at no additional cost to the MBTA.
- B Possible effects of the excavation on the lateral support system:
1. Deflection of the wall into the excavation due to soil, groundwater, and surcharge loads.
 2. Settlement adjacent to the lateral support wall due to inward deflection of the wall.
 3. Settlement adjacent to the lateral support wall due to ground loss into the excavation through gaps and voids in the wall.
- C Monitoring Deflection of Wall
1. Once the wall is installed to final elevation but before excavation begins, establish deformation-monitoring points on the top of the wall, spaced approximately every 20 feet along the wall (every other soldier pile). The monitoring points shall consist of painted marks on the steel member.
 2. Perform a baseline survey of each deformation monitoring point before excavation begins. Survey both vertical and lateral (into proposed excavation) position.
 3. Perform daily survey of each top-of-wall deformation monitoring point from when excavation begins until full excavation depth is reached adjacent to the wall. Thereafter, perform weekly survey of monitoring points until the wall is backfilled.
- D Monitoring Track Movement
1. Before the start of excavation, wall installation or any work near or adjacent to existing railroad tracks, install surface settlement points in the railroad ties along the tracks spaced approximately every 15½ feet along the proposed work zones and to 100 feet beyond either end of the proposed work zones.
 2. Perform two baseline elevation surveys of the surface settlement points before the start of excavation/wall installation. Survey both vertical and lateral (into excavation) position.
 3. Perform daily survey of settlement monitoring points from the beginning of excavation work until the track support structure is completed.
 4. Perform weekly survey following completion of the track support structure until all work for the access structure is completed including all concrete work, backfill and compaction. Landscaping work shall not be considered an outstanding work item.
 5. Any existing structures supporting tracks or embankments adjacent to tracks in the vicinity of work, such as bridges, abutments, retaining walls, or other structures where settlement, deflection, or failure could affect the tracks shall be included in any monitoring program.

- E Make adjustments to survey schedule and monitoring point locations (including the addition of monitoring points) as requested by the Owner if additional monitoring of wall performance is desired. Extra monitoring points and increases in survey frequency shall be considered incidental to the costs.
- F All monitoring data shall be reported to the Owner within twenty four (24) hours of measurement in tabular and graphical format, allowing comparison of current data to previous data, including baseline data.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02310

FINE GRADING

PART 1 - GENERAL

1.1 GENERAL

- A. The Work shall be performed in accordance with the following documents as issued by the Massachusetts Bay Transportation Authority:
 - 1. The Contract Specifications, which include Volume 1 DB Contract Terms and Conditions; Volume 2 Technical Provisions; and applicable Sections of Divisions 2 through 16.

1.2 SUMMARY

- A. This Section contains the following:
 - 1. Fine Grading.
- B. Related Sections include the following:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 02920 – SEEDING
 - 3. Section 02930 – PLANTING
 - 4. Section 02932 – PLANTING SOILS
 - 5. Section 02970 – LANDSCAPE MAINTENANCE

1.3 REFERENCES

- A. Comply with applicable requirements of:
 - 1. Commonwealth of Massachusetts, Standard Specifications for Highways and Bridges, Department of Public Works, latest edition.
 - 2. United States Department of Justice, ADA Standards for Accessible Design.
 - 3. Massachusetts Architectural Access Board (MAAB) 521 CMR.

1.4 SUBMITTALS

- A. Submittals: in accordance with Volume 2 Technical Provisions, Subsection 2.7, “Design Submittal Review Management” and Subsection 2.8, “Construction Submittal Requirements” and the source approval, sample provision and material testing requirements of Specification SECTION 02300 – EARTHWORK, Subsection 1.5, “Submittals”.
- B. Qualification Data: submit written project list and references for other Fine Grading project work.

1.5 EXAMINATION OF SITE AND DOCUMENTS

- A. Design-Builder responsible for judging extent of work requirements involved. By submitting bid, Design-Builder affirms he has carefully examined the site and conditions affecting work.

1.6 PERMITS AND CODES

- A. Work shall conform to Contract Documents and comply with applicable codes and regulations.
- B. Comply with rules, regulations, laws and ordinances of the local community, of the Commonwealth of Massachusetts and other authorities having jurisdiction.
- C. Arrange for and obtain permits and licenses required to complete Work. Fees not waived shall be paid by Design-Builder.
- D. Do not close or obstruct streets, sidewalks, alleys or passageways without prior notification and permission. Conduct operations to minimize interference with use of roads, driveways, alleys, sidewalks, or other facilities near enough to Work to be affected.

1.7 QUALITY ASSURANCE

- A. Qualifications: Design-Builder shall have minimum five years experience in fine grading.
- B. Pre-Installation Conference: Design-Builder shall convene a meeting with the MBTA present prior to start of fine grading.

1.8 PROJECT/SITE CONDITIONS

- A. Environmental Requirements: Do not deliver, handle or place soils when dry, wet, or frozen.
 - 1. Field Test: Compact Test per SECTION 02300 – EARTHWORK, paragraph 3.16.

1.9 SEQUENCING AND SCHEDULING

- A. Fine Grading
 - 1. Finish grade after soil preparation is accepted and prior to planting.

PART 2 - MATERIALS

2.1 SOILS

- A. See SECTION 02932 – PLANTING SOILS

2.2 EQUIPMENT

- A. Fine Grading: Grading Tractor or other approved equipment.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verification of Conditions: in the event field conditions are not in conformance with the Contract Documents, notify the MBTA in writing.
 - 1. Spot and Invert Elevations: verify that field elevations of existing site conditions, such as drainage and utility fixtures, pavements, curbs and subsurface piping conform to Existing Site Conditions Plan.

3.2 PREPARATION

- A. Protection:
 - 1. Prior to fine grading operations, field locate and protect from damage site improvements such as drainage and utility fixtures, pavements, site furnishings and curbs.
 - 2. Dust Control: upon acceptance of soil preparation provide dust control.
 - 3. Agricultural Chemicals: protect site improvements from contact with agricultural chemicals, soil amendments, and fertilizers.
 - 4. Protect benchmarks.

3.3 FINISH GRADING

- A. Subgrade: top of subgrade to be parallel to finish grade and of uniform depth with the finish grade.
- B. Positive Drainage: provide free and uninterrupted flow of surface waters without erosion.
- C. Gradients: finish grade between spot elevations and between contours shall be constant. Eliminate mounds and depressions.
- D. Slope: finish grade shall be smooth with gradual transitions between top and bottom of slopes.
- E. Grade Tolerances: +.01% to -.01%.
- F. Maintain levels, profiles, and contours of rough grades.
- G. Removal: clear stones, roots, weeds, and debris while grading landscape soil materials. Rake surface clean of stones 1" or larger and debris.

3.4 FIELD QUALITY CONTROL

- A. Notify the MBTA upon completion of fine grading. The MBTA shall review the work for conformance to Contract Documents and if the work is approved, subsequent lawn and planting work shall proceed.

- B. Soil compaction at moisture content near field capacity based on measurements with a CL 700 pocket penetrometer shall not exceed 2.5 tons per square foot.

3.5 ADJUSTING

- A. Repair and re-establish grades in settled, eroded, and damaged areas.
- B. The Design-Builder is responsible for the protection of the area from construction operations and anticipating weather conditions. Where completed areas are disturbed by construction operations or adverse weather, the Design-Builder shall regrade as required.

3.6 CLEANING

- A. Clean up debris generated under work of this section.
- B. Site Improvements
 - 1. Wash and sweep clean site improvements such as drainage and utility fixtures, pavements, existing plantings, and site furnishings.

3.7 PROTECTION

- A. Protect work of this section until Final Acceptance.
- B. Protect prepared soils from compaction by construction traffic and from contamination by construction materials.

PART 4 – MEASUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in Volume 1 DB Contract Terms and Conditions, Section 14, "Payment".

END OF SECTION

SECTION 02356

SOLDIER PILE AND LAGGING RETAINING WALLS

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing Soldier Pile and Lagging Retaining Walls (SPL) along portions of the railroad trackway as shown on the Design Builder's Detailed Shop Drawings.
- B. Soldier piles may be installed in augured holes at the size and locations shown on the Design Builder's Detailed Shop Drawings. Soldier piles may be driven or vibrated into place if there is sufficient control on placement and angularity as detailed herein. The Design Builder shall stay within approved noise and vibration limits as well.
- C. Soldier piles shall be installed through all material encountered to the depth shown on the Design Builder's Detailed Shop Drawings. Installation equipment shall be capable of drilling through boulders, and any other obstructions, encountered during installation at no additional cost to MBTA.
- D. For this project soldier pile and lagging walls are designed and detailed to be free draining and shall be constructed to conform to this intent.
- E. The supports for the soldier pile and lagging walls may consist of a pre-augured drilled shaft with an embedded galvanized steel soldier pile. Timber lagging shall be placed starting from the top and progressing to the bottom of the wall. A filter fabric shall be attached to the lagging. Precast concrete panels shall be installed and crushed stone shall be used to fill the void between the panel and the lagging. A cast-in-place concrete cap shall be placed on top of the wall. In some cases, the soldier pile and lagging walls shall support a noise wall. These soldier pile and lagging walls shall be furnished complete in place in accordance with the lines, grades, dimensions and all appurtenances shown on the Design Builder's Detailed Shop Drawings, as directed herein, or as directed by the Engineer.
- F. All protruding items such as anchor bolts or embedded items such as steel plates shall be embedded in the concrete of the cap and not drilled and grouted or cut in afterward. Such items must be coordinated with the striation patterns, if any, in the cap.
- G. Full length temporary casing drilled to the elevation shown on the Design Builder's Detailed Shop Drawings may be required for all drilled shaft holes for soldier piles
- H. Soldier pile and lagging walls shall be bonded for continuity by extending a continuous uncoated bar to connect the tops of all the soldier piles.
- I. Stray current criteria apply to this wall type in accordance with the Design Builder's Detailed Shop Drawings.

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
 - 1. Section 02015 – GEOTECHNICAL INSTRUMENTATION
 - 2. Section 02196 – GEOTEXTILE MATERIALS
 - 3. Section 02240 – DEWATERING
 - 4. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 - 5. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 - 6. Section 02300 – EARTHWORK
 - 7. Section 03300 – CAST-IN-PLACE CONCRETE
 - 8. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE
 - 9. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS
 - 10. Section 05500 – MISCELLANEOUS METALS
 - 11. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION

1.3 SUBMITTALS

- A. Working Drawings
 - 1. Submit working drawings at least two (2) weeks before beginning excavation or installation of excavation support system and bracing. Submit each Soldier Pile and Lagging Wall under separate cover and in the sequence of their installation.
- B. Additional Requirements for Working Drawings – Working drawings shall include the following:
 - 1. Grades and strengths of all construction materials used.
 - 2. Full excavation depth.
 - 3. Depths below the main excavation to which the excavation support system shall be installed if necessary.
 - 4. Materials, details, arrangement, and method of construction of the proposed excavation support system, per Section 02260 – EXCAVATION SUPPORT AND PROTECTION, and sequence of construction (including bottom elevation of excavation at each stage).
 - 5. Method for installing wall.
 - 6. Method for attaching lagging.
 - 7. Method for attaching concrete cap beam.
 - 8. Loads on the excavation support system for various stages of excavation.
 - 9. Anticipated equipment, traffic (and other surcharge) loads on adjacent ground during construction.
 - 10. Existing utility facilities, including underground and overhead utilities. After checking locations of utilities by field investigations, determine which affect or potentially may affect the wall.

- C. Submit Plan of Actions to be implemented in the event any Response Value for deformation, as specified in Table 02356-1, is reached.

**TABLE 02356-1
RESPONSE VALUES**

Monitoring Type	Value
<u>Lateral Deflection of Earth Support Wall</u>	
Top of pile	1.5%
Mid-Point of exposed pile	0.75%
<u>Ground Surface Settlement</u>	
Top of Rail	1/4 inch

- D. The Plan of Actions shall be positive measures by the Design Builder to limit further movement of the wall. The details of the mitigating measures shall include a schedule of implementation, location and/or availability of materials, and a detailed description of the method of implementation. The Design Builder shall be prepared to work twenty four (24) hours per day to implement such measures.
- E. Submit Welder Qualifications and Welding Procedures in accordance with AWS D1.1.
- F. Submit descriptive data and operating procedures for all equipment to be used. This shall include, at a minimum, machinery required to install wall and bracing, excavate soil, and remove obstructions. Submit all pertinent data including sizes, weights, capacities, torques and operating frequencies.
- G. Review of the wall system by the Engineer shall not relieve the Design Builder from the responsibility for the adequacy of the design and construction of temporary excavation support system, per Section 02260 - EXCAVATION SUPPORT AND PROTECTION, to achieve the required results.
- H. Means and methods to advance through obstructions. Review and approval of submittal by Engineer or MBTA does not relieve the Design Builder in any way from the responsibility to complete the construction.
- I. Submittals reviewed beyond the second rejection (or required re-submittal) shall be printed at no cost to the MBTA and shall be reviewed by the Engineer at the Design Builder's expense.

1.4 TOLERANCES

- A. Variation of center of any drilled shaft holes from the required plan location: Maximum 3 inches, measured at the existing ground surface in any horizontal direction.
- B. Horizontal deviation of the steel soldier pile during concrete placement in the drilled shaft, plus or minus 1 inch.

- C. Vertical tolerance of the steel soldier pile during concrete placement is plus or minus 1 inch.
- D. Angular deviation of the steel soldier pile in any direction during concrete placement is 1/2 percent.
- E. Bottom diameter: Minus 0, plus 3 inches measured in any direction. No additional payment will be made beyond the bid price for increased diameter.
- F. Wall elevation tolerance of the completed wall including the cap is minus 0 inches, plus 1/2 inch.
- G. Refer to attached Table 02356-1 for response values.
- H. Excavation equipment and methods shall be designed so that the completed drilled shaft holes shall have a planar bottom. The cutting edges of excavation equipment shall be normal to the vertical axis of the equipment within a tolerance of $\pm 3/8$ inch per foot of diameter.
- I. Any soldier pile wall or its components not in conformance with the above tolerances shall be rejected. The Design Builder shall notify the Engineer in writing and submit a plan of action to bring the wall or its components into conformity. Any rework required to bring the wall into conformity shall be at no additional cost to MBTA. Walls that are installed such that they cannot be brought into conformity shall need to be replaced in kind at no additional cost to MBTA.

1.5 PROJECT CONDITIONS

- A. Visit the site to review all details of the work and working conditions affecting Work under this Section and to verify dimensions in the field including potential interference from adjacent structures and utilities. Notify the Engineer in writing of any discrepancy before performing any work. The Design Builder is hereby notified that the job site is located adjacent to the active railroad and existing low rise buildings. Refer to Section 00700 – GENERAL CONDITIONS.
- B. The Design Builder shall be responsible for implementing all necessary traffic control measures, which may include but not be limited to traffic cones, barriers, barrels, signs, flagmen, and police details.
- C. Provisions for Contingencies
 - 1. Monitor the performance of components of the wall, for horizontal movement, at intervals specified herein. Take initial readings of the wall upon completion of the wall cap.
 - 2. Implement contingency plans if Response Values specified in Table 02356-1 are reached.
 - 3. Have materials and equipment available to implement the accepted Plan of Action.
- D. Consult official records of existing utilities, both surface and subsurface, and their connections to be fully informed on all existing conditions and limitations as they apply to this work and its relation to other construction work. Proceed with caution in areas of utility facilities. Expose them by hand excavation or by other methods acceptable to the utility owner. Protect existing utilities to remain within and adjacent to the work area in accordance with the requirements of authorities having

jurisdiction over same. The Design Builder is responsible for any damage to utilities caused by the Design Builder's operations and shall restore them to equal or better operation at no additional cost to MBTA.

1.6 SUBSURFACE DATA

- A. Logs of subsurface explorations performed at the site are shown in the Contract Documents. Approximate locations of these subsurface explorations are shown on the Contract Plans.
- B. The aforementioned data is for general information and is accurate only at the particular locations and times the subsurface explorations were made. It is the Design Builder's responsibility to make interpretations and draw conclusions based on the character of materials to be encountered and the impact on his work based on his expert knowledge of the area and of earthwork techniques. The Design Builder shall review test pit and boring logs and locations and other pertinent data for the site. The Design Builder, at his own expense, may conduct additional subsurface explorations for his own information after obtaining the MBTA's permission.

1.7 QUALITY ASSURANCE

- A. The Design Builder shall provide written certification indicating that the equipment used for monitoring of deformation monitoring points (DMP) (as specified in Paragraph 3.2 herein) has been calibrated and maintained in accordance with the test equipment manufacturer's calibration requirements. The accuracy/precision of horizontal and vertical survey monitoring shall be to the nearest 0.01 feet.

1.8 QUALIFICATIONS OF DESIGN BUILDER'S INSTRUMENTATION PERSONNEL

- A. The Design Builder shall have on his staff, or on the staff of a specialist instrumentation subcontractor, instrumentation/survey personnel who are responsible for furnishing, installing, and maintaining instrumentation/survey equipment, as well as obtaining and interpreting data from the instrumentation/survey equipment.
- B. The Design Builder's instrumentation/survey personnel shall have the following qualifications:
 - 1. A minimum of a Bachelor of Science Degree in Civil Engineering or related discipline.
 - 2. A minimum of 2 years' experience in the installation, monitoring, and interpretation of data from the types of monitoring equipment used to monitor deformation-monitoring points (as specified in Paragraph 3.2 herein).
- C. The Design Builder's instrumentation personnel shall:
 - 1. Be on site and supervise or perform installation of each monitoring point.
 - 2. Perform deformation monitoring in accordance with the Project Specifications.
 - 3. Interpret deformation-monitoring data.
 - 4. Ensure that deformation-monitoring data is tabulated accurately and in a format consistent with the Project Specifications.

5. Forward monitoring data to the designated review parties in a timely manner.

PART 2 – PRODUCTS

2.1 GENERAL

- A. The Design Builder shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Design Builder, or the supplier as his agent, shall furnish the Engineer a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the Engineer.

2.2 MATERIALS

- A. Structural Steel for soldier piles shall conform to applicable requirements of Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- B. Reinforcement Steel for use within cast-in-place concrete cap shall conform to Section 03300 – CAST-IN-PLACE CONCRETE.
- C. Concrete for drilled shaft hole fill (below bottom of excavation as shown on Design Builder’s Detailed Shop Drawings) shall conform to relevant articles of Section 03300 – CAST-IN-PLACE CONCRETE (4000 psi, 3/8”).
- D. Concrete for cast-in-place cap shall conform to relevant articles of Section 03300 – CAST-IN-PLACE CONCRETE (4000 psi, 3/4”).
- E. Concrete for precast panels for retaining walls shall conform to relevant articles of Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE (5000 psi, 3/4”).
- F. Controlled Density Fill (CDF), Type 2E in accordance with specification Section 02300 - EARTHWORK.
- G. Headed welded studs shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- H. Threaded welded studs shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- I. All structural timber used as lagging shall be rough sawn and conform to MBTA Guide Specifications for Structural Design of Rapid Transit and Light Rail Structures Article 9.6 and AREMA.
- J. Filter fabric shall conform to Section 02196 - GEOTEXTILE MATERIALS.
- K. Structural timber lagging supporting train loads whether temporary or permanent shall conform to MBTA Guide Specifications for Structural Design of Rapid Transit and Light Rail Structures Article

9.6 and AREMA. Structural timber lagging supporting earth and/or roadway loads whether temporary or permanent shall conform to AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002 with latest interims and shall meet requirements shown on the Design Builder's Detailed Shop Plans. Design Builder to supply chosen species, grade of wood, conditions of use, and submit for approval. Where timber lagging is used special care must be exercised in torch cutting or welding of steel components to eliminate the risk of fire. Appropriate fire extinguishing measures shall be ready for immediate implementation.

- L. Crushed stone used to fill the void space behind the precast panel shall be in accordance with specification Section 02300 - EARTHWORK if the void is greater than 4". If the void space is smaller than 4", crushed stone used to fill the void space behind the precast panel shall not be greater than 3/4" or smaller than 3/8".
- M. Corrosion control and stray current shall conform to Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION.

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS

- A. Install the wall in accordance with the accepted working drawings, and in such a manner as to prevent movement, settlement, loss of ground, removal of fines from the adjacent ground, and damage to or movement of adjacent structures and utilities. This could include the use of drilling slurry during installation of soldier piles in drilled shaft holes to maintain stable drill holes and limit the loss of ground outside the drill hole.
- B. Perform work from track side of the proposed wall unless temporary easements have been granted to minimize adjacent property impacts. Heavy equipment shall be placed on the track side of the proposed wall.
- C. Perform field welding by certified welders in accordance with American Welding Society Standards AWS D 1.1, "Structural Welding Code - Steel."
- D. Implement the Plan of Actions as submitted under Paragraph 1.3D, if Response Values as specified in Table 02356-1 are reached.
- E. Borings indicate below ground obstructions may be encountered. Such obstructions may include, but are not necessarily limited to, boulders and various other demolition and construction debris.
- F. Temporary casings used for drilled shaft holes for soldier piles shall be installed where needed to the top of weathered bedrock, as a minimum, using rotary drilling techniques over their full depth to limit potential vibration damage to adjacent structures and facilities.
- G. Protection of Existing Properties

1. Design Builder shall protect existing properties in accordance with specification Section 01545 – PROTECTION OF WORK AND PROPERTY.
2. Restore existing structures to conditions equivalent to those existing prior to the start of retaining wall construction and support work, unless otherwise indicated. Any damage to affected properties caused by the retaining wall construction shall be repaired by the Design Builder at no additional cost to the MBTA.
3. If in the opinion of the Engineer the integrity of the adjacent railroad tracks, bridge, buildings, structures, or paved areas are jeopardized due to movement, the Design Builder shall immediately discontinue further excavation in the affected area and implement accepted Plan of Action to mitigate further movement. Mitigating measures shall remain in effect until such time that the Engineer evaluates the impact on the structure and may direct the Design Builder to perform any remedial work. The Design Builder shall submit proposed remedial measures to the Geotechnical Engineer for review and approval. Submittals shall include methods and names of subcontractors. The Design Builder shall proceed with remedial work upon acceptance by the Engineer. Mitigating measures shall be at no additional cost to the MBTA.

3.2 MONITORING OF EXCAVATION

- A. The Design Builder shall monitor the performance of components of the excavation support system, both for vertical and horizontal movement, at intervals specified. If the Response Values as specified in Table 02356-1 in Article 1.3C are reached at any time during the work, the Design Builder shall immediately stop work and implement approved contingency plans.
- B. Visual effects of the excavation on the lateral support system shall be recorded and submitted to the Engineer along with monitoring deflection data.
 1. Deflection of the wall into the excavation due to soil, groundwater, and surcharge loads.
 2. Settlement adjacent to the lateral support wall due to inward deflection of the wall.
 3. Settlement adjacent to the lateral support wall due to ground loss into the excavation through gaps and voids in the wall.
- C. Monitoring Deflection of Wall (Section 02015 - GEOTECHNICAL INSTRUMENTATION)
 1. Once the soldier pile is installed to final elevation but before excavation begins, establish deformation-monitoring points on the top of the pile, spaced approximately every 24 feet along the wall. The monitoring points shall consist of painted marks or targets on the steel pile.
 2. Perform a baseline survey of each deformation monitoring point before excavation begins. Survey lateral positions.
 3. Perform daily survey of each top-of-pile deformation monitoring point from when excavation begins until full excavation depth is reached adjacent to the wall. Thereafter, perform weekly survey of monitoring points until the wall is complete to the bottom of the cap or as directed by the Engineer.

4. Monitoring shall continue until the backfill behind the wall shall be completed to its finished grade (not including loam and seeding) or to the bottom of the cap.
 5. For monitoring of temporary support walls see specification Section 02260 – EXCAVATION SUPPORT AND PROTECTION.
- D. Monitoring Track Movement
1. Before the start of excavation and wall installation, establish elevations along Top of Rail of nearest track, each rail, spaced approximately every 20 feet along the walls.
 2. Perform two baseline elevation surveys of the Top of Rail before the start of excavation/wall installation. Survey both vertical and lateral (into excavation) positions.
 3. Perform weekly survey of settlement monitoring points from the beginning of excavation until the structure is completely in place and fully backfilled.
- E. Make adjustments to survey schedule and monitoring point locations (including the addition of monitoring points) as requested by the Engineer if additional monitoring of wall performance is desired. Extra monitoring points and increases in survey frequency shall be considered incidental to the costs associated with this Section.
- F. Survey instruments used for vertical deformation monitoring shall have a minimum accuracy of ± 0.05 in and a minimum setting accuracy of ± 1.0 arc seconds. Leveling staffs shall be non-telescopic in design (i.e. 'Chicago' style leveling staff). A bull's eye bubble shall be used to plumb the leveling rod.
- G. Survey instruments used for horizontal deformation monitoring shall have a minimum accuracy of ± 3.0 arc seconds and a minimum display reading less than or equal to the accuracy. Distances less than 30 feet shall be measured with a standardized steel tape used in conjunction with a tension handle. Distances greater than 30 feet shall be measured with an Electro-Optical Distance Measuring Instrument (EDM). Distances between 30 and 100 feet shall be verified with a standardized steel tape in conjunction with a tension handle. Electronic pointing shall be used to minimize error due to possible misalignment of the EDM axis and telescope. Centering shall be accomplished using high precision optical plummets or mechanical centering devices.
- H. EDM equipment used for lateral deformation monitoring shall, after calibration, have a minimum accuracy of ± 0.02 in plus 5 parts per million.
- I. The Design Builder shall submit the results of the settlement point readings to the Engineer in draft form at the end of each working day. All monitoring data shall be reported to the MBTA and Engineer within twenty-four (24) hours of measurement in tabular format, allowing comparison of current data to previous data, including baseline, and showing a complete history of movement versus time.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02357

CAST IN PLACE CONCRETE RETAINING WALLS

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies constructing Cast-In-Place (CIP) Concrete Retaining Walls along portions of the railroad trackway as shown on the Contract Drawings. These cast-in-place concrete retaining walls shall be backfilled and furnished complete in place in accordance with the lines, grades, dimensions, and all appurtenances shown on the Contract Drawings, as directed herein, or as directed by the Engineer.
- B. Install temporary excavation support elements and excavate to one foot below the bottom of wall elevations shown on the Contract Drawings.
- C. When obstructions are encountered during excavation, the Design Builder shall remove or clear the obstructions. The Design Builder is responsible for the cost of this work.
- D. Place one foot of gravel borrow beneath the footing that shall extend one foot beyond in all directions.
- E. Cast-in-place concrete retaining walls shall be constructed to the dimensions and locations shown on the Contract Drawings. Membrane waterproofing shall be attached to the cast-in-place concrete retaining wall. One cubic yard of crushed stone wrapped in filter fabric shall be provided at each end of each 4” diameter weep hole at locations indicated on the Contract Drawings.
- F. For the GLX project, cast-in-place concrete retaining walls are designed to be free draining and shall be constructed to conform to this intent.
- G. The construction of cast-in-place concrete retaining walls shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design Builder at no additional cost to the MBTA.
- H. Construction operations not to exceed specified noise limits in accordance with Section 01560 - TEMPORARY CONTROLS.
- I. The Design Builder shall bear the entire cost and responsibility of correcting any failure, damages, subsidence, upheaval, or cave-ins as a result of installation of the cast-in-place concrete retaining walls. The Design Builder shall pay for all claims, costs, and damages that arise as a result of the work performed at no additional cost to the MBTA.

1.2 RELATED SECTIONS

A. Other specification sections that relate to the work include, but are not limited to, the following:

1. Section 01560 – TEMPORARY CONTROLS
2. Section 02196 – GEOTEXTILE MATERIALS
3. Section 02240 – DEWATERING
4. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
5. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
6. Section 02300 – EARTHWORK
7. Section 03300 – CAST-IN-PLACE CONCRETE
8. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS

1.3 SUBMITTALS

A. Working Drawings

1. Submit working drawings at least two (2) weeks before beginning excavation or installation of excavation support system and bracing.
2. Concrete mix designs, form work designs, rebar layout, etc. shall be submitted under Section 03300 – CAST-IN-PLACE CONCRETE.

B. Additional Requirements for Working Drawings – Working drawings shall include the following:

1. Grades and strengths of all construction materials used.
2. Full excavation depth.
3. Depths below the main excavation to which the excavation support system shall be installed.
4. Materials, details, arrangement, and method of construction of the proposed excavation support system and sequence of construction (including bottom elevation of excavation at each stage).
5. Method for installing wall.
6. Loads on the excavation support system for various stages of excavation.
7. Anticipated equipment, traffic (and other surcharge) loads on adjacent ground during construction.
8. Existing utility facilities, including underground and overhead utilities. After checking locations of utilities by field investigations, determine which utilities affect or potentially may affect the wall.

C. Submit Welder Qualifications and Welding Procedures in accordance with AWS D1.4.

D. Submit descriptive data and operating procedures for all equipment to be used. This shall include, at a minimum, machinery required to install wall and bracing, excavate soil, and remove obstructions. Submit all pertinent data including sizes, weights, capacities, torques and operating frequencies.

E. Review of the temporary support of excavation for wall system installation by the Engineer shall not relieve the Design Builder from the responsibility for the adequacy of the design and construction of temporary excavation support systems to achieve the required results.

- F. Submittals reviewed beyond the second rejection (or required re-submittal) shall be printed at no cost to the MBTA and shall be reviewed by the Engineer at the Design Builders expense.

1.4 TOLERANCES

- A. Concrete tolerances shall conform to Section 03300 – CAST-IN-PLACE CONCRETE.

1.5 PROJECT CONDITIONS

- A. The Design Builder shall visit the site to review all details of the work and working conditions affecting work under this Section and to verify dimensions in the field including potential interference from adjacent structures. Notify the Engineer in writing of any discrepancy before performing any work. The Design Builder is hereby notified that the job site is located adjacent to the active railroad and existing structures.
- B. The Design Builder shall be responsible for implementing all necessary traffic control measures, which may include but not be limited to traffic cones, barriers, barrels, signs, flagmen, and police details.
- C. Consult official records of existing utilities, both surface and subsurface, and their connections to be fully informed on all existing conditions and limitations as they apply to this work and its relation to other construction work. Proceed with caution in areas of utility facilities. Expose them by hand excavation or by other methods acceptable to the utility owner. Protect existing utilities to remain within and adjacent to the work area in accordance with the requirements of authorities having jurisdiction over same. The Design Builder is responsible for any damage to utilities caused by the Design Builder's operations and shall restore them to equal or better operation at no additional cost to the MBTA.

1.6 SUBSURFACE DATA

- A. Logs of subsurface explorations performed at the site are shown in the Contract Documents. Approximate locations of these subsurface explorations are shown on the Contract Plans.
- B. The aforementioned data is for general information and is accurate only at the particular locations and times the subsurface explorations were made. It is the Design Builder's responsibility to make interpretations and draw conclusions based on the character of materials to be encountered and the impact on his work based on his knowledge of the area and of earthwork techniques. The Design Builder shall review test pit and boring logs and locations and other pertinent data for the site. The Design Builder, at his own expense, may conduct additional subsurface explorations for his own information after obtaining the MBTA's permission.

1.7 QUALITY ASSURANCE

- A. The Design Builder shall provide written certification indicating that the equipment used for the monitoring of deformation monitoring points (DMP) (as specified in Paragraph 3.2 herein) has been calibrated and maintained in accordance with the test equipment manufacturer's calibration

requirements. The accuracy/precision of horizontal and vertical survey monitoring shall be to the nearest 0.01 feet.

- B. Temporary excavation support elements whose depth is equal to or less than the distance away from the closest rail shall be left in place and cut off below the sub-ballast so as not to impede track drainage. If sheeting must be pulled for any reason the Design Builder shall notify the Engineer for approval prior to implementing any work. The Design Builder shall be responsible for backfilling any void space with flowable fill. Any work associated with removal of any temporary excavation support walls shall require approval of train operations. A track monitoring plan shall be required and any ballasting required shall be done at the expense of the Design Builder.

1.8 QUALIFICATIONS OF DESIGN BUILDER'S INSTRUMENTATION PERSONNEL

- A. The Design Builder shall have on his staff, or on the staff of a specialist instrumentation subcontractor, instrumentation/survey personnel who are responsible for furnishing, installing, and maintaining instrumentation/survey equipment, as well as obtaining and interpreting data from the instrumentation/survey equipment.
- B. The Design Builder's instrumentation/survey personnel shall have the following qualifications:
 - 1. A minimum of a Bachelor of Science Degree in Civil Engineering or related discipline.
 - 2. A minimum of 2 years' experience in the installation, monitoring, and interpreting data from the types of monitoring equipment used to monitor deformation-monitoring points (as specified in Paragraph 3.2 herein).
- C. The Design Builder's instrumentation personnel shall:
 - 1. Be on site and supervise or perform installation of each monitoring point.
 - 2. Perform deformation monitoring in accordance with the Project Specifications.
 - 3. Interpret deformation-monitoring data.
 - 4. Ensure that deformation-monitoring data is tabulated accurately and in a format consistent with the Project Specifications.
 - 5. Forward monitoring data to the designated review parties in a timely manner.

PART 2 – PRODUCTS

2.1 GENERAL

- A. The Design Builder shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Design Builder, or the supplier as his agent, shall furnish the Engineer a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the Engineer.

2.2 MATERIALS

- A. Concrete for cast-in-place walls shall conform to relevant articles of Section 03300 – CAST-IN-PLACE CONCRETE (4000 psi, 3/4”).
- B. Reinforcement Steel for use within cast-in-place concrete walls shall be uncoated and conform to Section 03300 – CAST-IN-PLACE CONCRETE.
- C. Structural Steel shall conform to applicable requirements of Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- D. Headed welded studs for embedded items shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- E. Membrane waterproofing shall conform to the requirements of Protective Seal Coat Emulsion, M3.03.3, of the Massachusetts Highway Department Standard Specifications for Highways and Bridges, current Edition.
- F. Filter fabric shall conform to Section 02196 - GEOTEXTILE MATERIALS.
- G. Crushed stone used at each end of weep holes shall be 1 1/2”.
- H. Gravel borrow for cast-in-place concrete retaining walls shall consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings, and deleterious materials. Gradation requirements for gravel shall be determined by AASHTO-T11 and T27 and shall conform to the following:

<u>Sieve Designation</u>	<u>Percent Passing</u>
1/2 in.	50-85
No. 4	40-75
No. 50	8-28
No. 200	0- 5

Maximum size of stone in gravel shall be 3 inches (Type B).

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS

- A. Construct the walls in accordance with the accepted working drawings, and in such a manner as to prevent movement, settlement, loss of ground, removal of fines from the adjacent ground, and damage to or movement of adjacent structures and utilities.
- B. Perform work from track side of the proposed wall unless temporary easements have been granted to minimize adjacent property impacts. Heavy equipment shall be placed on the track side of the proposed wall.
- C. Perform field welding by certified welders in accordance with American Welding Society Standards AWS D 1.4, "Structural Welding Code - Steel."

- D. Borings indicate below ground obstructions may be encountered. Such obstructions may include, but are not necessarily limited to, boulders and various other demolition and construction debris.
- E. Protection of Existing Adjacent Structures
 - 1. The Design Builder shall repair all damage to adjacent properties and restore the surfaces and finishes to the original state.
 - 2. If in the opinion of the Engineer the integrity of any adjacent railroad tracks, bridges, buildings, structures, or paved areas are jeopardized due to movement, the Design Builder shall immediately discontinue further excavation in the affected area and implement accepted Plan of Action to mitigate further movement. Mitigating measures shall remain in effect until such time that the Engineer evaluates the impact on the structure and may direct the Design Builder to perform any remedial work. The Design Builder shall submit proposed remedial measures to the Geotechnical Engineer for review and approval. Submittals shall include methods and names of subcontractors. The Design Builder shall proceed with remedial work upon acceptance by the Engineer. Mitigating measures shall be at no additional cost to the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02358

SOIL NAIL RETAINING WALL

PART 1 – GENERAL

1.1 DESCRIPTION

- A. The Work shall consist of constructing a soil nail retaining wall with or without concrete facing as specified herein and as shown on the plans. The Design Builder shall furnish all labor, tools, materials, and Equipment to complete the Work.
- B. The Design Builder is responsible for the construction means and methods and the process of the Work. This includes the construction sequence, the safety of the workers, temporary handrails, excavation access, barriers, lifting of materials and construction Equipment into and out of the excavation, temporary bracing of form work, and the stability of all temporary cut slopes.
- C. The soil nail retaining wall is an earth retention system designed to support the excavated slope once the components of the soil nails and facing system are completely installed for all lifts up to and including the current excavation lift. The stability of interim temporary face cuts that exist prior to installation of the wall facing is the sole responsibility of the Design Builder.
- D. The Work shall consist of installing soil nails to the specified minimum length, diameter, and orientation as specified herein. Work also required includes excavating in accordance with the staged lifts as required, installing the wall drainage elements and shotcrete facing, performing soil nail pullout testing, and installing the concrete facing if shown on the plans.

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
 - 1. Section 02240 – DEWATERING
 - 2. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 - 3. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 - 4. Section 02300 – EARTHWORK
 - 5. Section 03300 – CAST-IN-PLACE CONCRETE
 - 6. Section 03371 – SHOTCRETE
 - 7. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS
 - 8. Section 05500 – MISCELLANEOUS METALS

1.3 SUBMITTALS

- A. Provide a brief description of at least 3 projects of similar size and scope, including the Owner's name, address, and current phone number; location of project; project contract value; and scheduled completion date and actual completion date for the project. The Design Builder shall demonstrate that they have successfully completed at least 3 permanent soil nail retaining wall projects in the last 5 years totaling at least 10,000 square feet of face area and at least 500 soil nails.

- B. For Soil nail walls construction used as temporary support of excavation, the Design Builder shall submit design calculations. All design calculations shall be performed stamped and sealed by a Professional Engineer registered in the Commonwealth of Massachusetts.
- C. The Design Builder is responsible for providing the necessary survey and alignment control during the excavation for each lift, locating drill holes and verifying limits of wall installation. At least 14 days before starting soil nail work, submit a Construction Plan to the Engineer that includes the following:
 - 1. The start date and proposed detailed wall construction sequence.
 - 2. Drilling and grouting methods and Equipment including drill rig type, use of cased or open-hole methods, proposed drill hole diameter, and method of cuttings removal to achieve the specified pullout resistance.
 - 3. Nail grout and shotcrete mix designs, including compressive strength test results (per AASHTO T1 06/ASTM C 109) supplied by a qualified independent testing lab verifying the specified minimum 3-day and 4,000 psi 28-day grout compressive strengths. Previous test results for the same grout mix completed within one year of the start of grouting may be submitted for verification of the required compressive strengths.
 - 4. Nail grout placement procedures, Equipment used for placement, and method of mixing.
 - 5. Shotcrete materials and methods of mixing and placement including methods of controlling the location of the finish face and determining shotcrete thickness.
 - 6. Soil nail testing methods and Equipment setup: Include details of the jacking frame and appurtenant bracing, methods of isolating test nails during shotcrete application, and methods of grouting the unbonded length of test nails after testing. The Design Builder shall submit test results and detailed daily field reports; as a minimum, the field reports shall indicate nail type, diameter, length, inclination, grout takes, and if the nail has been installed in accordance with plans and specs for each nail installed.
 - 7. Identification numbers and certified calibration records for each test jack and pressure gauge and load cell to be used. Jack and pressure gauge shall be calibrated as a unit. Calibration records shall include the date tested, the device identification number, and the calibration test results and shall be certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 90 days prior to submittal.
 - 8. Material certifications for soil nail reinforcement bars, couplers, facing reinforcement, Portland cement, centralizers, bearing plates, and epoxy coating or encapsulation if used.
- D. Soil nail test results and daily field reports documenting compliance with the plans and specification.
- E. Manufacture's data relative to drainage material.
- F. Grout mix designs.
- G. Bonding agent manufacturer's data.

1.4 PRECONSTRUCTION MEETING

- A. A preconstruction meeting shall be held prior to the start of the Work and shall be attended by the Owner's representatives, the Engineer, the general Design Builder, the excavation subcontractor, shotcreting subcontractor, the soil nail specialty subcontractor, and the wall facing contractor. Wall

construction requires excavation in soil and rock material, excavation in staged lifts and excavation in the vicinity of the wall face requires special care and effort compared to general earthwork excavation. The preconstruction meeting shall be conducted to clarify the requirements for the Work, to coordinate the construction activities, and to identify contractual relationships and responsibilities.

1.5 SUBSURFACE DATA

- A. Logs of subsurface explorations performed at the site are shown on the Contract Drawings. Approximate locations of these subsurface explorations are shown on the Contract Drawings.
- B. The aforementioned data is for general information and is accurate only at the particular locations and times the subsurface explorations were made. It is the Design Builder's responsibility to make interpretations and draw conclusions based on the character of materials to be encountered and the impact on his work based on his expert knowledge of the area and of earthwork techniques. The Design Builder shall review test pit and boring logs and locations and other pertinent data for the site. The Design Builder, at his own expense, may conduct additional subsurface explorations for his own information after obtaining the MBTA's permission.

1.6 QUALITY ASSURANCE

- A. Comply with local rules, and in conjunction with all city, state, and federal guidelines and regulations, laws and ordinances and all other authorities having jurisdiction. All labor, materials, Equipment and services necessary to make the Work comply with such requirements shall be provided without additional cost to the Owner.
- B. The Work defined in this Specifications Section is specialty construction requiring a specialty contractor who is highly knowledgeable and experienced in the fabrication and installation of soil nail walls. The Design Builder performing the Work in this Specifications Section shall submit proof of three projects on which the Design Builder has successfully installed soil nail walls (permanent and as temporary SOE) of similar capacities required for this project within the last 5 years. Provide an experienced supervisor with at least 3 years of experience in the construction of soil nail walls. The Design Builder's supervisor shall be present at all times during execution of this portion of the Work and shall be thoroughly experienced with materials being installed, referenced standards, and requirements of this work. Drilling operators, nozzle men, and foremen shall have a minimum of 2 years' experience installing soil nail walls with the Design Builder's organization.
- C. Certification of the quality of the soil nail wall assemblies to be used in the Work shall be furnished, in a form acceptable to the Engineer, at the time of delivery of materials to the site. As a minimum, the certification of the quality of the soil nail walls assemblies shall include all submittals required as specified herein.
- D. Install and conduct all pre-production verification tests at the locations indicated on the Drawings prior to the installation of soil nail walls. In addition, performance tests shall be required on each drill hole size; bond length; bar size and cement grout mix design combination.
- E. Monitor and record data associated with nail grouting, performance, lift off and proof tests and provide the Engineer with a typewritten record of the data for each soil nail within 2 days after testing.
- F. All grout shall be tested for conformance with this Specifications Section by an independent certified testing agency at no additional cost to the Owner.

- G. All concrete and reinforcement used for construction of the wall shall be tested for conformance with this Specification Section by an independent certified testing agency at no additional cost to the Owner.

1.7 EXISTING SITE CONDITIONS, UTILITIES, AND UNDERGROUND OBSTRUCTIONS

- A. The Design Builder shall visit the Site prior to any construction activities for the purpose of observing and documenting the preconstruction condition of all structures, infrastructure, sidewalks, roadways, and all other facilities adjacent to the Site. During construction the Design Builder shall observe the conditions above the soil nail wall on a daily basis for signs of ground or building movements. The Design Builder shall immediately notify the Owner's representative and the Engineer if a sign of movement such as slope deformation, new cracks, and increased size of old cracks or separation of joints in structures, foundations, streets or paved and unpaved surfaces are observed. The Design Builder shall provide the Engineer written documentation of the observed conditions within 24 hours of initial observation.
- B. The Design Builder must verify all existing dimensions and Site conditions. The Design Builder is responsible for placing a one-call notification with dig safe Massachusetts prior to the start of Work. The Design Builder shall also determine the location of all existing utilities or underground obstructions not shown on the Plans, that may impact or conflict with the soil nail wall.
- C. Based on the as-built locations of sewers, water service and gas or power service lines, the Design Builder shall seek approval of the Engineer to shift nail locations to avoid conflicts with these utilities.

1.8 SPECIAL INSPECTION

- A. If required by the local building code, special inspection shall be provided by the Engineer for all soil nail installation and testing and for all shotcrete work. Such Inspection shall include observation and testing of test panel, observation of nail installation and testing performed by the Design Builder, placement of reinforcing steel, drainage board, and placement of shotcrete.
- B. The Engineer providing the special inspection shall be a qualified geotechnical Engineer or his representative with experience monitoring soil nail wall construction. Accurate records documenting the soil nail wall construction shall be maintained by the Engineer. The Design Builder shall assist the Engineer as necessary to obtain the as-built nail locations, top of wall elevations, and all other information as required by the Owner and Engineer. The Design Builder shall provide access to the Work and allow the special inspector to observe the Work in an unimpeded manner. The Design Builder shall inform the Owner at least 24 hours in advance of construction activities commencing so that inspection activities can be coordinated. Special inspection of the Work by the Engineer shall not relieve the Design Builder from completing the Work in accordance with the Plans and Specifications.
- C. All shotcrete and soil nail grout shall be tested, and soil nail design adhesions verified, in accordance with these Specifications.

1.9 CONSTRUCTION REQUIREMENTS

- A. The Design Builder is responsible for providing construction Site drainage, both behind and in front of the soil nail wall that is independent of the wall drainage system.

- B. At least 15 days prior to initiating the Work, the Design Builder shall submit to the Engineer for review and approval a detailed construction Site drainage plan addressing all elements necessary to divert, control, and dispose of surface water. Among other means, control of surface water from behind the wall may be accomplished by grading away from the wall, trenches and sumps, or a shotcreted gutter system. In addition, the excavation should be graded so as to direct surface water away from the toe of the soil nail wall and to prevent the ponding of water.
- C. The Design Builder is responsible for the condition and maintenance of any pipe or conduit used to control surface water during construction. Upon substantial completion of the Work, surface water control pipes or conduits shall be removed from the Site. Alternatively, pipes or conduits that are left in place with the approval of the Owner's representative shall be fully grouted (abandoned) or left in a manner that protects the structure and all adjacent facilities from ground loss associated with migration of fines through the pipe or conduit.

PART 2 – PRODUCTS

2.1 GENERAL

- A. Materials for construction of soil nail walls shall be furnished new and without defects. Defective materials rejected by the Owner's representative shall be removed by the Design Builder with no additional cost to the Owner. The materials shall consist of the following:

2.2 SOIL NAILS

- A. All nail bars shall be carefully handled and shall be stored on supports to keep the steel from contact with the ground. Steel bars shall be picked up in such a way as to prevent overstressing. Damage to the nail steel as a result of overstressing, abrasion, cuts, nicks, welds, and weld splatter shall be cause for rejection Engineer. Grounding of welding leads to the nail steel is prohibited. Nail steel shall be protected from and sufficiently free of dirt, rust, and other deleterious substances prior to installation. Heavy corrosion or pitting of nails shall be cause for rejection by the Engineer. Light rust that has not resulted in pitting is acceptable.
- B. Nail Solid Bar: AASHTO M31/ASTM A615, Grade 75. Deformed bar, continuous without splices or welds, new, straight, undamaged, epoxy-coated, or encapsulated for corrosion protection as shown on the Plans. Bar shall be threaded a minimum of 12 inches on the wall anchorage end, to allow proper attachment of bearing plate and nut as well as embedment into facing attachment plate. Threading may be continuous spiral deformed ribbing provided by the bar deformations (continuous thread bars) or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, provide the next-larger bar number designation that is shown on the Plans, at no additional cost to the Owner.
- C. Bar couplers shall develop the full ultimate tensile strength of the bar as certified by the Manufacturer.
- D. Fusion Bonded Epoxy Coating: ASTM A 775 or AASHTO No. M284 Minimum 0.3-mm (0.016-in.) thickness electrostatically applied. Bend test requirements are waived. Coating at the wall anchorage end of epoxy-coated bars may be omitted over the length provided for threading the nut against the bearing plate.
- E. Encapsulation. Minimum 1-mm (0.04-in.) thick, corrugated, HDPE tube conforming to ASTM 01248 and AASHTO M252 or corrugated PVC tube conforming to ASTM DI784, Class 13464-B.

- F. Centralizers shall be constructed of schedule 40 PVC, shall be securely attached to the nail bar, sized to position the nail bar within 1 inch of the center of the drill hole, sized to allow tremie pipe insertion to the bottom of the drill hole, and sized to allow grout to flow freely up the drill hole.

2.3 SOIL NAIL GROUT

- A. Fine Aggregate. AASHTO M6/ASTM C33.
- B. Portland cement: AASHTO M85/ASTM C150, Type I or Type II.
- C. Admixtures: AASHTO M194/ASTM C494. Admixtures that control bleed, improve flowability, reduce water content, and retard set may be used in the grout subject to review and acceptance by the Engineer. Accelerators are not permitted. Expansive admixtures may only be used in grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the Manufacturer's recommendations.
- D. Nail grout shall be a neat cement or sand-cement mixture with a minimum 3-day comprehensive strength of 2000 psi and a minimum 28-day compressive strength of 4000 psi per ASTM C I 09/AASHTO T 106.
- E. Cement shall be adequately stored to prevent moisture degradation and partial hydration. Cement that has become caked or lumpy shall not be used.
- F. Film Protection: Polyethylene film per AASHTO M 171.

2.4 SOIL NAIL APPURTENANCES

- A. Bearing Plates, Nuts, and Welded Stud Shear Connectors.
 - 1. Bearing Plates: ASTM A36, Grade 36. Steel plate dimensions shall be within 0.25 inches of that shown on the Plans.
 - 2. Nuts and Washers: AASHTO M291, Grade B, hexagonal, fitted with beveled washer or spherical seat to provide uniform bearing.
 - 3. Shear Connectors: ASTM AI08. Shear connector locations shall be within 0.25 inches of that shown on the Plans.
- B. Welded Wire Fabric. AASHTO M55/ASTM A 185 or A497.
- C. Reinforcing Steel. AASHTO M3 1/ASTM A6 I 5, Grade 60, deformed.
- D. Geocomposite Sheet Drain: Manufactured with a drainage core (e.g., geonet) and a drainage geotextile attached to or encapsulating the core. Drainage core to be manufactured from long chain synthetic polymers composed of at least 85 percent by mass of polypropylenes, polyester, polyamine, polyvinyl chloride, polyoleofin, or polystyrene and having a minimum compressive strength of 275 kPa (40 psi) when tested in accordance with ASTM D 1621 Procedure A. The drainage core with the geotextile fully encapsulating the core shall have a minimum flow rate of 1 liter per second per meter of width tested in accordance with ASTM D 4716. The test conditions shall be under an applied load of 69 kPa (10 psi) at a gradient of 1.0 after a 100-hour seating period. Sheet drains shall be at least 12 inches wide, and overlaps shall be at least 12 inches long.

E. Underdrain and Perforated Pipe

1. Pipe: ASTM 1785 Schedule 40 PVC solid and perforated wall; cell classification 12454-B or 12354-C, wall thickness SDR 35, with solvent weld or elastomeric joints.
2. Fittings: ASTM D3034, Cell classification 12454-B or C, wall thickness SDR 35, with solvent or elastomeric joints.

2.5 SHOTCRETE

A. General:

1. All shotcrete shall comply with the requirements of ACI 506.2-95 except as specified otherwise herein. The Engineer shall contract an independent testing laboratory to core and test shotcrete panels and inspect all shotcrete and steel reinforcement placement in accordance with ACI 506.4R-94.
2. All workers, including foreman, nozzle men, finishers and delivery Equipment operators, shall be fully qualified to perform the Work. Qualification of the nozzle men shall be based on the results of test panels as required herein, unless approved otherwise by the Engineer.

B. Shotcrete Materials:

1. All materials for shotcrete shall conform to the following requirements:
 - a. Cement shall conform to ASTM C150 / AASHTO M85, Type I or Type II.
 - b. Fine aggregate shall conform to ASTM C33/ AASHTO M6.
 - c. Coarse aggregate shall conform to AASHTO M-80, Class B.
 - d. Water shall be potable, clean, and free from substances deleterious to concrete and steel or that would cause staining.
 - e. Accelerator shall be the fluid type, applied at nozzle, and meet the requirements herein.
 - f. Water-reducer and super-plasticizer shall conform to ASTM C494 / AASHTO M194; Type A, D, F, and G.
 - g. Air-entraining agent shall conform to ASTM C260 / AASHTO M154.
 - h. Fly ash shall conform to ASTM C618 / AASHTO M245, Type F or G, cement replacement up to 35% by weight of cement.
 - i. Silica fume shall conform to ASTM C1240, 90% minimum silicon dioxide solids content, not to exceed 12% by weight of cement.
 - j. Welded wire fabric shall conform to ASTM A185 / AASHTO M55.
 - k. All reinforcing steel shall conform to ASTM A615 / AASHTO M31, Grade 60. All reinforcing steel details shall conform to ACI 315.
 - l. Curing compounds shall conform to AASHTO M148, Type ID or Type 2.
 - m. Film protection for curing shall conform to AASHTO M171 or polyethylene film.

2. Shotcrete admixtures shall not be used unless approved by the Engineer. Admixtures used to entrain air, to reduce water-cement ratio, to retard or accelerate setting time, or to accelerate the development of strength, shall be thoroughly mixed into the shotcrete at the rate specified by the Manufacturer unless specified otherwise. Accelerating additives shall be compatible with the cement used, be non-corrosive to steel and shall not promote other detrimental effects such as cracking or excessive shrinkage. The maximum allowable chloride ion content of all ingredients shall not exceed 0.10 percent when tested per AASHTO T260.
3. Materials shall be delivered, stored and handled to prevent contamination, segregation, corrosion or damage. Liquid admixtures shall be shipped, stored, and handled to prevent evaporation and freezing.
4. Aggregates for shotcrete shall meet the strength and durability requirement of AASHTO M80.
5. Cement content shall be at least 600 pounds per cubic yard. The water/cement ratio shall not be greater than 0.45. For wet-mix shotcrete exposed to freezing and thawing, the air content at the truck shall be between 7 to 10 percent when tested in accordance with ASTM C231 /AASHTO T1 52.
6. Shotcrete shall be proportioned to attain a compressive strength of 2000 PSI in 3 days and 4000 PSI in 28 days. The average compressive strength of each set of three cores extracted from test panels or wall face must be equal to or exceed 85%, with no individual core less than 75% of the specified compressive strength in accordance with ACI 506.2.
7. Aggregate and cement may be batched by weight or by volume in accordance with the requirements of ASTM C94 / AASHTO M157. Mixing Equipment shall be capable of thoroughly mixing the materials in sufficient quantity to maintain placing continuity. Ready-mix shotcrete shall be delivered and placed within 1-1/2 hours of the batch time unless approved otherwise by the Engineer.

PART 3 – EXECUTION

3.1 GENERAL

- A. The construction sequence shall be as shown on the Plans, or in accordance with the approved submittal, unless approved otherwise by the Engineer. No excavations steeper or higher than those specified herein or on the Plans shall be made above or below the soil nail wall without written approval of the Engineer.
- B. Construction methods, sequence or closure times that are either indicated on the Plans or approved otherwise by the Engineer do not relieve the Design Builder of all responsibility for stability of the temporary cut face until it is closed and stabilized with hardened shotcrete and the nail head connection is completely installed.
- C. Where the Design Builder's construction sequencing results in a discontinuous lift along any nail row, the ends of the lift shall extend beyond the ends of the next lower lift by at least 10 feet. A soil berm shall be constructed immediately beneath these stepped lifts to prevent sloughing or failure that would result in loss of ground at the face.

3.2 EXCAVATION

- A. At least 15 days prior to initiating the Work, the Design Builder shall submit to the Engineer for review and approval excavation Equipment types, methods of excavating to nail benches, methods used to control the limits of excavation and overbreak, to the staged lifts indicated on the Plans.

- B. Mass excavation for site development at distances from the shotcrete wall face greater than the current shotcrete wall height or 10 feet, whichever is more, may occur at any time, but slopes shall be compliant with OSHA regulations or other applicable standards.
- C. Mass excavation of the drill bench for the next row of soil nails may occur at any time of the day after shotcreting the preceding lift, provided such excavation occurs no closer than 5 feet from the face of the shotcrete.
- D. Mass excavation beneath a preceding shotcrete lift, closer than 5 feet from the shotcrete wall face, shall not occur until: (1) nail grout and shotcrete on the preceding lift shall have reached 50% of their specified 28-day compressive strengths; and (2) installation of connection hardware and nail testing for the preceding lift are complete and acceptable to the Owner's representative. Mass excavation closer than 5 feet to the shotcrete face must be in accordance with the drill berm requirements described below and shown on the plans, unless approved otherwise by the Engineer.
- E. During mass excavation of the drill bench for the next row of soil nails, the Design Builder shall maintain a bench of material to serve as a platform for the drilling Equipment and as a stabilizing berm for the wall excavation face (neat line). In accordance with the Plans or as approved by the Engineer, the stabilizing berm may be either: (1) a native berm, (2) a fill berm, or (3) neat cut. In all three cases, the drill bench shall be established not more than 1 foot below the row of nails to be installed and shall extend out from the wall face a minimum distance necessary to provide a safe working bench for the drill Equipment and workers,
- F. Excavation to the neat line shall be done using procedures that prevent over excavation or loosening, minimize degradation of the soil bearing support below the overlying portions of the soil nail wall and below the soil nails currently being installed, minimize loss of soil moisture and prevent ground freezing. The Design Builder is responsible for all costs associated with the shotcrete facing necessary to address excavation and overbreak beyond the neat line.
- G. The duration of time between final excavation to the neat line and the application of shotcrete is referred to as the closure time. The closure time for all wall excavation faces shall be less than a single work shift, unless shown otherwise on the Plans or approved otherwise by the Engineer.
- H. Extension of the closure time shall be submitted to the Engineer for review and approval. No extension of closure time shall be approved until a test cut is constructed and the Design Builder demonstrates for each material type that the cut face shall be stable over the proposed closure time. Extensions to the closure time may be revoked by the Engineer at any time depending on the performance of the cut face.
- I. Methods of removal of face protrusions (e.g. cobbles, boulders, rubble, or other objects) to accomplish the construction shall be determined by the Design Builder. The Design Builder shall notify the Engineer of the proposed method for mitigation of face protrusions prior to initiation of the Work. Should the removal of face protrusions result in voids beyond the neat line, the Design Builder shall determine the appropriate method of backfilling and shall submit to the Engineer such methods prior to initiating the Work.

3.3 NAIL INSTALLATION

- A. For each different method of nail installation, two successful verification tests shall be performed in soil units comprised of soil/ weathered rock, and sound rock prior to starting installation of production nails in the various soil units. Final verification test locations shall be determined by the Design Builder and approved by the Owner's representative.

- B. Nails shall be installed at the locations and to the lengths indicated on the Plans. The Engineer may add, eliminate, or relocate nails to accommodate actual field conditions.
- C. The Design Builder shall select the drilling Equipment and methods suitable for the ground conditions described in the geotechnical report. The drill hole diameter shall be as shown on the Plans and provide the minimum specified grout cover over the nail bar and to develop the specified pullout resistance. Water, drilling muds, or other fluids used to assist in cutting removal shall not be allowed for uncased drill holes. Uncased drill holes shall be observed for cleanliness prior to insertion of the nail bar. In caving ground, the Design Builder shall use cased or augercast drilling methods to support the sides of the drill hole.
- D. The Design Builder shall immediately suspend drilling operations if ground subsidence is observed, if the soil nail wall is adversely affected, or if adjacent structures are damaged as a result of the drilling operation. The adverse conditions shall be stabilized immediately and the Engineer shall be notified of such conditions within 24 hours.
- E. Nail bars shall be inserted into the drill hole to the required length without difficulty and in such a manner as to prevent damage to the drill hole. Nail bars that cannot be fully inserted to the design depth shall be removed from the drill hole and the drill hole wall be cleaned sufficiently to allow unobstructed installation of the bar.
- F. If the nail bar is installed using cased or augercast methods, centralizers are not required provided the installation method ensures that the bar shall remain in the central portion of the grout. In such situations, grout slump shall not exceed 8 inches.

3.4 NAIL GROUTING

- A. Grout Equipment shall produce a uniformly mixed grout free of lumpy and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge that can measure at least twice but no more than three times the intended grout pressure. The grouting Equipment shall be sized to enable the entire nail to be grouted in one continuous operation. The mixer shall be capable of continuously agitating the grout during usage.
- B. Uncased drill holes shall be grouted after installation of the nail bar. Grouting prior to insertion of the nail bar may be allowed provided neat cement grout is used and the nail bar is immediately inserted through the grout to the specified length without difficulty. No portion of the nail hole shall be left open for more than 1 hour prior to grouting unless approved otherwise by the Engineer. The grout shall be injected at the lowest point of each drill hole through a tremie pipe, hollow-stem auger, or drill rods with the drill hole filled in one continuous operation. Cold joints in the grout placement are allowed for construction of test nails. The conduit delivering the grout shall be kept below the surface of the grout as the conduit is withdrawn. The grouting conduit shall be withdrawn as the nail hole is filled in a manner which prevents the creation of voids. The quantity of grout and the grouting pressures shall be recorded for each soil nail. Grout pressures shall be controlled to prevent excessive ground heave or fracturing.
- C. During casing removal for drill holes advanced by either cased or augercast methods, the grout surface within the casing shall be continually monitored for maintenance of "head" sufficient to offset the external groundwater/soil pressure.
- D. Nail grout shall have a minimum compressive strength of 2,000 psi in 3 days and 4,000 psi in 28 days. Nail grout shall be tested by a testing agency under contract with the Owner in accordance with ASTM

CI 09 / AASHTO T 106 at a frequency of no less than one test for every 50 cubic yards of grout placed or once per day, whichever is first.

- E. Temporary unbonded lengths shall be provided for each test nail. The test nail bar shall be isolated from the wall facing and the reaction frame during testing. Satisfactory test nails may be incorporated in the Work provided the temporary test unbonded length is fully grouted subsequent to testing.

3.5 NAIL TOLERANCES

- A. The soil nails shall not extend beyond the right-of-way or easement limits shown on the plans, unless approved otherwise, bars shall be centered within 1 inch of the center of the drill hole. Individual nails shall be positioned plus or minus 1 foot from the design locations shown in the Plans. Location tolerances shall be considered applicable to only one nail and not cumulative over large wall areas. The nail inclination shall be plus or minus 3 degrees of that shown in the Plans. Nail splay angle shall be plus or minus 3 degrees. Nails that encounter unanticipated obstructions during drilling shall be relocated by the Design Builder with the approval of the Engineer.

3.6 NAIL TESTING

- A. General:

1. Verification tests shall be performed at the locations shown on the Plans. Alternate locations selected by the Design Builder are subject to approval by the Engineer. Proof tests shall be performed at the locations selected by the Engineer. All test data shall be recorded by the Engineer and the Design Builder. Pullout testing of nails shall not be performed until the nail grout and wall facing have attained at least 50 percent of their specified 28-day compressive strengths.
2. Where temporary casing of the unbonded length of test nail is provided, the casing shall be installed to prevent any reaction between the casing and the grouted bond length of the nail and/or the stressing apparatus.
3. Testing Equipment shall include two dial gauges, a dial gauge support, jack and pressure gauge, a pump, and a reaction frame.
4. A minimum of two dial gauges capable of measuring to 0.001-inch shall be available at the Site to measure the nail movement. The dial gauges shall be aligned within 5 degrees of the axis of the nail and shall be supported independent of the jacking setup and the wall. A hydraulic jack, pressure gauge, and pump shall be used to apply and measure the test load.
5. The jack and pressure gauge wall shall be calibrated by an independent testing laboratory as a unit. The pressure gauge shall be graduated in 100 psi increments or less and shall have a range not exceeding twice the anticipated maximum pressure during testing unless approved otherwise by the Engineer. The ram travel of the jack shall be sufficient to enable the test to be performed without resetting the jack.
6. The jack shall be independently supported and centered over the nail so that the nail does not carry the height of the jack. The stressing Equipment shall be placed over the nail in such a manner that the jack, bearing plates, and stressing anchorage are in alignment. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack during the test shall not be required.

7. The test reaction frame shall be sufficiently rigid and of adequate dimension such that excessive deformation of the test apparatus requiring repositioning of any components does not occur during testing. Where the reaction frame bears directly on the wall, the reaction frame shall be designed to prevent damage or cracking of the wall facing.

B. Pre-Production Verification Testing of Sacrificial Nails:

1. Pre-production verification testing in each soil unit shall be performed in that unit to verify the Design Builder's installation methods, nail pullout capacity, and design assumptions. A minimum of 4 tests shall be performed. The nails used for the verification tests may not be incorporated as production nails. Payment for additional verification test nails required due to differing Site conditions, as determined by the Engineer, shall be per nail tested.
2. Test nails shall be constructed using the same Equipment, methods, and hole diameter as planned for the production nails. Changes in the drilling or installation method may require additional nail testing as determined by the Engineer.
3. The unbonded length of test nails shall be at least 3 feet unless approved otherwise by the Engineer. The bond length of test nails shall be determined by the Design Builder such that the allowable bar load is not exceeded but shall not be less than 3 feet. The bar load during testing shall not exceed 90% of the steel yield strength for grade Grade 75 bars.
4. The Design Test Load (DTL) during testing shall be determined by multiplying the bond length of the nail times the design pullout resistance. Verification test nails shall be incrementally loaded in 0.25 DTL increments to a maximum load of 1.50 DTL in accordance with the following schedule. Verification test nails shall be incrementally loaded and unloaded in accordance with the following schedule:

Load	Hold Time
AL	1 minute
0.25 DTL	10 minutes
0.50 DTL	10 minutes
0.75 DTL	10 minutes
1.00 DTL	10 minutes
1.25 DTL	10 minutes
1.50 DTL	60 minutes
1.75 DTL	10 minutes
2.00 DTL	10 minutes

5. The Alignment Load (AL) should be the minimum load required to align the testing apparatus and should not exceed 0.05 DTL. Dial gauges should be zeroed after the alignment load is applied.
6. Each load increment shall be held for at least 10 minutes. The verification test nail shall be monitored for creep for 60 minutes at the 1.50 DTL load increment. Nail movements during the creep portion of the test shall be measured and recorded At 1, 2, 3, 5, 6, 10, 20,30, 50, and 60 minutes.

C. Proof Testing of Production Nails:

1. Proof testing shall be performed on approximately 5 percent of the production nails or as determined by the Owner's Engineer. If nail installation methods are substandard on any particular nail or series of nails, additional tests may be required.
2. The unbonded length of test nails shall be at least 3 feet unless approved otherwise by the Engineer. The bond length of test nails shall be determined by the Owner's representative such that the allowable bar load is not exceeded but shall not be less than 7 feet. The bar load during testing shall not exceed 90% of the steel yield strength for grade 60 and Grade 75 bars.
3. Proof test nails shall be incrementally loaded in 0.25 DTL increments to a maximum load of 1.50 DTL in accordance with the following schedule:

AL	1.00 DTL
0.25 DTL	1.25 DTL
0.50 DTL	1.50 DTL
0.75 DTL	

4. The Alignment Load (AL) should be the minimum load required to align the testing apparatus and should not exceed 0.05DTL. Dial gauges should be zeroed after the alignment load is applied.
5. Depending on performance, either a 10 minute or 60 minute creep test shall be performed at 1.50DTL. Nail movement shall be measured and recorded at 1,2,3,5,6, and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 0.04 inches, the maximum test load shall be maintained an additional 50 minutes and movements shall be recorded at 20,30,50, and 60 minutes.

D. Test Nail Acceptance:

1. A test nail shall be considered acceptable when:
 - a. For verification tests, a creep rate less than 0.08 inches per log cycle of time between the 6 and 60 minute readings is observed during creep testing, and the rate is linear or decreasing throughout the creep test load hold period.
 - b. For proof tests, a creep rate less than 0.04 inches per log cycle of time between the 1 and 10 minute readings is observed or a creep rate less than 0.08 inches per log cycle of time between the 6 and 60 minute readings, and the creep rate is linear or decreasing throughout the creep test load hold period.
 - c. The total movement at the maximum test load exceeds 80% of the theoretical elastic elongation of the unbonded length.
 - d. A pullout failure does not occur during testing. Pullout failure is defined as the load at which attempts to increase the test load simply result in continued pullout movement of the test nail.

2. At the Design Builder's option, successful proof test nails meeting the above test acceptance criteria may be incorporated as production nails provided that (1) the unbonded test length of the nail hole has not collapsed during testing, (2) the minimum required hole diameter has been maintained, and (3) the test nail length and bar size are equal to or greater than the scheduled production nail length and bar size. Test nails meeting these requirements shall be completed by satisfactorily grouting the unbonded test length. Maintaining the temporary unbonded test length for subsequent grouting is the Design Builder's responsibility.
3. The Engineer shall evaluate the results of each verification test. Nail installation methods that do not satisfy the nail testing requirements shall be considered inadequate. The Design Builder shall propose alternative methods and install replacement verification test nails.
4. The Engineer may require that the Design Builder replace some or all of the production nails represented by inadequate proof tests with no additional cost to the Owner.

3.7 EXECUTION OF PRODUCTION SHOTCRETE WORK

A. Alignment Control:

1. Alignment wires and/or thickness control pins shall be provided as necessary to establish and maintain the minimum shotcrete thickness shown on the Plans. The maximum distance between the wires and/or thickness control pins on any surface shall be equal to the vertical nail spacing. The Design Builder shall ensure that alignment wires are tight, true to line, and placed to allow further tightening.

B. Surface Preparation:

1. Prior to shotcreting the ungrouted zone above the nail grout at the excavation cut face (bird's beak), the Design Builder shall remove all loose materials from the surface of the grout.
2. The Design Builder shall remove all loose materials and loose dried shotcrete from previous placement operations and from all receiving surfaces by methods acceptable to the Engineer. The removal shall be accomplished in such a manner as not to loosen, crack, or shatter the surfaces to receive the shotcrete. Any surface material that, in the opinion of the Engineer, is so loosened or damaged shall be removed to sufficient depth to provide a base that is suitable to receive the shotcrete. Material that loosens as the shotcrete is applied shall be removed. Shotcrete shall not be placed on frozen surfaces.

C. Delivery and Application:

1. A clean, dry, oil-free supply of compressed air sufficient for maintaining adequate nozzle velocity for all parts of the Work and for simultaneous operation of a blow pipe for cleaning away rebound shall be maintained at all times. The Equipment shall be capable of delivering the premixed material accurately, uniformly, and continuously through the delivery hose.
2. The shotcrete shall be applied from the lower part of the work area upwards to prevent accumulation of rebound on uncovered surfaces. Thickness, methods of support, air pressure, and rate of placement of shotcrete shall be controlled to prevent sagging or sloughing of freshly applied shotcrete. Where shotcrete is used to fill the bird's beak, the nozzle shall be positioned

into the mouth of the drill hole to completely fill the void. Rebound shall not be worked back into the placement nor shall the rebound be salvaged. Rebound that does not fall clear of the working area shall be removed. The nozzle shall be held at a distance and at an angle approximately perpendicular to the working face so that rebound shall be minimal and compaction shall be maximized. The nozzle should be rotated steadily in a small circular pattern.

3. Shotcrete placement shall be by the bench gunning method when the thickness of the shotcrete layer is 6 inches or greater. The gunning method shall consist of building up a thick layer of shotcrete from the bottom of the lift and maintaining the top surface at approximately a 45-degree slope.

D. Visual Observation:

1. A clearly defined pattern of continuous horizontal or vertical ridges or depressions at the reinforcing elements after they are covered shall be considered indication of insufficient cover of reinforcement or poor application and probable void. In this case, the Work shall be immediately suspended and the Work carefully inspected by the Owner's representative. The Design Builder shall implement and complete corrective measures prior to resuming the shotcrete operations.
2. The shotcreting procedure may be corrected by adjusting the nozzle distance and orientation perpendicular to the surface, adjusting the water content of the shotcrete mix, or other means acceptable to the Engineer. All overspray and rebound shall be removed from the surface.
3. Surface defects shall be repaired as soon as possible after initial placement of shotcrete. All shotcrete that lacks uniformity, exhibits segregation, sagging, honeycombing, or lamination, or contains any voids or sand pockets shall be removed and replaced with fresh shotcrete by the Design Builder to the satisfaction of the Engineer.

E. Attachment of the Nail Head Connection Hardware:

1. For bearing plate connections, the plate shall be wet-set while the shotcrete is plastic to assure full shotcrete bearing behind the plate. However, the retention nut shall only be hand tightened such that full bearing is achieved without excessively squeezing fresh shotcrete out from under the plate.
2. For embedded plate connections (typically with headed studs), the embedment's wall shall be located within the wall such that the proper shotcrete cover is provided as shown on the Plans. In addition, the plate, washer, and nut shall BE installed so that they have sufficient contact with each other as shown on the Plans.

F. Construction Joints:

1. Construction joints shall be watertight and uniformly tapered toward the excavation face over a minimum distance equal to the thickness of the shotcrete layer. The surface of the joints shall be rough, clean, sound and damp. The hardened surface shall be cleaned of all laitance, foreign substances, washed with clean water, and wetted thoroughly immediately prior to placement of fresh shotcrete.

G. Finishing and Curing Requirements:

1. Shotcrete finish shall be as applied.
2. The shotcrete shall be protected from loss of moisture for at least 7 days after placement. When shotcrete is being protected from low temperatures, curing shall be terminated no sooner than one day after the removal of low temperature protection. Curing of shotcrete shall be by methods that shall keep shotcrete surfaces adequately wet and protected during the specified period. Curing shall commence within one hour of shotcrete application. When the ambient temperature exceeds 80 degrees Fahrenheit, the Design Builder shall plan the Work such that curing can commence immediately after finishing, the curing shall be completed using water, membrane, or film curing methods in accordance with the following requirements.
3. For water curing, the rate of water application shall be regulated to provide complete surface coverage with a minimum of runoff.
4. For membrane curing, curing compounds shall not be used on any surfaces against which additional shotcrete or other finishing materials are to be bonded unless the surface is sandblasted in a manner acceptable to the Owner's representative. Membrane curing compounds shall be spray applied as quickly as practical after initial shotcrete set at coverage of not less than 40 square feet per gallon.
5. For film curing, polyethylene sheeting may be used to supplement water curing on shotcrete that shall be covered later with additional shotcrete or concrete. The sheeting shall completely cover all surfaces, and have edges overlapped for proper sealing and anchorages.

H. Test Panels:

1. In general, preconstruction and production shotcrete test panels shall be required. However, depending on the amount of shotcrete wall reinforcement, the Engineer may waive the requirements for a reinforced preconstruction test panel. Preconstruction and production test panels shall not be disturbed or moved within the first 24 hours after shooting. Test panels shall be field cured under conditions similar to those anticipated for the Work. Shotcreting and coring of test panels shall be performed by qualified personnel in the presence of the Engineer. The Design Builder shall notify the Engineer not less than 2 days prior to the shooting of the preconstruction test panels.
2. Each nozzle man shall furnish at least two preconstruction test panels for each proposed mixture being considered and for each shooting position encountered on the job. Preconstruction test panels shall be made by each application crew using the Equipment, materials, mixture proportions, and procedures proposed for the job prior to the commencement of the Work.
3. Preconstruction test panels shall be 30 inches by 30 inches (minimum), in accordance with ACI 506.2-95 and the following:
 - a. One test panel shall be the maximum shotcrete thickness shown on the plans and shall include the maximum anticipated reinforcing congestion. Cores extracted from the reinforced test panel shall demonstrate encapsulation of the reinforcement in accordance with ACI 506.2 equal to core grade 2 or better.

- b. One test panel shall be un-reinforced, at least 8 inches thick, and used for compressive strength testing.
- c. The sides of the test panels shall be chamfered outward at 45 degrees over the full thickness of the panel.
4. The Design Builder shall furnish at least one production test panel or, in lieu of production test panels, six 3-inch diameter cores from the shotcrete face during the first application of shotcrete and henceforth for every fifth application of shotcrete, or every 5000 square feet, or 50 cubic yards of shotcrete placed, whichever is less. The production test panels shall be constructed simultaneously with the shotcrete facing installation at times designated by the Engineer. The production test panels shall have minimum dimensions of 18 inches by 18 inches by 8 inches.
5. Shotcrete shall be accepted based on the 28-day strength of cores taken from the production test panels. The frequency specified for the production test panels is approximate. A greater number of panels may be required by the Engineer.
6. At least six cores shall be cut from each preconstruction and production test panel for compressive strength testing. Cores shall be soaked in water for at least 40 hours in accordance with AASHTO T24 or ACI 506.2. Cores shall be at least 3 inches in diameter and shall have a minimum length to diameter ratio of one. When the length of a core is less than twice the diameter, apply the correction factors given in ASTM C42 to obtain the compressive strength of individual cores. Three cores shall be tested at 3-days, and three cores shall be tested at 28-days for compressive strength. Core holes in the wall shall be filled with patching mortar after cleaning and thorough dampening.

I. Weather Limitations:

1. Shotcrete shall not be placed in cold weather unless adequately protected when the ambient temperature is below 40° F and falling and/or when the shotcrete is likely to be subjected to freezing temperatures before reaching a minimum strength of 750 psi. Cold weather protection shall be maintained until the strength of the shotcrete is greater than 750 psi. Cold weather protection shall include heating under tents, blankets or other means acceptable to the Engineer. The temperature of the shotcrete, when deposited, shall be not less than 50° F or more than 80° F. The air in contact with shotcrete surfaces shall be maintained at temperatures above 32° F for a minimum of 7 days.
2. Shotcrete application shall also be suspended during high winds and heavy rains when in the opinion of the Engineer the quality of the application is not acceptable. Newly-placed shotcrete exposed to rain that washes out cement or otherwise makes the shotcrete unacceptable to the Owner's representative shall be removed and replaced. The Design Builder shall provide adequately secured polyethylene sheeting or equivalent when adverse exposure to weather is anticipated.

J. Tolerances:

1. The tolerances for shotcrete facings shall be as follows:
 - a. The vertical location of a horizontal shotcrete joint shall be within 0.5 feet of the elevation shown on the Plans
 - b. The shotcrete wall thickness shall be no less than that shown on the Plans minus 0.5 inches.

- c. The horizontal and vertical locations of reinforcing bars shall be within 1 inch of the locations shown on the Plans.
- d. Reinforcing bar lap lengths shall be no less than that shown on the Plans minus 1 inch.
- e. Reinforcing bar spacing's shall not exceed that shown on the Plans plus 1 inch.
- f. The deviation in planeness of the finished wall surface shall not exceed 0.5 inches in 10 feet.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02359

MODULAR PRECAST BLOCK RETAINING WALLS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This work shall consist of the designing, furnishing, and construction of Modular Precast Block Retaining Walls (MPB) in accordance with these specifications and in close conformity with the lines, grades, and dimensions shown on the Design Builder's Approved Drawings or established by the Engineer. Final design details for these structures such as, concrete unit thickness, connection details, and loading appurtenances shall be as designed by the manufacturer from design parameters contained herein. This specification is intended to cover all modular precast block retaining wall systems, some of which may be proprietary.
- B. The Walls shall consist of precast concrete units, select fill, filter fabric, drainage piping and a leveling pad. The precast concrete units shall be sized to have sufficient external stability resistance at each module course to satisfy the design requirements. The material, fabrication, and construction shall comply with this specification and the requirements specified by the supplier of the wall system.

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
 - 1. Section 02100 – SITE PREPARATION
 - 2. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 - 3. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 - 4. Section 02300 – EARTHWORK
 - 5. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 6. Section 02470 – SITE IMPROVEMENTS
 - 7. Section 03300 – CAST-IN-PLACE CONCRETE
 - 8. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE

1.3 REFERENCE DOCUMENTS

- A. American Society for Testing and Materials (ASTM)
 - 1. ASTM C140 Rev A Sampling and Testing Concrete Masonry Units and Related Units
 - 2. ASTM C666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing
 - 3. ASTM C1262 Evaluating the Freeze-Thaw Durability of Dry-Cast Segmental Retaining Wall Units and Related Concrete Units
 - 3. ASTM C1372 Dry-Cast Segmental Retaining Wall Units
 - 4. ASTM D422 Particle Size Analysis of Soils
 - 5. ASTM D698 Laboratory Compaction Characteristics of Soil Using Standard Effort
 - 6. ASTM D4318 Liquid Limit, Plastic Limit, and Plasticity Index of Soils
 - 7. ASTM D3034 Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings
 - 8. ASTM F2619 High-Density Polyethylene (HDPE) Line Pipe

- B. AASHTO LRFD Bridge Design Specifications - American Association of State Highway and Transportation Officials (AASHTO).
- C. Standard Specifications for Transportation Materials and Methods of Sampling and Testing, American Association of State Highway and Transportation Officials (AASHTO).
- D. American Railway Engineering and Maintenance-of-Way Association - AREMA

1.4 SUBMITTALS

- A. Final design computations demonstrating compliance with the design requirements specified herein and shown on the Design Builder's Approved Drawings, prepared, signed and stamped by a registered Professional Engineer registered in the Commonwealth of Massachusetts with structural/geotechnical engineering expertise. The drawings and design calculations shall include:
 1. Statement of all assumptions made and copies of all references used in the calculations.
 2. Design Builder shall submit construction drawings and design calculations for the modular precast block retaining wall system prepared and stamped by a structural/geotechnical Professional Engineer registered in the Commonwealth of Massachusetts.
 3. Analyses demonstrating compliance with all applicable earth, water, surcharges, seismic, or other loads, as specified herein and required by AREMA and AASHTO.
 4. Analyses or studies demonstrating durability and corrosion resistance of modular precast block retaining wall systems for the proposed location and environment. The designers shall provide all corrosion protection devices necessary for the modular precast block retaining wall to have a minimum service life of 75 years in the proposed location and environment.
 5. Existing ground elevations that have been verified by the Design Builder for each location involving construction wholly or partially in original ground.
 6. Layout of retaining walls that shall effectively retain the earth but not less in height or length than that shown for the wall system in the Design Builder's Approved Drawings.
 7. Complete design calculations substantiating that the proposed design for each alternative proprietary or nonproprietary earth retaining system as permitted or specified satisfies the design parameters and minimum requirements shown in the Design Builder's Approved Drawings.
 8. Complete details of all elements required for the proper construction of the system, including complete material specifications and connection details.
 9. Earthwork requirements including specifications for material and compaction of backfill.
 10. Details of revisions or additions to drainage systems or other facilities required to accommodate the system.

The Design Builder shall not start work on any earth retaining system for which shop drawings and installation drawings are required until such drawings have been approved by the Engineer. Approval of the Design Builder's Approved Drawings shall not relieve the Design Builder of any of his responsibility under the contract for the successful completion of the work

- B. A detailed resume of the wall designer listing similar projects and demonstrating necessary experience to perform the modular precast block retaining wall design, including a brief description of each

project that is similar in scope. A reference shall be included for each project listed. As a minimum, the reference shall include an individual's name, address and current phone number.

- C. A detailed listing of modular precast block retaining walls that the Design Builder has constructed including a brief description of each project and a listing of personnel who shall construct the walls demonstrating their experience in construction of modular precast block retaining walls. A reference shall be included for each project listed. As a minimum, the reference shall include an individual's name, address and current phone number.
- D. Manufacturer's product data for the modular precast block retaining wall system, including material, manufacturer and erection specifications, all specified erection equipment necessary, details of buried modular precast block retaining wall elements, special details required of reinforcing layout around drainage structures and sign foundations as applicable, structures design properties, type of backfill and details for connections between facing panels.
- E. Concrete mix design in accordance with Section 03300 – CAST-IN-PLACE CONCRETE and 03410 – PLANT PRECAST STRUCTURAL CONCRETE.
- F. Work/shop drawings showing the configuration and all details, dimensions, quantities and cross-sections necessary to construct the modular precast block retaining wall, including but not limited to the following:
 - 1. A plan view of the wall which shall include Contract limits, stations and offsets, and the face of wall line shown on the Design Builder's Approved Drawings.
 - 2. An elevation view of the wall which shall include the elevation at the top of the wall at all horizontal and vertical break points and at least every 30 feet along the face of the wall, all steps in the leveling pads, the designation as to the type of retaining wall system(s), and an indication of the final ground line and maximum calculated bearing pressures. The face of wall shown on the Design Builder's Approved Drawings shall be indicated.
 - 3. A typical cross section or cross sections for each different wall configuration showing the elevation relationship between existing ground conditions and proposed grades, and the proposed wall configuration, including details for the proposed methods for connecting to existing conditions. The sections shall also indicate the location of the face of wall, surcharge fill, and outline of concrete barriers and base slabs, as shown on the Design Builder's Approved Drawings.
 - 4. General notes pertaining to design criteria and wall construction.
 - 5. A listing of the summary of material quantities for each wall.
 - 6. Details of sleeves and pipes and other embedded items to be installed through the walls.
 - 7. Clearly indicated details for construction of walls or reinforcing elements around drainage, foundations, utilities, culverts, or any other potential obstructions.
 - 8. Details of the architectural treatment of facing panels.
 - 9. Drainage design detail and design scheme.
 - 10. Location of utilities.
 - 11. Sequence and schedule of construction, including overall construction schedule.
 - 12. Methods of excavation and backfill.

13. Method of maintaining stability of excavated trenches.
 14. Method of monitoring plumbness and deviation of wall.
 15. Excavation support system, if any.
 16. Any acceptance testing and frequency.
 17. Details and location of all necessary construction and expansion joints. Due to the concerns of differential settlement, vertical slip joints shall be designed and constructed at a spacing of no greater than 30 feet apart.
 18. Connection details at the interface of the wall and any adjacent proposed cast in place retaining wall or abutment structure.
 19. Details of impermeable membrane connection to facing panels and to runoff collection system.
- G. Submit Plan of Actions to be implemented in the event any Response Value for deformation, as specified in Table 02359-1, is reached.

**TABLE 02359-1
RESPONSE VALUES**

Monitoring Type	Value
<u>Lateral Deflection of Earth Support Wall</u>	
Top of wall	1%
Mid-Point of wall	0.5%
<u>Vertical Deflection of Earth Support Wall</u>	
Top of wall	0.5 inches per 10 feet of wall
<u>Ground Surface Settlement</u>	
Top of Rail	¼ inch

- H. The Plan of Actions shall be positive measures by the Design Builder to limit further movement of the wall.
The details of the mitigating measures shall include a schedule of implementation, location and/or availability of materials, and a detailed description of the method of implementation. The Design Builder shall be prepared to work twenty four (24) hours per day to implement such measures.
- I. Samples:
1. Modular Precast Block Units shall be submitted in accordance with the provisions of Section 03410 –PLANT-PRECAST STRUCTURAL CONCRETE.
- J. Design Builder shall submit a Manufacturer's certification, 30 days prior to start of work, that the retaining wall system components meet the requirements of this specification and the structure design.

K. Design Builder shall submit a test report documenting strength of specific modular concrete.

1.5 DESIGN REQUIREMENTS

- A. The Modular Precast Block Retaining Walls shall be designed to provide the grade separation shown on the Design Builder's Approved Drawings with a service life of not less than 75 years.
- B. The Modular Precast Block Retaining Wall System shall be designed in accordance with the manufacturer's requirements, as specified herein, with the minimum requirements shown on the Design Builder's Approved Drawings, in accordance with AREMA (American Railway Engineering and Maintenance of Way Association), Manual for Railway Engineering, and in accordance with the AASHTO LRFD Standard Specifications for Highway Bridges. Design the wall system to support all applicable loads including, earth pressures, unrelieved hydrostatic pressures, Railroad loads (E-80), HS20-44 traffic loads, and any adjacent structure surcharge loads, utility loads, equipment loads, and construction loads. HS20-44 load shall be as set forth by the latest edition of AASHTO Standard Specification for Highway Bridges. The Design Builder shall verify that the latest editions of AREMA Manual and AASHTO manuals are being used for design. Where conflicting requirements occur, the more stringent shall govern. The design shall consider the internal and external stability of the wall mass.
- C. The structures shall be designed such that the following minimum factors of safety are achieved:
- | | |
|---------------------------|-----|
| 1. Sliding | 1.5 |
| 2. Overturning | 2.0 |
| 3. Bearing Capacity | 2.5 |
| 4. Global Slope Stability | 1.5 |
- D. The minimum wall embedment shall be to the local frost depth or at least 4 feet from the bottom of the leveling pad to the final exterior grade. The bottom of crushed stone leveling pads is inclusive of the 4 foot minimum.
- E. The modular precast block retaining wall design shall follow the dimensions of the wall envelope shown on the Design Builder's Approved Drawings. Base of leveling pad elevation shall be as shown on the Design Builder's Approved Drawings. All wall elements shall be within the right-of-way limits shown on the Design Builder's Approved Drawings. The facing panels shall be placed so as not to interfere with drainage or other utilities, or other potential obstructions.
- F. Facing panels shall have tongue and groove, ship lap, or similar approved connections along all joints, both vertical and horizontal. The top of wall panels shall be sloped to match the profile or as shown on the Design Builder's Approved Drawings.
- G. Modular precast block facing panels shall be installed on 6 inch cast-in-place concrete or 12 inch crushed stone leveling pads.
- H. All appurtenances behind, in front of, under, mounted upon, or passing through the wall such as drainage structures, utilities, fences, light poles, or other appurtenances shown on the Contract Drawings shall be accounted for in the final design of the wall.
- I. Walls or wall sections which intersect at an angle of one hundred thirty (130) degrees or less shall include a special corner element to cover the joint formed by the abutting walls or wall sections and to permit relative movement. Corner elements shall not consist of connected standard facing panels.
- J. Vertical slip joints shall be designed and installed at a spacing of no greater than 30 feet apart.

1.6 QUALITY ASSURANCE

- A. Modular Precast Blocks units shall be manufactured in a concrete products plant with approved facilities. Before proceeding with production, precast sample units shall be provided for the Engineer's acceptance. These samples shall be kept at the plant to be used for comparison purposes during production. The Inspector shall be allowed access to the plant for a prescheduled inspection.
- B. Verify that all calculations and working/shop drawings are signed and stamped by a Professional Engineer registered in the Commonwealth of Massachusetts and specializing in structural/geotechnical construction.
- C. Requirements for the precast units for this project may be different from the standard units from the approved systems. Appropriate, alternative details shall be prepared by the Design Builder and submitted for approval by the Engineer.
- D. All MPB walls shall be built in accordance with the Design Builder's Approved Drawings and accepted Shop Drawings for the proposed wall systems.
- E. A qualified representative from the wall manufacturer shall be present during construction of the MPB walls.
 - 1. One or more qualified civil engineer(s) representing the Manufacturer of the MPB wall shall be on site at the start of construction of each MPB wall to assist and advise the Design Builder in methods of construction and to advise the Engineer, in methods of ensuring that the walls are constructed in accordance with the Manufacturer's recommendations. The Engineer shall be notified as to which day the representative shall be present at the site. Additionally, the representative shall be available on an as-needed basis, as requested by the Engineer at any time during construction of the walls. In no case shall changes in the Design Builder's Approved Drawings or specifications recommended by the Manufacturer's Representative be made unless submitted in writing and approved by the Engineer.
- F. The Design Builder shall submit to the Engineer for approval a daily report of the wall Manufacturer's Representative activities. The report shall be prepared by the wall Manufacturer's Representative and shall describe all items investigated, inspected, and discussed with MBTA inspectors and personnel on the job site for that day.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. The Design Builder shall submit for approval, prior to fabrication, all materials to assure that the proper type, grade, color, and certification have been received.
- B. The Design Builder shall check all materials upon delivery to assure that the proper type, grade, color, and certification have been received.
- C. The Design Builder shall protect all materials from damage due to jobsite conditions and in accordance with manufacturer's recommendations. Damaged materials shall not be incorporated into the work.

PART 2 - PRODUCTS

2.1 GENERAL

- A. The Design Builder shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Design Builder, or the supplier as his agent, shall furnish the Engineer a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the Engineer.

2.2 MATERIALS

A. Modular Precast Block Units

1. The precast units shall be manufactured of 5000 psi, 3/4 in, air-entrained cement concrete in accordance with the provisions of Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE and the following:
 - a. The panels shall be cast using custom architectural form liners that conform to the finish as shown on the Design Builder's Approved Drawings.
 1. All modular precast blocks to be manufactured to maintain a flush face upon completion of installation.
 2. Double sided panels shall be used when a panel or any portion of a panel is exposed above final grade. This applies to all end units as well.
 3. The top panel shall be designed such that the majority of the top surface is below finish grade.
 - b. Tolerances - All units shall be manufactured within the following tolerances:
 1. Panel Dimensions - Position panel connection devices within 1 inch, except for all other dimensions within 3/16 inch.
 2. Panel Squareness - Squareness as determined by the difference between the two diagonals shall not exceed 1/2 inch.

B. Attachment Devices

1. All attachment devices shall be carefully inspected to insure they are true to size and free from defects that may impair their strength and durability.
2. Coil Embeds/Loop Embeds - shall be fabricated of cold drawn steel wire conforming to ASTM A510M, UNS G 10350 or AASHTO M32/M (ASTM A82). Loop imbeds shall be welded in accordance with AASHTO M55/M (ASTM A185). Both shall be galvanized in accordance with ASTM B633.
3. Coil Embed Grease - The cavity of each coil embed shall be completely filled with no-oxide type grease.
4. Coil Bolt - The coil bolts shall have 2 inches of thread. They shall be cast of 80-55-06 ductile iron conforming to ASTM A536. Galvanization shall conform to ASTM B633.
5. Fasteners - Fasteners shall consist of hexagonal cap screw bolts and nuts, which are galvanized and conform to the requirements of AASHTO M164/M (ASTM A325M) or equivalent.
6. Connector Bars and Pins - Connector pins and mat bars shall be fabricated from cold drawn steel wire confirming to the requirements of AASHTO M32/M (ASTM A82) and

welded to the soil reinforcement mat. Galvanization shall conform to AASHTO M111/M (ASTM A123M).

C. Joint Materials

1. Installed to the dimensions and thickness in accordance with the Design Builder’s Approved Drawings or approved shop drawings.
2. Provide either preformed ethylene propylene diene monomer (EPDM) rubber pads conforming to ASTM D2000 for Type AA, 812 rubber or neoprene elastomeric bearing pads having a Durometer Hardness of 55 ±5.
3. Cover all joints between panels on the back side of the wall with a geotextile fabric. The geotextile fabric shall conform to the requirements of AASHTO M288. Slit film and multifilament woven and resin bonded non-woven geotextile fabrics are not allowed for this application. The minimum width of the fabric shall be at least 18 inches. Lap fabric at least 6 inches where splices are required.

D. Wall Base

1. The wall base shall consist of a minimum of 12” dense graded crushed aggregate. A minimum of 75% of coarse material shall have 2 or more fractured faces. Wall base material shall meet the following gradation:

<u>US Standard Sieve Size</u>	<u>Percent Passing</u>
1-1/2”	80-100
3/4”	50-90
#4	0-40
#200	0-5

2. The Design Builder may substitute the granular base material for concrete with a minimum 28-day compressive strength of 3,000 psi, in accordance with Section 03300 – CAST-IN-PLACE CONCRETE. Concrete leveling pad shall have minimum dimensions of 6 inch thickness, a width that extends beyond the inner and outer concrete face by a minimum of 6”, and be placed at the design elevation shown on the Design Builder’s Approved Drawings within a 1/8 inch tolerance. Crushed stone leveling pads shall have minimum dimensions of 12 inch thickness, a width that extends beyond the inner and outer concrete face by a minimum of 12 inches, and be placed at the design elevation shown on the Design Builder’s Approved Drawings within ¼ inch tolerance.

E. Unit Fill and Select Zone Behind MPB Blocks

1. Unit fill and select zone behind the MPB blocks shall meet the requirements of Section 02300 – EARTHWORK, and consist of clean 1” minus crushed stone or crushed gravel meeting the following gradation tested in accordance with ASTM D422:

<u>Sieve Size</u>	<u>Percent Passing</u>
1 inch	100
3/4 inch	75-100
No. 4	0 - 10
No. 50	0 – 5

2. One cubic foot, minimum, of drainage fill shall be used for each square foot of wall face.

Drainage fill shall be placed within cores of, between, and behind units to meet this requirement.

F. Backfill Material

1. All other backfill behind and in front of the wall shall consist of suitable on-site soil or imported borrow and shall be approved by the Geotechnical Engineer. Backfill shall generally consist of sands, silts, or lean clays with a liquid limit less than 45 and a plasticity index less than 20. Fat clay soils, cobbles, and large rock should generally be avoided unless approved by the Geotechnical Engineer based on local practices. Frozen soils, excessively wet or dry soils, debris, and deleterious materials shall not be used.
2. For areas adjacent to the tracks, see AREMA 2010 Section 1.2.3 – Fills.

G. Drainage Pipe

1. If required, the Drainage pipe shall be perforated or slotted PVC pipe manufactured in accordance with ASTM D3034 or corrugated HDPE pipe manufactured in accordance with ASTM F2619.

H. Geocomposite Strip

1. Prefabricated Drainage Mat/Geocomposite strip: Miradrain 6000, Amerdrain 500, or approved equivalent material.

2.3 ACCEPTANCE OF MATERIALS

- A. The Design Builder shall furnish to the Engineer a Certificate of Compliance certifying that the above materials comply with the applicable contract specifications. A copy of all test results performed by the Design Builder necessary to assure contract compliance shall also be furnished to the Engineer. Acceptance shall be based on the Certificate of Compliance, accompanying test reports, and visual inspection by the Engineer.

PART 3 - EXECUTION

3.1 EXCAVATION

- A. Design Builder shall excavate to the lines and grades shown on the Design Builder's Approved Drawings. The manufacturer's representative and the Engineer shall inspect the excavation and approve prior to placement of leveling material or fill soils. Proof roll foundation area as directed to determine if remedial work is required.
- B. Remove all unsuitable subgrade material and replace with new granular structural fill (borrow) per specification 02300 – EARTHWORK, which shall be performed below the base of leveling pad and within the entire modular precast block footprint, as shown on the Design Builder's Approved Drawings. A layer of high strength/density woven geotextile, such as Mirafi HP570 or equivalent, shall be placed at the base of undercut zone prior to new structural fill placement.
- C. Earth excavations shall be performed in accordance with the applicable requirements of Section 02300 – EARTHWORK, and in close conformity to the limits and construction stages shown on the Design Builder's Approved Drawings.

3.2 FOUNDATION SOIL PREPARATION

- A. The foundation soils for the structure shall be graded level as recommended by the manufacturers design. Prior to wall construction, undercut and replacement of the foundation soils shall be performed and the base of the undercut shall be compacted with a hand compactor. Any foundation soils found to be unsuitable shall be further removed and replaced in accordance with the requirements of Section 02300 – EARTHWORK. The foundation for the structure shall be approved by the Engineer before erection is started.
- B. The maximum backfill lift thickness for foundation preparation after compaction shall not exceed 8 inches.

3.3 BASE LEVELING PAD

- A. Leveling pad base material shall be placed to the lines and grades shown on the Design Builder's Approved Drawings, to a minimum thickness of 12 inches and extend laterally a minimum of 12 inches in front and behind the modular precast block retaining wall unit.
- B. Leveling pad shall be prepared to insure full contact to the base surface of the concrete units.
Allowable elevation tolerances are 1/8 inch from the design elevation for concrete leveling pads and 1/4 inch from design elevation for crushed stone leveling pads.

3.4 WALL ERECTION

- A. Precast concrete units shall be placed so that their final position is vertical as shown on the Design Builder's Approved Drawings. For erection, units are handled by means of lifting devices as designed by the wall unit manufacturer. Wall Units should be placed in successive horizontal lifts in the sequence shown on the approved Shop Drawings as backfill placement proceeds. As backfill material is placed behind the units, the units shall be maintained in position by means of temporary wedges or bracing according to the wall supplier's recommendations. Concrete facing vertical tolerances and horizontal alignment tolerances shall not exceed 1/2 inches when measured with a 10 foot long straight edge. During construction, the maximum allowable offset in any panel joint shall be 3/4 inch. The overall vertical tolerance of the wall (top to bottom) shall not exceed 1/2 inch per 10 feet of wall height.

3.5 BACKFILL PLACEMENT

- A. Backfill placement shall closely follow erection of each course of wall units. Backfill shall be placed in such a manner as to avoid any damage or disturbance of the wall materials or misalignment of the wall units. Any wall materials which become damaged during backfill placement shall be removed and replaced at the Design Builder's expense. Any misalignment or distortion of the wall units due to placement of backfill outside the limits of this specification shall be corrected at the Design Builder's expense. At each wall unit level, the backfill shall be placed to the level of the connection. Backfill placement methods near the facing shall assure that no voids exist.
- B. Backfill shall be compacted to 95 percent of the maximum density as determined by AASHTO T-99, Method C or D (with oversize corrections as outlined in Note 7 of that test). For backfills

containing more than 30 percent retained on the 3/4 inch sieve, a method of compaction consisting of a hand compactor behind the walls shall be used.

- C. The moisture content of the backfill material prior to and during compaction shall be uniformly distributed throughout each layer. Backfill materials shall have a placement moisture content less than or equal to the optimum moisture content. Backfill material with a placement moisture content in excess of the optimum moisture content shall be removed and reworked until the moisture content is uniformly acceptable throughout the entire lift.
- D. The maximum lift thickness for backfill materials after compaction shall not exceed 10 inches. The Design Builder shall decrease this lift thickness, if necessary, to obtain the specified density.
- E. Compaction within 3 ft of the back face of the wall shall be achieved by a hand compactor.
- F. At the end of each day's operation, the Design Builder shall slope the last lift of the backfill away from the wall facing to rapidly direct runoff away from the wall face. In addition, the Design Builder shall not allow surface runoff from other areas to enter the wall construction site.

3.6 ROADWAY RUNOFF COLLECTION SYSTEM

- A. The Design Builder shall place an impervious membrane and drainage layer at the locations directed by the Engineer after consultation with the modular precast block retaining wall manufacturer's representative. The impervious membrane shall be placed just below the drainage layer. If angular fill material is to be placed above or below the impervious membrane, a suitable thickness of sand shall be used to protect the membrane from puncture. The membrane shall be continuous throughout the length of the wall with watertight seams at any splices. Repair any holes created during installation according to the membrane manufacturer's recommendation before covering.

3.7 AS-BUILT CONSTRUCTION TOLERANCES

- A. Vertical alignment: $\pm 1/2$ " over any 10' distance.
- B. Wall Batter: within 1 percent of design batter.
- C. Horizontal alignment: $\pm 1/2$ " over any 10' distance.
- D. Corners, bends, curves ± 1 feet to theoretical location.
- E. Maximum horizontal gap between erected units shall be 1/2 inch.

3.8 FIELD QUALITY CONTROL

- A. The Design Builder shall engage inspection and testing services, including independent laboratories, to provide quality assurance and testing services during construction. This does not relieve the Design Builder from securing the necessary construction control testing during construction.
- B. Testing and inspections services shall only be performed by qualified and experienced technicians and engineers.

- C. As a minimum, quality assurance testing should include foundation soil inspection, soil and backfill testing, verification of final design parameters, and observation of construction for general compliance with Design Builder's Approved Drawings and specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02360

DRIVEN PILES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the furnishing of all labor, materials, tools, and equipment, and performance of all operations necessary for the design, installation, and testing of driven piles for structures.
- B. The work of this Section also includes, but is not limited to, the following:
 - 1. Evaluate need for verification borings in the vicinity of driven pile locations. Perform verification borings, as needed, to allow for design of driven piles.
 - 2. The Design-Builder's design shall meet the requirements of all applicable Codes and Specifications. The design shall be prepared, signed, sealed, and dated by a Professional Engineer registered in the Commonwealth of Massachusetts.
 - 3. Perform dynamic and/or static load testing of driven piles, as required by the relevant code applicable to the driven pile supported structure.
 - 4. Revise installation procedures and driven pile length as required based on load test data and/or as directed by the MBTA.
- C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements".
 - 2. Section 02015 – GEOTECHNICAL INSTRUMENTATION
 - 3. Section 03300 - CAST-IN-PLACE CONCRETE.

1.2 DEFINITIONS

- A. Test Pile: An individual pile, which is observed to determine its behavior during driving and under static axial compression load.
- B. Reaction Pile: An individual pile which provides the reaction load required to perform the load test on a test pile. During this process the reaction pile can be subjected to either an axial compression load or an axial tension load.

1.3 SUBMITTALS

- A. General: Submit items B through F for acceptance by the MBTA not less than thirty (30) calendar days prior to the start of the respective work:

- B. The Design-Builder shall prepare and submit to the Engineer for review and approval, working drawings and design submission, signed, sealed, and dated by a Professional Engineer registered in the Commonwealth of Massachusetts, describing the driven pile system or systems intended for use. The design submittal shall include the applicable code requirements and design references. The working drawings and design submission shall be submitted 30 calendar days prior to the commencement of the driven work. The working drawing and design submission shall include a drawing showing the location and orientation of each driven pile, splice details, pile tips, installation procedures for driven-piles including equipment technical specifications and all calculations showing axial and lateral resistance capacities and estimated deformations. The working drawing and design submission shall include a monitoring schedule, installation procedures and location plans for vibration/noise monitoring as specified in Volume 2 Technical Provisions, Exhibit 2I, “Additional Project Requirements”, and Section 02015 – GEOTECHNICAL INSTRUMENTATION.
- C. Submit boring logs for verification borings to the MBTA.
- D. Pile Schedule and Installation Plan
 - 1. Steel H-Pile: Show typical details of size, weight, splices, tip construction, and welding design of section connection.
 - 2. Steel Pipe: Show typical details of sizes, configuration, tip construction, and welding design of section connection, and class of concrete fill.
 - 3. Prestressed Concrete Piles (Pretensioned): Show typical details of size, weight, splices, tip construction, and class of concrete.
 - 4. Piles intended for use as reaction test piles: Show tension steel reinforcing and connections for uplift loads.
- E. Pile Driving Sequential Layout
 - 1. Submit layout drawings showing the proposed sequence of driving the piles.
 - 2. Indicate if preaugering is required prior to driving piles.
 - 3. On the sequential layout show each pile identified as indicated on the working drawings, its driving sequence number, type, size, and load bearing capacity.
- F. Equipment Review and Working Drawings
 - 1. Submit complete list of the equipment proposed for use, including a description of the characteristics of each piece of driving equipment.
 - 2. Submit working drawings of driving accessories showing compatibility with the size, configuration, handling, and driving requirements of each type of pile indicated on the Contract Drawings.
 - 3. Submit working drawings showing the methods and equipment proposed for loading test piles.
- G. Pile Driving Record. Maintain a pile driving record during pile driving and submit it to the MBTA upon completion of pile driving. On the record indicate, for each pile driven, the information specified, and the following: type and rating of driving equipment, blow count, number of blows per inch penetration for the last 12 inches, and any unusual conditions encountered during driving.

1.4 QUALITY ASSURANCE

- A. Installation Tolerances
 - 1. Drive piles as close as practicable to the plan location. A maximum lateral deviation from the correct location at cutoff elevation equal to 3 inches will be permitted. A maximum vertical

- deviation from design cutoff elevation equal to 1 inch will be permitted. Pulling piles into position will not be permitted.
2. Provide to the MBTA an accurate survey when otherwise acceptably installed piles exceed the specified tolerances and are subject to eccentric loading. The Design-Builder will then analytically determine the total loads on individual piles based on this survey data, and provide the analyses to the MBTA. If the load on any pile exceeds 110% of the specified load capacity, appropriate corrections shall be made subject to approval by the MBTA.
- B. The MBTA may review the proposed driving equipment, accessories, and methods for adequacy for the conditions expected to be encountered. The adequacy of the equipment and accessories shall remain the responsibility of the Design-Builder. Should the equipment used by the Design-Builder prove inadequate to drive the scheduled types of piles in the locations shown, or should the use rate of accessories show damage to the piles, the MBTA shall require replacement, or use different types of expendable accessories, or additional equipment.
- C. Piles delivered to the site shall be visually inspected by the Design-Builder prior to installation. Piles which are cracked, bowed, chipped, undersize, or which break under driving stresses shall be rejected; remove such piles from the site and replace with sound piles.
- D. Reference Codes and Specifications:
1. American Society for Testing and Materials (ASTM):
 - a. A252, Welded and Seamless Pipe Piles,
 - b. A615, Reinforcing Bars,
 - c. A722 Thread Bars,
 - d. C33, Standard Specification for Concrete Aggregates,
 - e. C109, Compressive Strength of Hydraulic Cement Mortars (using two inch or 50 mm cube specimens),
 - f. C150, Portland Cement,
 - g. D1143, Standard Test Method for Piles under Static Axial Compressive Load,
 - h. D1586, Standard Test Method for Penetration Test and Split Barrel Sampling of Soils,
 - i. D2113, Standard Practice for Diamond Core Drilling for Site Investigation,
 - j. A36, Specification for Structural Steel,
 - k. C136, Sieve Analysis of Fine and Coarse Aggregates,
 - l. C939, Flow of Grout for Preplaced - Aggregate Concrete.
 2. American Concrete Institute (ACI)
 - a. ACI 304, Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete.
 - b. ACI 305, Hot Weather Concreting
 - c. ACI 306, Cold Weather Concreting
 3. American Welding Society (AWS):
 - a. AWS D1.1, Structural Welding Code
 4. Commonwealth of Massachusetts, State Building Code.
 5. AREMA 2016
 6. AASHTO LRFD Bridge Design Specifications.

PART 2 - PRODUCTS

2.1 STEEL H-PILES

- A. ASTM A36 and the AISC Manual of Steel Construction.

2.2 STEEL PIPE PILES

- A. Shell: Steel pipe conforming to ASTM A252, Seamless, diameter and weight as indicated on the working drawings.

2.3 PRECAST, PRESTRESSED CONCRETE PILES

- A. Materials:

1. Portland Cement: ASTM C 150, "Standard Specification for Portland Cement."
2. Aggregates: ASTM C 33, "Standard Specification for Concrete Aggregates."
3. Water: Clean, potable and free from injurious amounts of oils, acids, alkalis, organic materials, or other substances that may be deleterious to concrete or steel.
4. Admixtures: ASTM C 494, "Standard Specification for Chemical Admixtures for Concrete."
5. Mild Steel Reinforcement: ASTM A 615, "Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement," Grade 60.
6. Wire Spiral Ties: ASTM A 82 "Standard Specification for Steel Wire, Plain, for Concrete Reinforcement," smooth or deformed.
7. Prestressing Strand: ASTM A 416, "Standard Specification for Steel Strand, Uncoated Seven-Wire, for Prestressed Concrete."

- 8. Concrete Mixtures:

- a. Mix designs shall be developed by the pile Manufacturer using the materials as specified herein. The designs shall comply with the requirements of ACI 318 and shall have been prepared in accordance with ACI 211.1, for the concrete strengths shown on the working drawings. The mix designs shall be based on materials previously evaluated by the pile Manufacturer using established methods of statistical quality control that conform to ACI 214.

- B. Formwork:

1. Provide exterior forms of steel on concrete founded casting beds. Side forms for square piles may have minimum draft adequate for stripping. Interior forms shall be of steel and either the fixed-collapsible or moving-mandrel type capable of maintaining specified dimensional tolerances. Forms shall be cleaned and oiled prior to placement of reinforcing.

- C. Placement of Reinforcing:

1. Place prestressing strands symmetrically in the piles and jack simultaneously to specified force. Space spiral wire to specified pitch and tie adequately to maintain position during placement of concrete.
- D. Placement of Concrete:
1. Place concrete continuously and consolidate with high frequency vibration. Strike-off unformed surfaces and apply good float finish.
- E. Curing:
1. Cover forms with moisture-retaining cover and apply heat in uniform manner. Embed thermocouples in piles and connect through central computer to electrically heated test cylinders for constant monitoring of curing temperatures and to insure that test cylinders and piles are heated equally.
- F. Stripping and Handling:
1. When a test cylinder made from the concrete pour for the piles involved reaches the minimum release strength specified, detension strands gradually and simultaneously so as to maintain internal stresses uniform across the pile cross sections. Burn strands flush with ends of piles. Handle and transport piles as described above. Do not drive piles until they have reached their required 28 day strength and have been cured a for a minimum of 10 days.
- G. Finishes:
1. Piles with minor imperfections which do not impair the structural integrity of the pile, such as small surface holes caused by air bubbles, color variations, form joint marks, and minor chips and spalls will be accepted as is. Piles with defects such as honeycomb which could reduce the structural capacity of the pile will be accepted only if repaired to the Engineer's satisfaction.
- H. Patching of Lift Loops:
1. Prior to driving piles in a marine or fresh water location, cut off and patch embedded lifting loops at elevations higher than 10 feet below the mudline using materials and methods as recommended by the Manufacturer.
- I. Manufacturing Tolerances:
1. Length: +6 in., -2 in.
 2. Width or diameter: $\pm 3/8$ in.
 3. Sweep (variation from straight line parallel to centerline of pile) (considered to be a form tolerance): $\pm 1/8$ in. per 10 ft.
 4. Position of tendons: $\pm 1/4$ in.
 5. Wall thickness: $-1/4$ in., $+1/2$ in.
 6. Position of handling devices: +6 in.
 7. Position of steel driving tips: $\pm 1/2$ in.
 8. Variation from specified end squareness or skew: $\pm 1/4$ in. per 12 in., $\pm 1/2$ in. max.
 9. Local straightness any surface: $\pm 1/4$ in. per 10 ft.
 10. Longitudinal spacing of spiral reinforcement: $\pm 3/4$ in.

PART 3 - EXECUTION

3.1 GENERAL

- A. The Design Submittal will specify piling type. End-bearing piles shall be driven to the required bearing value. The bearing value for each pile shall be determined by the Design-Builder. Friction piles shall be driven to the required penetration, as determined by the Design-Builder.
- B. The Design-Builder shall order and drive the test piling. The safe bearing capacities of the test piling will be determined by the Design-Builder using methods described below. From the test pile data and behavior and his subsurface exploration data, the Design-Builder will determine the penetration required. The Design-Builder may also determine the required penetration based upon settlement criteria or any other factors which in the opinion of the Design-Builder are applicable to the work.
- C. Bearing Value and Penetration: The determination of the safe bearing value will be obtained from observing and recording the behavior of the test pile(s) from the time first placed in the leads until it attains practical refusal or reaches the required depth and/or required axial capacity presented in the Design Submittal.

3.2 PILE LOAD TESTS FOR PILES UNDER AXIAL COMPRESSION LOAD

- A. Install test piles and reaction piles, of the same type and kind as permanent piles, in the locations required by design.
 - 1. Reinforce reaction piles for the full length to resist uplift loads.
 - 2. Install test piles vertically.
- B. Test piles which pass the load test in an undamaged condition may be utilized as permanent piles in the work. Reaction piles are not to be used as permanent piles. Either withdraw reaction piles and damaged test piles and remove from the site, or cut them off three feet below any structure to be installed above.
- C. A minimum of one test per structure. Use ASTM D1143 at a minimum, other test procedures may be submitted for review and acceptance by MBTA.
- D. When the safe bearing capacity of the pile is less than 90% of the required bearing capacity the MBTA may require additional load tests.
- E. The MBTA may require the Design-Builder to make additional load tests in the event that the behavior of the test pile or any other pile shows any peculiarity, erratic actions, or otherwise causes suspicion as to the reliability of the safe bearing capacity determined by the formulae given herein.
- F. Immediately following completion of load testing, submit two copies of a test report to the MBTA. Include in the test report the data required by ASTM D1143.

3.3 DYNAMIC PILE DRIVING TESTING

- A. Dynamic measurements shall be performed in accordance with ASTM D-4945. The Design-Builder shall employ a qualified specialty Consultant, which has successfully completed no less than ten

dynamic pile driving tests, to perform the testing and report preparation for all Dynamic Pile Driving Analysis (PDA) Tests to be performed. The specialty Consultant shall provide pile driving recommendations, including hammer recommendations, pile driving criteria (blows per inch), and criteria for practical refusal.

- B. At least thirty days prior to driving the test piles the Design-Builder shall submit to the MBTA for review and approval the qualified specialty consultant, as well as the complete installation, and testing procedures. The submittal shall include all necessary pile driving equipment and support facilities to drive the piles to capacities and depths shown on the plans within allowable stress limits. As part of the submittal the Design-Builder's Consultant shall perform wave equation analyses, and a summary report confirming that the pile driving system proposed by the Design-Builder can meet the capacity, driving resistance and allowable stress limits.
- C. The pile test equipment shall conform to the requirements of ASTM D-4945, Standard Test Method for High Strain Dynamic Testing of Piles, and be capable of testing the pile to one and one-half times the ultimate pile capacity. An experienced engineer, who has successfully completed no less than ten dynamic pile driving tests, shall operate the Pile Driving Analyzer in the field.
- D. Prior to lifting the pile to be dynamically tested, the Design-Builder shall provide as a minimum 3 feet of clear access to 180 degrees opposite face of the pile for pile preparation. The Consultant shall then drill and prepare holes in the pile for gage attachment.
- E. The Consultant shall attach the gages to the pile before driving the piles. Pile driving shall be performed using routine pile installation procedures. When the level of the gages is within one foot of the ground surface, or obstruction, driving shall be halted to remove the gages from the pile. If additional driving is required, the pile shall be spliced and gages shall be reattached to the head of the next pile segment.
- F. With the dynamic testing equipment attached, the Design-Builder shall drive the pile to the design penetration depth or to a depth specified in their design. The Design-Builder will use the ultimate pile capacity estimates at the time of driving and/or restriking from dynamic test methods to determine the required pile penetration depth for the ultimate pile capacity. The stresses in the piles shall be monitored during driving with the dynamic test equipment to ensure that the actual driving stresses do not exceed the maximum allowed values. If necessary, the Design-Builder shall reduce the driving energy transmitted to the pile by using additional cushions or reducing the energy output of the hammer in order to maintain driving stresses below the maximum values. If non-axial driving is indicated by dynamic test equipment measurements, the Design-Builder shall immediately realign the driving system.
- G. After the initial drive of the pile, the Design-Builder shall wait a minimum of 24 hours and restrike the dynamic monitoring test pile with the dynamic testing instruments attached. A cold hammer shall not be used for the restrike. The hammer shall be warmed up before restrike begins by applying at least 20 blows to another pile. The maximum amount of penetration allowed during restrike shall be 6 inches, or 50 hammer blows, whichever occurs first.
- H. The Design Builder shall provide preliminary estimates of pile capacity of the test pile to the MBTA within 24 hours of the restrike of each tested pile. The Design Builder shall also prepare and submit a written report within 5 calendar days of the completion of the testing. This report shall contain a discussion of the pile capacity obtained from the dynamic testing. CAPWAP analyses of the dynamic testing data shall be performed on data obtained at the end of initial driving and the beginning of restrike. The MBTA may request additional analyses at selected pile penetration depths. The report shall also discuss hammer and driving system performance, driving stress levels, and pile integrity. The report is to be prepared, signed, sealed and dated by a Professional Engineer licensed in the

Commonwealth of Massachusetts. No production piles can be driven until the report has been submitted and approved by the MBTA.

- I. Test piles shall be driven to a driving resistance established by the Design-Builder at the estimated pile toe elevation. The Design-Builder shall excavate the ground at each test pile to the elevation of the bottom of the footing before the pile is driven. All test piles shall be driven with impact hammers unless specifically otherwise required by design. In general, the specified length of test piles shall be greater than the estimated length of production piles in order to provide for variation in soil conditions. The driving equipment used for driving test piles shall be identical to the equipment proposed for driving the production piling.
- J. Test piles that do not attain the specified driving resistance at a depth of 6 inches above the estimated pile tip elevation, or are specified as a dynamic monitoring pile, shall be redriven after being allowed to set up. The minimum time period before restrrike shall be 24 hours, or as required by design. A cold hammer shall not be used for the restrrike. The hammer used shall be warmed up by applying at least 20 blows to another pile. The maximum amount of penetration allowed during restrrike shall be 6 inches, or 50 hammer blows, whichever occurs first.
- K. The Design-Builder shall not order piling to be used in the permanent structure until test pile data has been reviewed by the MBTA.

3.4 INSTALLATION OF PILES

- A. General. Provide piling of the type required by design and of the length and configuration necessary to:
 - 1. Achieve the required penetration as required by the design;
 - 2. Extend into the pile cap or structure footing to the location as required by design; and
 - 3. Attain the indicated bearing capacity.
- B. Install piling to the required penetration, or to the required bearing, as indicated in the design. Water jetting to obtain the required penetration will not be permitted.
- C. The construction of driven piles shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design-Builder.
- D. Adjacent structures shall be monitored and protected as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
- E. Vibration monitoring for driven pile installation will be performed by the Design-Builder’s Instrumentation Engineer as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
- F. Construction operations not to exceed specified noise limits in accordance with Volume 2 Technical Provisions, Exhibit 2I, “Additional Project Requirements”.
- G. Predrilled Holes
 - 1. Predrilling through existing embankments and fill material or natural soils with the potential for containing obstructions shall be performed in accordance with the design requirements. After driving the pile, fill any annular space around the pile with dry sand or pea gravel.
- H. Drive Piles
 - 1. Do not drive piles within 20 feet of concrete less than seven days old.

2. Drive piles at interior of bases of footings before driving perimeter piles.
3. If necessary, provide adequate lateral support for installed individual piles, to prevent excessive temporary flexural stresses or movement of the pile top out of tolerance.
4. Maintain the hammer coaxial with the pile during the driving operation by using a combination of driving cap and leads. Equipment used to drive production piles shall be identical to the equipment used to drive acceptable test piles.
5. Investigate any sudden decrease in driving resistance for possible breakage of the pile. If sudden decrease in driving resistance cannot be correlated to boring data or some incident in the driving, and if the pile cannot be removed for inspection, such decrease in driving resistance shall be cause for rejection of the pile.
6. Redrive any pile which is raised during driving of adjacent piles, to at least the original tip elevation.
7. Splice piles only by methods and at places accepted by the Engineer.
8. Cut off piles at top elevation as required by design. Replace or repair, to the satisfaction of the MBTA, piles which are damaged when cut off.

I. Steel H-Piles

1. Design the driving cap with grooves in the base that loosely conform to the shape of the pile. The bearing surface of the grooves shall be true, without roughness. The driving cap shall extend down the side of the pile at least four inches and be loosely attached to the hammer so that it will at all times rest squarely over the entire surface of the pile.
2. Make splices as detailed on the Working Drawings by electric-arc field welding in accordance with AWS D1.1. Cut-off damaged portion of pile top before splicing. Take care to align the sections connected so that the axis of the pile will be straight.

J. Steel Pipe Piles

1. Shells shall be inspected for collapse, tears, splits or reduced diameter throughout their length after pipes have been driven and before reinforcing steel and concrete are placed therein.
2. For acceptance, the pile shell shall be:
 - a. Free of collapsed sections and tears;
 - b. Free of water, except that a minor amount of water may be allowed if it can be absorbed by placing a suitable amount of dry sand-cement mixture in the tip of the pile; and
 - c. Visible to the bottom of the casing.
3. Remove rejected pipe piles and replace with new pipe piles. When rejected pipes cannot be removed, furnish and install replacements. Cut off abandoned pipes three feet below the structure and fill the abandoned pipes with concrete. Backfill and compact holes.
4. Assemble reinforcing steel, if any, as a complete unit and install in pile before starting to place concrete.

5. Place concrete through a short funnel hopper on the top of the pipe. Vibration of the concrete will not be required except in the top 15 feet of the pipe. Discharge concrete into the hopper at a continuous and rapid rate.

K. Precast, Prestressed Concrete Piles

1. Piles with approved mechanical splices shall be permitted only when shown in the Working Drawings.
2. Suitable techniques shall be used to prevent the spalling or weakening of concrete below the cut-off elevation. For example, during easy driving conditions the stroke shall be reduced to minimize tensile stresses.
3. Cutting Off: Cut off tops of driven piles square with pile axis and at elevations indicated.

L. Remove piles not meeting the requirements of the design and replace with acceptable piles. The Design-Builder may accept piles which do not meet these tolerances, subject to acceptable redesign of the pile group and pile cap.

M. Repair or replace piles which are split, broken, or otherwise damaged. Perform such repair at the discretion of the MBTA, subject to acceptance upon completion.

3.5 MONITORING TRACK MOVEMENT

- A. Before the start of driven pile installation, establish elevations along Top of Rail of nearest track, each rail, spaced approximately every 20 feet in the vicinity of the driven pile work.
- B. Perform two baseline elevation surveys of the Top of Rail before the start of driven pile installation. Survey both vertical and lateral (into excavation) positions.
- C. Perform weekly survey of settlement monitoring points from the beginning of driven pile installation until the structure is completely in placed and fully backfilled.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02362

STEEL SHEET PILE RETAINING WALLS

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing Permanent Steel Sheet Pile Retaining Walls (SSP) along portions of the railroad trackway as shown on the Contract Drawings. The steel sheet pile retaining walls shall form a water-tight barrier to cutoff groundwater/seepage and serve as a flood protection system. The walls include, but are not limited to, driven or vibrated steel sheet piles with a reinforced cast-in-place concrete cap. Additionally they may include welded studs and reinforcing with a cast-in-place concrete or shotcrete facing. Concrete striation details shall be in accordance with the Contract Drawings.
- B. The Contractor shall either pre-trench or use a guide frame to maintain the lines and grades and offset distances to the nearest existing/proposed track. Steel sheeting installed out of tolerance shall be removed and reinstalled at no additional cost to Authority. The Contractor shall prepare a level surface and verify location and orientation of each sheet prior to initiating installation.
- C. The steel sheet pile retaining walls shall be driven to the elevations shown on the Contract Drawings.
- D. The construction of steel sheet pile retaining walls shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Contractor at no additional cost to Authority.
- E. Adjacent structures include but are not limited to the following: existing building to the west of the existing abandoned Red Bridge abutment. Monitor and protect adjacent structures as specified and indicated.
- F. Vibration monitoring for steel sheet pile retaining wall installation shall be performed by Contractor's vibration consultant and monitoring firm as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
- G. Construction operations not to exceed specified noise limits in accordance with Section 01560 - TEMPORARY CONTROLS.
- H. The Contractor shall bear the entire cost and responsibility of correcting any failure, damages, subsidence, upheaval, or cave-ins as a result of installation of the steel sheet pile retaining walls. The Contractor shall pay for all claims, costs, and damages that arise as a result of the work performed at no additional cost to Authority.
- I. The Contractor shall use polyurethane chemical grout to seal leaks at steel sheet pile joints.
- J. Steel sheet piles shall be installed through all material encountered to the depths shown on the Contract Drawings. Installation equipment shall be capable of driving through boulders, and any other obstructions, encountered during installation. If obstruction cannot be driven through, equipment shall be on hand to remove or drill through such obstructions. Sheet piles shall be removed and re-driven if necessary. No additional cost to Authority shall be incurred for this work.

- K. Stray current criteria apply to this wall type in accordance with the Contract Documents.

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:

1. Section 01560 – TEMPORARY CONTROLS
2. Section 02015 – GEOTECHNICAL INSTRUMENTATION
3. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
4. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
5. Section 02300 – EARTHWORK
6. Section 03300 – CAST-IN-PLACE CONCRETE
7. Section 03371 – SHOTCRETE
8. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS
9. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION

1.3 SUBMITTALS

- A. Submit the following in accordance with Section 01300 - SUBMITTALS:

1. Submit the following qualifications four (4) weeks prior to construction:
 - a. Qualifications of Contractor's steel sheet pile retaining wall installer as specified in Paragraph 1.8D.
 - b. Qualifications of Contractor's steel sheet pile retaining wall installation supervisor as specified in Paragraph 1.8E.
 - c. Qualifications of the Contractor's Professional Land Surveyor.

- B. Submit a steel sheet pile retaining wall installation plan at least two (2) weeks prior to start of the construction. The review shall be only for the information of the Owner and third parties for an overall understanding of the project relating to access, maintenance of existing facilities and proper utilization of the site. The Contractor shall remain responsible for the adequacy and safety of the means, methods and sequencing of construction. The plan shall include the following items as a minimum:

1. Proposed steel sheet pile details, location, layout, depths, and methods and sequence of installation and removal.
2. List of equipment used for installing the steel sheet pile retaining wall system.
3. Monitoring schedule, installation procedures and location plans for vibration/noise monitoring as specified in Section 01560 - TEMPORARY CONTROLS and Section 02015 - GEOTECHNICAL INSTRUMENTATION.

- C. Submit the as-built location and top and bottom elevations of the steel sheet pile retaining wall prior to installation of concrete facing and cap. This work is to be performed by a Professional Land Surveyor.

- D. Working Drawings

1. Submit working drawings at least two (2) weeks before beginning excavation or installation of excavation support system and bracing. Submit each sheet pile wall under separate cover and in the sequence of their installation. Submittals in excess of 40 sheets shall require a 60 day review period.
- E. Additional Requirements for Working Drawings – Working drawings shall include the following:
1. Grades and strengths of all construction materials used.
 2. Full excavation depth.
 3. Tip elevation.
 4. Materials, details, arrangement, and method of construction of the permanent steel sheet pile wall system and sequence of construction. For temporary sheet pile walls used as excavation support system see Section 02260 – Excavation Support and Protection.
 5. Method for attaching facing components and concrete cap beam.
 6. Loads on the excavation support system for various stages of excavation.
 7. Anticipated equipment, traffic (and other surcharge) loads on adjacent ground during construction.
 8. Existing utility facilities, including underground and overhead utilities. After checking locations of utilities by field investigations, determine which affect or potentially may affect the wall.
- F. Submit Plan of Actions to be implemented in the event any Response Value for deformation, as specified in Table 02362-1, is reached.

TABLE 02362-1 RESPONSE VALUES

Monitoring Type	Value
<u>Lateral Deflection of Earth Support Wall</u>	
Top of steel sheet	1.5%
Mid-Point of steel sheet	0.75%
<u>Ground Surface Settlement</u>	
Top of Rail	1/4 inch

- G. The Plan of Actions shall be positive measures by the Contractor to limit further movement of the wall. The details of the mitigating measures shall include a schedule of implementation, location and/or availability of materials, and a detailed description of the method of implementation. The Contractor shall be prepared to work twenty four (24) hours per day to implement such measures.
- H. Submit Welder Qualifications and Welding Procedures in accordance with AWS D1.1.
- I. Submit descriptive data and operating procedures for all equipment to be used. This shall include, at a minimum, machinery required to install wall and bracing, excavate soil, and remove obstructions. Submit all pertinent data including sizes, weights, capacities, torques and operating frequencies.

- J. Review of the wall system by the Engineer shall not relieve the Contractor from the responsibility for the adequacy of the installation and construction of excavation support system.
- K. Means and methods to advance through obstructions. Review and approval of submittal by Engineer or Authority does not relieve the Contractor in any way from the responsibility to complete the construction.
- L. Submittals reviewed beyond the second rejection (or required re-submittal) shall be reviewed by the Engineer at the Contractors expense.

1.4 TOLERANCES

- A. Variation of center of any steel sheet pile from the required plan location: Maximum 3 inches, measured at the existing ground surface in any horizontal direction.
- B. Vertical tolerance of the steel sheet pile shall be ± 1 " from Contract Drawing elevations.
- C. Angular deviation of the steel sheet pile shall be less than 1% of the height measured from the top of the sheet to the bottom of the excavation.
- D. Wall elevation tolerance of the completed cap is minus 0 inches, plus 1/2 inches.
- E. Refer to attached Table 02362-1 for response values.
- F. Any steel sheet pile wall or its components not in conformance with the above tolerances shall be rejected. The Contractor shall notify the Engineer in writing and submit a Plan of Action to bring the wall or its components into conformity. Any rework required to bring the wall into conformity shall be at no additional cost to Authority. Walls that are installed such that they cannot be brought into conformity may need to be replaced in kind at no additional cost to Authority. This shall be at the sole discretion of the Engineer.

1.5 PROJECT CONDITIONS

- A. Visit the site to review all details of the work and working conditions affecting Work under this Section and to verify dimensions in the field including potential interference from adjacent structures and utilities. Notify the Engineer in writing of any discrepancy before performing any work. The Contractor is hereby notified that the job site is located adjacent to the active railroad and existing buildings. Refer to Section 00700 – GENERAL CONDITIONS.
- B. The Contractor shall be responsible for implementing all necessary traffic control measures, which may include but not be limited to traffic cones, barriers, barrels, signs, flagmen and police details.
- C. Provisions for Contingencies
 - 1. Monitor the performance of components of the wall, for horizontal movement, at intervals specified herein.
 - 2. Implement contingency plans if Response Values specified in Table 02362-1 are reached.
 - 3. Have materials and equipment available to implement the accepted Plan of Action.
- D. Consult official records of existing utilities, both surface and subsurface, and their connections to be fully informed on all existing conditions and limitations as they apply to this work and its relation to

other construction work. Proceed with caution in areas of utility facilities. Expose them by hand excavation or by other methods acceptable to the utility owner. Protect existing utilities to remain within and adjacent to the work area in accordance with the requirements of authorities having jurisdiction over same. The Contractor is responsible for any damage to utilities caused by the Contractor's operations and shall restore them to equal or better operation at no additional cost to the Authority.

1.6 SUBSURFACE DATA

- A. Logs of subsurface explorations performed at the site are shown in the Contract Documents. Approximate locations of these subsurface explorations are shown on the Contract Drawings.
- B. The aforementioned data is for general information and is accurate only at the particular locations and times the subsurface explorations were made. It is the Contractor's responsibility to make interpretations and draw conclusions based on the character of materials to be encountered and the impact on his work based on his expert knowledge of the area and of earthwork techniques. The Contractor shall review test pit and boring logs and locations and other pertinent data for the site. The Contractor, at his own expense, may conduct additional subsurface explorations for his own information after obtaining the MBTA's permission.

1.7 QUALITY ASSURANCE

- A. The Contractor shall provide written certification indicating that the equipment used for monitoring of deformation monitoring points (DMP) (as specified in Paragraph 3.2 herein) has been calibrated and maintained in accordance with the test equipment manufacturer's calibration requirements. The accuracy/precision of horizontal survey monitoring shall be to the nearest 0.01 feet.
- B. If sheeting must be pulled for any reason the Contractor shall notify the Engineer for approval prior to implementing any work. The Contractor shall be responsible for backfilling any void space with Controlled Density Fill (CDF) Type 2E in accordance with Section 02300 - EARTHWORK. Any work associated with removal of any sheet pile in the zone of influence of the rail shall require approval of train operations. A track monitoring plan shall be required and any ballasting required will be done at no additional cost to the Authority.

1.8 QUALIFICATIONS OF CONTRACTOR'S INSTRUMENTATION PERSONNEL

- A. The Contractor shall have on his staff, or on the staff of a specialist instrumentation subcontractor, instrumentation/survey personnel who are responsible for furnishing, installing, and maintaining instrumentation/survey equipment, as well as obtaining and interpreting data from the instrumentation/survey equipment.
- B. The Contractor's instrumentation/survey personnel shall have the following qualifications:
 - 1. A minimum of a Bachelor of Science Degree in Civil Engineering or related discipline.
 - 2. A minimum of 2 years' experience in the installation, monitoring, and interpretation of data from the types of monitoring equipment used to monitor deformation-monitoring points (as specified in Paragraph 3.2 herein).
- C. The Contractor's instrumentation personnel shall:

1. Be on site and supervise or perform installation of each monitoring point.
 2. Perform deformation monitoring in accordance with the Project Specifications.
 3. Interpret deformation-monitoring data.
 4. Ensure that deformation-monitoring data is tabulated accurately and in a format consistent with the Project Specifications.
 5. Forward monitoring data to the designated review parties in a timely manner.
- D. The Contractor's sheet pile retaining wall Installer's personnel shall:
1. A minimum of three (3) years experience in the installation of similar types and equal complexity as the proposed system
 2. Have completed not less than three (3) successful excavation support systems of similar type and equal complexity as the proposed system
- E. Install the sheet pile retaining wall system under the supervision of a supervisor having the following qualifications:
1. Not less than five (5) years experience in installation of systems of similar type and equal complexity as the proposed system.
 2. Completed at least five (5) successful excavation support systems of similar type and equal complexity as the proposed system.

PART 2 – PRODUCTS

2.1 GENERAL

- A. The Contractor shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Contractor, or the supplier as his agent, shall furnish the Engineer a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the Engineer.

2.2 MATERIALS

- A. Structural Steel for sheet piles shall conform to applicable requirements of Section 05126 - STRUCTURAL STEEL FOR RETAINING WALLS.
- B. Reinforcement Steel for use within cast-in-place concrete caps and facing shall conform to Section 03300 – CAST-IN-PLACE CONCRETE.
- C. Concrete for cast-in-place caps and facing shall conform to relevant articles of Section 03300 – CAST- IN-PLACE CONCRETE, 4000 psi, 3/4”.
- D. Shotcrete shall conform to relevant articles of Section 03371 – SHOTCRETE.
- E. Controlled Density Fill (CDF), Type 2E in accordance with specification Section 02300 - EARTHWORK.

- F. Headed welded studs shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.
- G. Polyurethane Chemical Grout
- H. Corrosion control and stray current shall conform to Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION.

2.3 EQUIPMENT

- A. A vibratory hammer shall be utilized for driving the sheet piling providing that such operations do not exceed vibration/noise requirements of the specifications. Impact hammer shall be utilized when vibratory hammer is unable to drive temporary sheet piling to required depth and/or unable to meet vibration requirements. Impact hammer shall also meet noise requirement.

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS

- A. Install the wall in accordance with the accepted working drawings, and in such a manner as to prevent movement, settlement, loss of ground, removal of fines from the adjacent ground, and damage to or movement of adjacent structures and utilities.
- B. Perform work from track side of the proposed wall unless temporary easements have been granted to minimize adjacent property impacts. Heavy equipment shall be placed on the track side of the proposed wall.
- C. Perform field welding by certified welders in accordance with American Welding Society Standards AWS D 1.1, "Structural Welding Code - Steel."
- D. Implement the Plan of Actions as submitted under Paragraph 1.3G, if Response Values as specified in Table 02362-1 are reached.
- E. Borings indicate below ground obstructions may be encountered. Such obstructions may include, but are not necessarily limited to, boulders and various other demolition and construction debris.
- F. Protection of Existing Properties
 - 1. Contractor shall protect existing properties in accordance with Section 01545 – PROTECTION OF WORK AND PROPERTY.
 - 2. Restore existing structures to conditions equivalent to those existing prior to the start of retaining wall construction and support work, unless otherwise indicated. Any damage to affected properties caused by the retaining wall construction shall be repaired by the Contractor at no additional cost to the Authority.
 - 3. If in the opinion of the Engineer the integrity of the adjacent railroad tracks, bridge, buildings, structures, or paved areas are jeopardized due to movement, the Contractor shall immediately discontinue further excavation in the affected area and implement accepted Plan of Action to mitigate further movement. Mitigating measures shall remain in effect until such

time that the Engineer evaluates the impact on the structure and may direct the Contractor to perform any remedial work. The Contractor shall submit proposed remedial measures to the Engineer for review and approval. Submittals shall include methods and names of subcontractors. The Contractor shall proceed with remedial work upon acceptance by the Engineer. Mitigating measures shall be at no additional cost to the MBTA.

3.2 MONITORING OF EXCAVATION

- A. The Contractor shall monitor the performance of components of the excavation support system, for horizontal movement, at intervals specified below. If the Response Values as specified in Table 02362-1 attached are reached at any time during the work, the Contractor shall immediately stop work and implement approved contingency plans.
- B. Visual effects of the excavation on the lateral support system shall be recorded and submitted to the Engineer along with monitoring deflection data.
 - 1. Deflection of the wall into the excavation due to soil, groundwater, and surcharge loads.
 - 2. Settlement adjacent to the lateral support wall due to inward deflection of the wall.
 - 3. Settlement adjacent to the lateral support wall due to ground loss into the excavation through gaps and voids in the wall.
- C. Monitoring Deflection of Wall (Section 02015 - GEOTECHNICAL INSTRUMENTATION.)
 - 1. Once the sheet piles are installed to final elevation but before excavation begins, establish deformation-monitoring points on the top of the sheet piles, spaced approximately every 24 feet along the wall. The monitoring points shall consist of painted marks on the steel member.
 - 2. Perform a baseline survey of each deformation monitoring point before excavation begins. Survey lateral positions.
 - 3. Perform daily survey of each top-of-pile deformation monitoring point from when excavation begins until full excavation depth is reached adjacent to the wall. Thereafter, perform weekly survey of monitoring points until the wall is complete to the bottom of the cap or as directed by the Engineer.
 - 4. Monitoring shall continue until the backfill behind the wall shall be completed to its finished grade (not including loam and seeding) or to the bottom of the cap.
 - 5. Contractor may perform External Device Monitoring (EDM) as an approved alternate survey method.
 - 6. For monitoring of temporary support walls see specification Section 02260 – EXCAVATION SUPPORT AND PROTECTION.
- D. Monitoring Track Movement
 - 1. Before the start of excavation and wall installation, establish elevations along Top of Rail of nearest track, each rail, spaced approximately every 20 feet along the walls.
 - 2. Perform two baseline elevation surveys of the Top of Rail before the start of excavation/wall installation. Survey both vertical and lateral (into excavation) positions.
 - 3. Perform weekly survey of settlement monitoring points from the beginning of excavation until the structure is completely in place and fully backfilled.
- E. Make adjustments to survey schedule and monitoring point locations (including the addition of monitoring points) as requested by the Engineer if additional monitoring of wall performance is

desired. Extra monitoring points and increases in survey frequency shall be considered incidental to the costs associated with this Section.

- F. Survey instruments used for horizontal deformation monitoring shall have a minimum accuracy of ± 3.0 arc seconds and a minimum display reading less than or equal to the accuracy. Distances less than 30 feet shall be measured with a standardized steel tape used in conjunction with a tension handle. Distances greater than 30 feet shall be measured with an Electro-Optical Distance Measuring Instrument (EDM). Distances between 30 and 100 feet shall be verified with a standardized steel tape in conjunction with a tension handle. Electronic pointing shall be used to minimize error due to possible misalignment of the EDM axis and telescope. Centering shall be accomplished using high precision optical plummets or mechanical centering devices.
- G. EDM equipment used for lateral deformation monitoring shall, after calibration, have a minimum accuracy of ± 0.02 in plus 5 parts per million.
- H. The Contractor shall submit the results of the settlement point readings to the Engineer in draft form at the end of each working day. All monitoring data shall be reported to the Authority and Engineer within twenty-four (24) hours of measurement in tabular format, allowing comparison of current data to previous data, including baseline, and showing a complete history of movement versus time.

3.3 EXECUTION

- A. Installation of steel sheet pile retaining wall systems shall not commence until the related earth excavation and dewatering submittals have been reviewed by the Engineer with all of the Engineer's comments satisfactorily addressed.
- B. Install the steel sheet pile retaining wall systems in accordance with the installation plan and as specified.
- C. Install and read geotechnical instrumentation in accordance with the steel sheet pile retaining wall installation plan. Notify the Engineer immediately if any geotechnical instrumentation is damaged. Repair or replace damaged geotechnical instrumentation at the sole option of the Engineer and at no additional cost to the Authority.
- D. Notify utility companies or municipalities if existing utilities interfere with the wall system. Modify the existing utility with the utility company's or municipality's permission or have the utility company or municipality make the modifications at no additional cost to the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02369

DRILLED MINI-PILES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the furnishing of all labor, material, tools, and equipment and performance of all operations necessary for the design and installation of Drilled Mini-Piles.
- B. The work of this Section also includes, but is not limited to, the following:
1. Evaluate need for verification borings in the vicinity of mini-pile locations. Perform verification borings, as needed, to complete design of drilled mini-piles. Additional borings required by the Design-Builder for the design of the drilled mini-piles will be at his expense.
 2. Excavated soils and soil/grout mixtures shall be managed and disposed of in accordance with applicable federal, state, and local laws, regulations, and ordinances and as directed by the Licensed Site Professional for this Project and in accordance with specification Section 02282- HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS.
 3. The Design Builder's design shall meet the requirements of all applicable Codes and Specifications including satisfying allowable stress requirements at welded joints. The design shall be prepared, signed, sealed, and dated by a Professional Engineer registered in the Commonwealth of Massachusetts.
 4. Perform load testing of mini-piles, as required by the relevant code applicable to the mini-pile supported structure, a minimum of one load test on mini-piles per structure.
 5. Monitor settlement of the test mini-pile by surveying methods and dial gages during the performance of load tests.
 6. Revise installation procedures and mini-pile length as required based on load test data and/or as directed by the MBTA.
 7. Control all wash water used in the installation of drilled mini-piles.
 8. Remove all equipment, including testing equipment, tools, and materials including unused materials, and any spoils generated during mini-pile installation, and perform final cleanup of the site for all work pertaining to drilled mini-piles.
 9. The construction of drilled shafts shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design-Builder at no additional cost to the MBTA.
 10. Adjacent structures shall be monitored and protected as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.

11. Construction operations not to exceed specified noise limits in accordance with Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements".

C. Related Work: Other specification sections that relate to the work of this section include, but are not limited to, the following:

1. Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements"
2. Section 02015 – GEOTECHNICAL INSTRUMENTATION
3. Section 02060 – EROSION AND SEDIMENTATION CONTROL
4. Section 02240 – DEWATERING
5. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
6. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL EXCAVATED MATERIAL
7. Section 02300 – EARTHWORK
8. Section 02650 – EXISTING SITE UTILITIES
9. Section 03300 – CAST-IN-PLACE CONCRETE

1.2 SUBMITTALS

A. The Design-Builder shall prepare and submit to the MBTA for review and approval, working drawings and corresponding design submission, signed, sealed, and dated by a Professional Engineer registered in the Commonwealth of Massachusetts, describing the mini-pile system or systems intended for use. The design submittal shall include the applicable code requirements and design references. The design submission shall be submitted 30 calendar days prior to the commencement of the mini-pile work. The working drawing and design submission shall include a drawing showing the location and orientation of each mini-pile, details of casing, splice details for steel pipe, grouting sequence, installation procedures for drilled mini-piles including mini-pile equipment technical specifications, calculations for axial static capacity and a schedule giving:

- a. Mini-pile number;
- b. Mini-pile design load; and
- c. Type and size of mini-pile.

B. The MBTA shall approve or reject the Design-Builder's drawings and design submission within 20 working days after receipt of the submission.

C. Submit boring logs for verification borings to the MBTA.

D. Prior to the start of work, the Design-Builder shall furnish a load test plan for each structure to be supported by mini-piles. The load test plan shall include a description of the load test procedure, planned equipment, method of loading the test mini-piles with planned loading range (e.g. twice the design load). The Design-Builder shall furnish a calibration curve for the jack and gage to be used for the load tests. The curve shall be certified by a recognized testing laboratory. Each load test shall include the use of a recently calibrated load cell and a ball joint to assure concentric loading of the mini-pile top.

E. Furnish load test reports using data recorded during the test. Submit survey and other data necessary to complete these reports within 2 days after the completion of tests.

F. Prior to placement, submit the grout mix design(s) to the MBTA for approval along with supportive certification from an independent testing laboratory listing seven and 28-day compression strength testing results, and identification of constituent materials. Submit flow cone data for each design mix in accordance with ASTM C939 except a 3/4-inch opening shall be used for sand/cement grout mixes

in the flow cone rather than the 1/2 -inch opening specified. Submit specific gravity data for each design mix of neat cement grout. Duplicate grout cube testing, including 3, 7, 10, 14, and 28 day strengths, shall be provided for each design mix.

- G. Mini-pile installation record. Furnish a complete and accurate record of all mini-piles, including:
 - 1. The date of installation.
 - 2. The mini-pile number or identification, final location, size, length, elevation of tip and top of mini-pile and reinforcement, elevation of top and bottom of the pipe, elevation of top and bottom of the socket.
 - 3. Rate of drilling for each foot of penetration throughout the entire length of each mini-pile.
 - 4. Grout pressure applied and any change in grout pressure with depth.
 - 5. Any unusual occurrence during installation of the mini-pile.
 - 6. Quantity of grout used excluding wastage, measured to the nearest 1/10 cubic foot.
 - 7. Compressive test results of grout cube samples to be submitted within 1 day after completion of tests.
- H. Submit test report or certifications for materials when the materials are delivered to the site.
- I. Report mini-pile deviation beyond mini-pile installation tolerances to the MBTA. Stop work until corrective measures are established.
- J. Submit the qualifications of the proposed Independent Testing Agency for approval by the MBTA.
- K. Submit monitoring schedule, installation procedures, and location plans for noise monitoring as specified in Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements", and Section 02015 – GEOTECHNICAL INSTRUMENTATION.

1.3 QUALITY CONTROL

- A. Qualifications:
 - 1. The Design-Builder's subcontractor(s) performing this work shall be a reputable firm regularly engaged in installation of these types of mini-piles or similar work. The subcontractor shall have had experience in this type of construction for a period of at least five years, with a proven record of successfully completing a minimum of 10 projects similar in scope. Installation of mini-piles shall be continuously supervised by a foreman having supervised at least 10 comparable projects.
 - 2. The Design-Builder Independent Testing Agency performing the mini-pile load testing shall be a reputable firm regularly engaged in the testing of mini-piles or similar work. The subcontractor shall have had experience in this type of testing for a period of at least five years, with a minimum of 10 projects similar in scope. Load testing of mini-piles shall be performed by an Engineer having performed at least 5 comparable projects. The Engineer performing the load testing shall be responsible for collecting, interpreting, plotting, and reporting data to the Engineer. The Design-Builder's Independent Testing Agency Field Engineer shall have, at a minimum:
 - a. Bachelor of Science degree in Civil Engineering.
 - b. Four years of direct field experience in performing the type of load testing specified herein.

B. Reference Codes and Specifications:

1. American Society for Testing and Materials (ASTM):
 - a. A252, Welded and Seamless Pipe Piles,
 - b. A615, Reinforcing Bars,
 - c. A722 Thread Bars,
 - d. C33, Standard Specification for Concrete Aggregates,
 - e. C109, Compressive Strength of Hydraulic Cement Mortars (using two inch or 50 mm cube specimens),
 - f. C150, Portland Cement,
 - g. D1143, Standard Test Method for Piles under Static Axial Compressive Load,
 - h. D1586, Standard Test Method for Penetration Test and Split Barrel Sampling of Soils,
 - i. D2113, Standard Practice for Diamond Core Drilling for Site Investigation,
 - j. A36, Specification for Structural Steel,
 - k. C136, Sieve Analysis of Fine and Coarse Aggregates,
 - l. C939, Flow of Grout for Preplaced - Aggregate Concrete.
2. American Concrete Institute (ACI)
 - a. ACI 304, Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete.
 - b. ACI 305, Hot Weather Concreting
 - c. ACI 306, Cold Weather Concreting
3. American Welding Society (AWS):
 - a. AWS D1.1, Structural Welding Code
4. Commonwealth of Massachusetts, State Building Code.
5. AREMA 2016
6. AASHTO LRFD Bridge Design Specifications.

- C. The Design-Builder shall take a minimum of one set of 2" x 2" x 2" cubes of grout for each day during which mini-piles are grouted. A set of cubes shall consist of six cubes with one cube tested at three, seven and ten days and three cubes tested at twenty-eight days. Test cubes shall be made and tested in accordance with ASTM C109. Install and load test mini-piles in accordance with ASTM D1143. Provide complete testing materials and equipment as required.
- D. Store materials in accordance with the recommendations of "Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete", ACI 304.
- E. The Design-Builder shall engage an independent testing agency to collect samples in the field, perform laboratory tests, maintain and distribute test results, provide calibrated test equipment, and perform other duties associated with quality control.

1.4 JOB CONDITIONS

- A. The Design-Builder shall inspect the site to evaluate the conditions affecting the work.

- B. Details of the subsurface explorations performed for this project are included in the Geotechnical Data Report. Refer to the Geotechnical Data Report for additional details and boring logs. The Design-Builder shall assume that subsurface conditions between subsurface explorations could differ from conditions shown on the boring logs. The Design-Builder shall perform additional borings, as they deem necessary, to complete their design.
- C. The mini-piles shall be designed, detailed, and constructed to avoid impact to existing or proposed utilities. The Design-Builder shall protect utilities in accordance with Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements".

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Cement shall conform to "Standard Specification for Portland Cement (ASTM C150)".
- B. Mixing water for cement grout shall be clean and potable, free from oil, acids, alkali, salts, organic material, or other deleterious substances.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Preparation shall include, but not be limited to, the following:
 1. Layout of mini-pile locations. All mini-pile locations shall be clearly marked on the ground surface. Design-Builder shall confirm the location of all utilities through field observations. Utilities interfering with mini-pile installation shall be moved, temporarily rerouted, or relocated to permit mini-pile installation.
 2. Protect structures, underground utilities, and other construction from damage caused by installation operations.
 3. Protection of work areas: surrounding areas shall be protected from damage. Refer to Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements.
 4. Areas shall be returned to their "pre-work" condition upon completion of the work. Any and all damage arising from the Design-Builder's actions shall be replaced or repaired to the satisfaction of the MBTA. Damage is further defined to include items requiring additional clean-up as a result of the Design-Builder's failure to provide adequate protection.
 5. Obtain any and all necessary permits, licenses, and notifications related to the work.

3.2 INSTALLATION

- A. Mini-Pile Drilling:
 1. The equipment and procedures used by the Design-Builder shall provide a stable bottom within the casing during drilling and be capable of advancing and seating the casing at the tip elevation

and without causing damage to the surrounding areas. The equipment shall be of sufficient capacity to install the pipe to the depths required by the design or as revised by the load test results whichever is greater.

B. Bond Zone for Drilled Mini-Piles:

1. The length of the bond zone for production mini-piles shall be determined based on the results of the mini-pile load tests. The bond zone shall be measured from the bottom of the pipe.

3.3 GROUT PLACEMENT

- A. Special precautions shall be exercised as deemed necessary by the Design-Builder to avoid grout intrusion into existing utilities and spaces not intended to be grouted.
- B. The grouting sequence shall be submitted to the MBTA for approval.
- C. Grout shall be mixed in batches of 10 cubic feet or less, unless the Design-Builder demonstrates to the satisfaction of the MBTA that larger batches can be used without premature hydration and specific approval for a larger batch size is obtained from the MBTA.
- D. The Design-Builder shall test each truck load of grout using the flow cone test (ASTM C939) with 3/4" opening. Maintain grout within acceptable tolerances determined by the mix design.
- E. Protect grout from physical damage or reduced strength which could be caused by frost, freezing actions or low temperatures, in compliance with ACI 306.
- F. Place grout in accordance with ACI 305 when hot weather conditions exist that would seriously impair the grout's quality and strength.
- G. The Design-Builder shall prepare and submit daily to the MBTA, a record showing the quantity of holes drilled, pipe drilled and grout pumped per hole.
- H. The Design-Builder be responsible for maintaining all areas in a neat and orderly condition, both during and upon completion of the work. All waste material and Construction debris shall become the property of the Design-Builder and shall be removed from the site and disposed of in a legal manner.

3.4 TOLERANCES

- A. Horizontal: Location of mini-piles shall be installed within two inches from the theoretical location as required by design. The locations shall be determined by a Professional Land Surveyor registered in the Commonwealth of Massachusetts who shall prepare an As-Built Plan. The As-Built Plan shall be updated by the Professional Land Surveyor as necessary.
- B. Vertical: Plumbness of mini-piles shall be installed with no more than 1% deviation from the plumb position.

3.5 MINI-PILES OUT OF TOLERANCE

- A. Mini-Piles installed more than two inches from the design locations may not be acceptable for full design loading. Remedial measures, if required, shall be implemented by the Design-Builder.
- B. Any mini-pile out of tolerance for either location or plumbness by more than the amounts stated above may be rejected. If rejected, it shall be replaced by another mini-pile or mini-piles, at locations approved by the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02370

DRILLED SHAFTS

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies requirements for foundations constructed by drilling or otherwise excavating a shaft, and filling it with steel reinforcement and concrete.
- B. The Work of this Section also includes:
1. Excavation, backfilling, and disposal of existing obstructions encountered within the limits of the drilled shaft foundation construction. Transportation and disposal of excavation materials from the drilled shaft foundations. Soils shall be managed and disposed of in accordance with applicable Federal, State, and Local laws, regulations, and ordinances and as directed by the Licensed Site Professional (LSP) for this Project and in accordance with specification Section 02282- HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS.
 2. Supply, circulation, maintenance, and disposal of mineral slurry or other drilling fluid in accordance with all applicable federal, state, and local laws, regulations, and ordinances.
 3. Verification borings and reports; Design-Builder shall perform verification borings at the centerline of all drilled shaft locations and provide final boring logs to MBTA for review.
 4. Crosshole Sonic Logging (CSL) will be performed on all drilled shafts to verify proper concrete consolidation, placement, and integrity of the concrete in the drilled shaft foundations, and to determine the extent and location of defects in the shafts (internal voids, shaft perimeter integrity, transverse cracks, soil intrusions, and weak concrete or grout). CSL measurements shall be performed by an approved testing agency hired by the Design-Builder at all completed drilled shafts. CSL shall be performed between 1 and 7 days after concrete placement.
 5. Removal of concrete overpour or other irregularities which interfere with other structural elements, utilities, or other planned construction.
 6. The Design-Builder shall examine the site prior to mobilization to determine existing surface conditions.
 7. The Design-Builder shall be responsible for all coordination with the MBTA and utility companies.
 8. The Design-Builder shall obtain required permits from all authorities having jurisdiction.
 9. The construction of drilled shafts shall not disturb existing structures or the completed work. Damage to such structures shall be repaired by the Design-Builder at no additional cost to the MBTA.
 10. Adjacent structures shall be monitored and protected as specified in Section 02015 – GEOTECHNICAL INSTRUMENTATION.
 11. Construction operations not to exceed specified noise limits in accordance with Section 01560 – TEMPORARY CONTROLS.
- C. Related Work: Other specification sections that relate to the work of this section include:
1. Volume 2 Technical Provisions, Exhibit 2I, “Additional Project Requirements”.
 2. Volume 1 DB Contract Terms and Conditions, Subsection 9.4, Railroad Coordination and Requirements.

3. Section 02015 – GEOTECHNICAL INSTRUMENTATION
4. Section 02060 – EROSION AND SEDIMENTATION CONTROL
5. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
6. Section 02240 – DEWATERING
7. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
8. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIAL
9. Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
10. Section 02300 – EARTHWORK
11. Section 03300 – CAST-IN-PLACE CONCRETE

1.2 WORK RESTRICTIONS

- A. The Design-Builder shall refer to MBTA General Specifications related to work on or adjacent to MBTA Railroad Property. These specifications are published by MBTA under the title “Railroad Operations Directorate”. It is the responsibility of the Design-Builder to obtain the latest version of all the necessary specifications including Volume 1 DB Contract Terms and Conditions, Subsection 9.4, Railroad Coordination and Requirements and strictly follow the guidelines specified during the execution of this work.

1.3 SUBMITTALS

- A. Unless otherwise specified, the Design-Builder shall submit the information specified herein to the MBTA not less than 30 days before the start of the Work of this Section.

- B. Core Borings and Report

Beyond the mandatory minimum requirements indicated herein, requirements for drilled shaft design and construction shall be determined by the Design-Builder based on subsurface information collected at the project site. The MBTA’s field representative will be onsite during drilling of drilled shafts to confirm the subsurface conditions assumed in the Design-Builder’s design. The results of subsurface explorations and/or tests including test core borings, rock core samples and Rock Quality Designations (RQD) for each core sample, shall be submitted to the MBTA prior to construction of any drilled shafts.

- C. The Design-Builder shall prepare and submit to the MBTA for review and approval, working drawings and design submission describing the drilled shaft design. The design submittal shall include the applicable code requirements and design references. The working drawings and design submission shall be submitted 30 calendar days prior to the commencement of the drilled shaft work. The working drawing and design submission shall include a drawing showing the location of each drilled shaft, details of casing, reinforcement, concrete design and placement details, installation procedures for drilled shafts including equipment technical specifications, and a schedule giving:

1. Drilled shaft number;
2. Drilled shaft design load; and
3. Diameter or drilled shaft and rock socket, if applicable.

- D. Submit shop drawings in accordance with these specifications.

1. Submit details of proposed equipment, methods, and sequence of operations to be used to excavate both soil and rock and maintain an open shaft, remove and dispose of obstructions within the limits of the shaft excavation, clean the shaft walls and bottom, produce, maintain, mix, and reclaim slurry, place reinforcing steel, and place concrete and backfill.
2. Submit test reports and drilled shaft installation logs as specified herein and in Article 1.6 of this Section. Submit proposed drilled shaft installation log forms for acceptance.
3. Submit description of equipment and method of providing and checking the cleanliness of shaft bottoms and identifying type of bearing material for consistency with design assumptions prior to placing concrete.
4. Submit the type of proposed access tubes and associated materials to prepare drilled shaft foundations for CSL, see Article 2.4 for limitations on material types. Submit shop drawings detailing installation of materials.
5. When drilling slurry is used, submit data from the supplier giving the recommended physical and chemical properties of the slurry. During construction, furnish the results of quality control tests performed on the slurry promptly after the tests are completed. Submit record copies each week.
6. Submit method of monitoring and continuously maintaining slurry level in drilled shafts in two principal perpendicular planes.
7. Submit method of monitoring verticality of the shaft excavation during excavation and details of proposed corrective measures to be implemented as necessary. For personnel who will perform verticality monitoring, submit documentation of training by the manufacturer in the use of the device to monitor verticality.
8. Submit method of maintaining stability of drilled shafts in the event of sudden slurry loss or loss of slurry stabilization properties.
9. Submit proposed building materials such as concrete mix design, reinforcing steel, and casing steel.
10. Submit method of securing and maintaining position of steel reinforcing.
11. Submit method of placing concrete, including number, location, and details of tremie pipes.
12. Submit monitoring schedule, installation procedures, and location plans for noise monitoring as specified in Volume 2 Technical Provisions, Exhibit 2I, "Additional Project Requirements", and Section 02015 – GEOTECHNICAL INSTRUMENTATION.

1.4 INSPECTION AND TESTING

- A. Concrete test cylinders for acceptance testing shall be made as specified in Section 03300 - CAST-IN-PLACE CONCRETE.
- B. Welding Inspection - all welds shall be visually inspected. All complete joint penetration welds shall be 100% ultrasonic examined.
- C. Hold Point - After completion of excavation and prior to placement of reinforcing steel and concrete, the condition of the excavation will be inspected by the MBTA.
- D. Remove any debris or other loose material from the shaft prior to placing reinforcing steel and concrete. An accumulation of muck in the bottom of the excavation will not be allowed.

1.5 TOLERANCES

- A. Variation of center of any drilled shaft foundation from the required plan location: Maximum 3 inches, measured at the ground surface in any horizontal direction, unless noted otherwise.

- B. Bottom diameter: Minus 0, plus 6 inches measured in any direction.
- C. Maximum variation from vertical: 1:100 measured continuously along the length of the shaft.
- D. Elevation of the top of shaft: Within 1 inch of cut-off elevation as required by design.
- E. After all the concrete is placed, the top of the reinforcing steel cage shall be no more than 1” above and no more than 3” below the position required by design.
- F. Excavation equipment and methods shall be designed so that the completed shaft excavation will have a horizontal planar bottom.

1.6 RECORD INFORMATION

- A. For each drilled shaft foundation installed, record on drilled shaft installation logs the location, alignment, dimensions, elevations of top and bottom, depth of bearing stratum penetration, description of materials encountered at all elevations, elevation of water table during excavation, condition of bottom of excavation, concrete data, verticality and deviation from plan location, and other data called for on the report form or pertinent to the drilled shaft. Record the theoretical volume of excavation, volume of concrete placed vs. depth, and total volume of concrete placed. Report irregularities to the MBTA within 24 hours of discovery.
- B. Submit draft record information for each completed shaft weekly to the MBTA. Submit final record drawings of each drilled shaft installed no more than 3 weeks after completion.
- C. Maintain daily job records of mineral or polymer slurry testing performed under Article 3.6 “Control Testing of Slurry”. Submit records to the MBTA on a weekly basis, and more frequently if variations occur.

PART 2 - PRODUCTS

2.1 CONCRETE AND REINFORCING STEEL

- A. Provide concrete and reinforcing steel in accordance with the requirements of Specification Section 03300 - CAST-IN-PLACE CONCRETE.

2.2 TEMPORARY CASING STEEL

- A. The thickness of temporary steel casing shall be as required to support soil and water pressure and withstand handling stress.

2.3 SLURRY

- A. Slurry shall be a stable suspension of either mineral or polymer in potable water. The Design-Builder shall anticipate encountering brackish groundwater, ash and cinder fill, leakage from storm and sanitary sewers, and other agents that may be deleterious to the slurry. The Design-Builder is responsible for and shall modify the slurry mix as required so as to maintain a stable suspension at all times.
- B. Density shall be such that adequate excavation support is provided, and that the slurry will be readily displaced by the tremie concrete.
- C. Additives shall be used in the slurry if needed to maintain the necessary properties, as approved by the MBTA.
- D. Fluid loss in the open excavation shall be limited to a drop in the slurry level of no greater than one inch per hour per 20 feet of excavation depth, and no more than 2 feet total in a 24-hour period.
- E. Mineral slurry shall be premixed thoroughly with clean fresh water and adequate time (as prescribed by the mineral manufacturer) shall be allotted for hydration prior to introduction into the shaft excavation. Slurry tanks of adequate capacity will be required for slurry circulation, storage, and treatment.

No excavated slurry pits will be allowed in lieu of slurry tanks without the written permission of the MBTA. Desanding equipment shall be provided by the Design-Builder, as necessary, to control slurry sand content to less than 4 percent by volume at any point in the borehole at the time the slurry is introduced, including situations in which temporary casing will be used.

The Design-Builder shall take all steps necessary to prevent the slurry from “setting up” in the shaft. Such methods include: agitation, circulation, and/or adjusting the properties of the slurry. Disposal of all slurry shall be done off site by the Design-Builder in accordance with applicable federal, state, and local laws, regulations and ordinances.

- F. Control tests using suitable apparatus shall be carried out on the mineral slurry by the Design-Builder to determine density, viscosity, and pH. An acceptable range of values for those physical properties is shown in the following table:

MINERAL SLURRY			
Acceptable Range of Values			
Property (Units)	At Time of Slurry Introduction	In Hole at Time of Concreting	Test Method
Density (pcf)	64.3* - 69.1*	64.3* - 75.0*	Density Balance
Viscosity (sec./qt**)	28 - 45	28 - 45	Marsh Cone
pH	8 - 11	8 - 11	pH paper, pH meter

* Increase the Acceptable Range by 2 pcf in salt water.

** Note that standard measurements are in seconds per quart, not seconds per liter.

- H. Tests shall be performed when the slurry temperature is above 40 degrees Fahrenheit. If de-sanding is required, sand content shall not exceed 4 percent by volume at any point in the borehole as determined by the American Petroleum Institute sand content test when the slurry is introduced.
- I. Tests to determine density, viscosity, and pH value shall be performed during the shaft excavation to establish a consistent working pattern. A minimum of four sets of tests shall be made during the first 8 hours of slurry use. When the results show consistent behavior, the testing frequency may be decreased to one set every four hours of slurry use.
- J. Polymer slurry, either natural or synthetic, may be used if approved by the MBTA. Slurry properties at the time of mixing and at the time of concreting shall be in conformance with the written recommendations of the manufacturer. The sand content at the base of the drilled shaft excavation shall not exceed 1 percent when measured by Method API (American Petroleum Institute) 13B-1, Section 5, immediately prior to concreting.
- K. The Design-Builder shall maintain the level of mineral slurry at not less than 4 feet above the highest expected piezometric pressure head. For polymer slurry maintain at a level not less than 6 feet above the highest expected piezometric head.

2.4 CROSSHOLE SONIC LOGGING ACCESS TUBES

- A. Access tubes for Crosshole Sonic Logging (CSL) shall be schedule 40 steel pipe conforming to ASTM A53, Grade A or B Type E, F, or S. The access tubes shall be placed in all drilled shafts, have a round, regular internal diameter free of defects and obstructions in the tube and at joints, in order to permit free, unobstructed passage of the source and receiver probes. The tubes shall be watertight and free from corrosion, with clean internal and external surfaces to ensure a good bond between the concrete and tubes. The tubes shall be fitted with threaded caps at the top and bottom ends. Submit proposed alternatives for the top caps for acceptance by the MBTA. In the event the tube is obstructed, the Design-Builder shall remove the obstruction and repair the tube at his/her own expense.

2.5 DRILLING MONITORING UNIT

- A. Provide a Drilling Monitoring Unit and a qualified technician for monitoring the dimensions and plumb of drilled shaft excavations.

PART 3 - EXECUTION

3.1 EXCAVATION

A. General

1. It is the obligation of the Design-Builder to become completely familiar with the conditions existing at the site. The Design-Builder may carry out whatever additional explorations are deemed necessary at no additional cost to the MBTA. It is the Design-Builder's sole responsibility to make interpretations and draw conclusions about the character of the material to be encountered and their impact upon the work based upon knowledge of the area and of shaft installation techniques. The MBTA assumes no responsibility for the accuracy of the data other than the location and the time the subsurface exploration was made.
2. Design-Builder shall perform conformational borings at the centerline of all proposed drilled shafts, prior to finalizing design and installation. Design-Builder shall develop final boring logs for each conformational boring and submit them to the MBTA for review.
3. The Design-Builder shall consult official records of existing utilities at the site to determine any conflicts with the work and shall advise the MBTA of any discrepancy before performing any work. Existing utilities found on the project site which are to remain shall not be disturbed or damaged. Provisions for protection of the utilities shall be made in accordance with the requirements of the authorities having jurisdiction.
4. Excavate drilled shafts by drilling, augering, or other effective methods to advance the excavation through overburden materials and bedrock to the required bottom design elevation. Use whatever means necessary to maintain a stable shaft without loss of ground.
5. Protect the excavation walls with steel cylinder casing, or accepted sheeting as necessary to prevent instability or displacement of the surrounding earth, excessive water intrusion, or damage from construction operations.
6. Monitoring and evaluation of the shafts at each stage will be performed by the MBTA. Do not place concrete in the shaft until the shaft excavation has been accepted by the MBTA.
7. Design-Builder shall remove obstructions encountered during shaft excavation. Obstructions are defined as man-made or man-placed objects, man-made or man-placed materials, man-made or man-placed structures, such as granite blocks, concrete, timber, logs, piles, or other man-placed materials, and naturally occurring boulders encountered at or below ground surface which unavoidably and completely stop the progress of the shaft excavation or subsurface drilling work for more than one (1) hour, despite the Design-Builder's diligent efforts, as determined by the MBTA. In drilled shaft operations, abandoned utilities and utility structures indicated on the existing reference documents or found by the Design-Builder, shall not be considered. Bedrock shall not be treated as an obstruction during any drilled shaft operations. The Design-Builder shall probe to locate the extent of the obstruction and propose a method of passing or removing it.
8. Potential obstructions include:
 - a. Abandoned or active deep foundations consisting of timber piles, concrete piles, and steel piles.
 - b. Active or demolished structures including: miscellaneous granite blocks, granite block foundations; walls, granite pavements and slabs; concrete foundations, walls, pavements, slabs and pile caps; brick pavements; brick foundations; miscellaneous construction debris and rubble from demolished structures including steel members, concrete, steel,

brick and timber structures; abandoned steel transit rails; timber cribbing and bulkheads; timber sheeting; timber ties.

- c. Abandoned and active utilities and utility structures not indicated on the existing reference documents or found by the Design-Builder.
 - d. Riprap, naturally occurring boulders, or stone fill.
 - e. Drilling tools, which are lost in the excavation, shall not be considered obstructions and shall be promptly removed by the Design-Builder without compensation. All costs due to lost tool removal shall be borne by the Design-Builder including but not limited to, costs associated with hole degradation due to removal operations or the time the hole remains open.
9. Do not excavate new shafts closer than 20 feet from newly concreted shafts until the shaft concrete has been in place a minimum of 24 hours.
 10. Design-Builder shall be responsible for the characterization of the drilling spoils. If the spoils are characterized as oil and hazardous materials (OHM), Design-Builder shall handle and transport the spoils in accordance with specification Section 02081 – HAZARDOUS MATERIALS ABATEMENT and specification Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIAL.

B. Groundwater Control

1. Should groundwater be encountered during excavation operations, pumping shall be performed in accordance with Section 02240 - DEWATERING, and provided that no soil movement, caving of the excavation walls, bottom heaving, or ground settlement occurs. Dewatering discharge shall be in accordance with the requirements of Section 02240 - DEWATERING and Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER.
2. If groundwater intrusion endangers the security of the excavation or adjacent property or structures, mitigative measures shall be implemented in accordance with the requirements of Volume 2 Technical Provisions, Exhibit 2, “Additional Project Requirements”.

C. Inspection

1. Details of shaft construction shall be recorded on the drilled shaft installation logs.
2. Core borings shall be drilled by the Design-Builder at each shaft location, the bottom elevation of the drilled shaft will be adjusted to obtain the required design capacity based on the elevation and quality of the bearing material encountered during installation of drilled shaft.
3. Sound, measure, and record the final bottom of shaft excavation depth and elevation in the presence of the MBTA at the following times, to verify that soil from the sides of the shaft has not fallen into the shaft and sediment has not collected on the shaft bottom:
 - a. Immediately after excavation has been performed to the final depth.
 - b. Immediately after the excavation has been cleaned of all loose material.
 - c. Immediately prior to and after placing reinforcing steel in the shaft.
 - d. Immediately prior to concrete placement.
4. Before the placement of reinforcing steel and concrete, ensure that loose material from the bottom and sides of the excavation has been removed and that the shaft is within the specified tolerances. Remove all loose material at the bottom of the shaft to permit the development of end bearing as per the Design-Builder’s design using a combination of clean-out buckets and airlifts. Document drilled shaft excavation dimensions versus depth and verticality using the approved Drilling Monitoring Unit to verify that the shaft is within the specified tolerance.

- D. The Design-Builder shall be responsible for correcting drilled shafts not constructed within the specified tolerances. Remedial measures, including engineering analysis and redesign, to correct for out-of-tolerance drilled shaft foundations, shall be performed at no additional cost to the MBTA.

3.2 INSTALLATION OF CASING

- A. Provide steel casing as needed to construct a stable shaft excavation. Excavations using permanent casing shall be made in a manner such that the outside of the casing is in direct contact with undisturbed natural soils.
- B. Permanent casing joints shall be continuously welded.

3.3 INSTALLATION OF REINFORCING STEEL

- A. Prior to installation, inspect and clean reinforcing steel of materials that prevent effective bonding.
- B. The reinforcing steel cage, consisting of longitudinal bars, ties, cage stiffeners, spacers, centralizers, and other necessary appurtenances, shall be completely assembled and placed as a unit immediately after the shaft excavation is inspected and accepted, and prior to concrete placement. Internal stiffeners shall be removed as the cage is placed in the borehole so as not to interfere with the placement of concrete.
- C. The reinforcing steel in the shaft shall be tied and supported so that the reinforcing steel will remain within allowable tolerances given in Article 1.5 "Tolerances" of this specification. Concrete spacers or other approved non-corrosive spacing devices shall be used at sufficient intervals (near the bottom and at intervals not exceeding 5 feet up the shaft) to ensure concentric spacing for the entire cage length. Spacers shall be constructed of a material equal in quality and durability to the concrete specified for the shaft. The spacers shall be of adequate dimension to insure a minimum 3" annular space between the outside of the reinforcing cage and the side of the excavation hole. Approved cylindrical concrete feet (bottom supports) shall be provided to ensure that the bottom of the cage is maintained at the proper distance above the base.
- D. Dropping or forcing the reinforcing steel into the shaft shall not be permitted. If the reinforcing cage does not properly or smoothly enter the excavation, it shall be retrieved and the excavation adjusted and properly cleaned as specified until the reinforcing fits smoothly. Repair or replace any damaged reinforcing.
- E. After the installation of reinforcing steel and immediately prior to concrete placement, the bottom of the excavation shall be measured to determine if sediment has accumulated on the shaft bottom. If sediment is found to have accumulated on the shaft bottom, clean the bottom of the excavation with an air-lift or other equipment which is capable of removing the sediment.

3.4 PLACING CONCRETE

- A. Place concrete immediately after inspection by the MBTA of the completed excavation, and the placement of reinforcement. Shaft concrete shall be placed within 24 hours of completion of shaft excavation.
- B. Place concrete in one continuous operation. Concrete shall be placed through a tremie or concrete pump.

- C. When the casing is to be removed, withdraw the casing while concrete is still fluid, before initial set.
 - 1. Withdraw the temporary steel casing used to support the excavation walls as the concrete is being placed unless otherwise indicated, or unless the casing is to be left in place. Concrete shall be a minimum of 5 feet above the bottom of casing at all times while the casing is being withdrawn. The tremie pipe shall be raised to the minimum 5-foot embedment depth following the delivery of concrete from each truckload of concrete. Withdraw the casing when the concrete pressure at the casing seal exceeds water and soil pressure at that level. Remove the steel casing in a manner that prevents water and earth from entering the casing at the bottom. Do not damage or displace the reinforcing cage when withdrawing the casing. Ensure the fluid trapped behind the casing is displaced upward without contaminating shaft concrete.
 - 2. Check concrete level before, during, and after withdrawing casing to confirm that separation of shaft concrete has not occurred.
 - 3. Do not vibrate concrete internally before casing is withdrawn.
- D. Vibrate the top 5 feet of concrete after the casing has been withdrawn, and in locations where the casing is permanent.
- E. Fill the void space between permanent casing and shaft excavation with concrete or fluid grout.
- F. Cure and finish the top of the shaft to comply with the construction methods of Specification Section 03300 CAST-IN-PLACE CONCRETE.

3.5 SLURRY

- A. Use equipment that produces a stable suspension and provides mechanical agitation. Transport slurry by means of a temporary pipeline or other safe methods.
- B. Use equipment that removes detrimental quantities of excavated material from the slurry.

3.6 CONTROL TESTING OF SLURRY

- A. Perform control testing of mineral slurry in accordance with API Standard RP 13B, “Standard Procedure for Testing Drilling Fluids” and as specified herein. If polymer slurry is used, modify the parameters in accordance with the slurry manufacturer’s recommendations. The Design-Builder or his representative shall have demonstrated experience in testing on at least 5 projects.
- B. Test the slurry to determine the following:
 - 1. Freshly Mixed Slurry. Measure density, pH, and Marsh Cone viscosity of freshly mixed slurry. Perform an API fluid loss test on freshly mixed mineral slurry.
 - a. Calibrate density measuring devices monthly, or more often if there is evidence of needed calibration, to an accuracy of ± 0.05 PCF.
 - b. Perform an API fluid loss test in accordance with American Petroleum Institute Standard 13A. Fluid loss shall not exceed 25cc in 30 minutes.
 - 2. Slurry Inside Excavation. Perform tests specified below to verify that properties of slurry inside excavations are within the specified limits.

- a. Obtain samples from the top and bottom of the shaft, and perform the following tests once every 2 hours.
 1. Density, by mud density balance.
 2. Viscosity, by Marsh Cone Method.
 3. pH.
 4. Sand content.
 - b. Perform fluid loss measurements in the shaft at the beginning or end of every shift as directed by the MBTA.
 - c. Perform an API fluid loss test for polymer slurry once every 3 days at times directed by the MBTA. Fluid loss shall not exceed 25cc in 30 minutes.
3. Prior to concreting, obtain samples from the top and bottom of the shaft and at intervals not exceeding 10 feet up the slurry column in shaft until 2 consecutive samples produce the acceptable values for density, viscosity, and pH.

3.7 INSTALLATION REQUIREMENTS FOR CROSSHOLE SONIC LOGGING

- A. Preparation of Crosshole Sonic Logging (CSL) Access Tubes. The access tubes shall be placed in all drilled shafts. The access tubes shall be installed as shown on the approved shop drawings. The tubes shall be securely fastened at 3-foot intervals to the interior of the reinforcement cage in a parallel manner. Care shall be taken during reinforcement installation operations not to damage the tubes or break the fasteners of the tubes. Immediately prior to concrete placement of the drilled shaft, the tubes shall be filled with clean water and capped. All CSL test results shall be submitted to the MBTA.

3.8 ACCEPTANCE OR REJECTION OF DRILLED SHAFT

- A. In addition to other Contract acceptance criteria, drilled shafts shall be accepted when the CSL test reports are reviewed and accepted by the MBTA. Rejection of a drilled shaft, based on the results of the CSL, will require conclusive evidence that a defect exists in the drilled shaft that will result in inadequate or unsafe performance under service loads. If the record is complex or inconclusive, coreholes shall be drilled in the drilled shaft of questionable quality. When a defect is confirmed by coring of the concrete, the Design-Builder shall repair the defect and perform additional CSL testing to confirm that the repair was successful. Repaired drilled shafts shall be accepted when the CSL test reports are reviewed and accepted by the MBTA. The MBTA will be the sole judge of drilled shaft acceptance.
- B. In the case that a drilled shaft is determined to be unacceptable, the Design-Builder shall submit a plan for remedial action to the MBTA. Calculations and working drawings for the remedial action shall be stamped by a Registered Professional Engineer in the Commonwealth of Massachusetts. The Design-Builder shall carry out the remediation work without cost to the MBTA and without an extension of the contract time.
- C. Following final acceptance of each drilled shaft by the MBTA, the Design-Builder shall completely fill all CSL access tubes with minimum 5,000 psi tremied concrete grout.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions, Section 14, Payment.

END OF SECTION

SECTION 02400

DRAINAGE AND SEWER SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies construction of drainage facilities and sanitary sewer facilities.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 - 2. Section 02081 – HAZARDOUS MATERIALS ABATEMENT
 - 3. Section 02221 – DEMOLITION
 - 4. Section 02240 – DEWATERING
 - 5. Section 02282 – HANDLING, TRANSPORTATION AND DISPOSAL OF EXCAVATED MATERIALS
 - 6. Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
 - 7. Section 02296 – TRAFFIC DECKING
 - 8. Section 02300 – EARTHWORK
 - 9. Section 02359 – MODULAR PRECAST BLOCK RETAINING WALLS
 - 10. Section 02402 – STORMWATER TREATMENT AND DISPOSAL SYSTEMS
 - 11. Section 02450 – SECONDARY CONTAINMENT SYSTEMS - GEOSYNTHETIC BARRIERS
 - 12. Section 02509 – PAVEMENT BASE COURSES
 - 13. Section 02615 – DUCTILE IRON PIPE AND FITTINGS FOR STORMWATER PUMP STATIONS
 - 14. Section 02632 – STORMWATER BYPASS PUMPING SYSTEMS
 - 15. Section 02633 – WASTEWATER BYPASS PUMPING SYSTEMS
 - 16. Section 02650 – EXISTING SITE UTILITIES
 - 17. Section 03300 - CAST-IN-PLACE CONCRETE
 - 18. Section 05500 – MISCELLANEOUS METALS
- C. The Design-Builder is required to comply with all requirements of the MBTA Railroad Operations Directorate Specifications Part IV, Pipeline Occupancy Specifications, and shall comply with the MBTA Commuter Rail Design Standards Manual.

1.2 SUBMITTALS

- A. Shop Drawings. Include details of sewers and drains, including relationship to other systems; true position and details of interfaces, connections, inlets, cleanouts, manholes, safety gates, alignment, grade, changes of direction, offsets, bedding, protection, materials and other pertinent data.

- B. Product Data: Submit copies of manufactures' printed product data, specifications, standard details, installation instructions, use limitations and recommendations for each material used. Provide certifications that materials and systems comply with specified requirements.
- C. Product data for all materials shall be submitted for approval. Product data shall be submitted for any installed materials, including but not limited to the following materials:
1. PVC pipe and fittings
 2. PVDF pipe and fittings
 3. Reinforced concrete pipe and box culvert
 4. Ductile iron pipe
 5. High density polyethylene (HDPE) pipe
 6. Fiberglass reinforced pipe (FRP)
 7. Precast concrete manhole sections
 8. Precast concrete catch basins
 9. Pipe and structure joint gaskets and seals
 10. Manhole steps, joint sealer, brick and mortar and frames and grates/covers.
 11. Fiberglass manhole tee bases, risers and cones.
 12. Filter fabric
 13. Underdrain filter
 14. Perforated pipe
 15. Polyethylene encasement for ductile iron pipe
 16. Steel casing pipe, casing spacers and end seals
 17. Galvanized steel grating
 18. Stop logs and appurtenances
 19. Controlled density fill
 20. Inline check valve
 21. Area Drains
 22. Concrete admixtures
 23. Splash Pads
 24. Galvanized steel pipe

1.3 PERMITS AND LICENSES

- A. The Design-Builder is required to submit permit applications and pay the associated fees to the Cities of Boston, Cambridge, Medford and Somerville to obtain permits for the construction of the sanitary sewer and storm water drainage improvements.

- B. The Design-Builder is required to apply for and obtain Drainlayers Licenses from the Cities of Boston, Cambridge, Medford and Somerville. The Design-Builder shall submit a General Service Application to the Boston Water and Sewer Commission (BWSC).
- C. For drainage installations within the City of Boston, the Design-Builder shall coordinate installation schedules with BWSC inspectors.
- D. The Design-Builder is required to comply with all requirements of 520 CMR 14.00: *Excavation and Trench Safety*, which has established standards to prevent unauthorized access to unattended trenches.

1.4 PRESSURE AND LEAKAGE TESTING AND TOLERANCES

- A. Gravity Lines: Maximum allowable leakage for any section or sections, or for the total lengths of pipelines: 200 gallons per inch of diameter per mile per 24 hours.
- B. Polyvinyl Chloride PVC and Polyvinylidene Fluoride PVDF:
 1. Testing of Pipe: After completing installation and backfill of pipe, the Design-Builder shall, at his expense, conduct a line acceptance test using low pressure air. Equipment used shall meet the following minimum requirements: Pneumatic plugs shall have a sealing length equal to or greater than the diameter of the pipe to be inspected; Pneumatic plugs shall resist internal test pressures without requiring external bracing or blocking; All air used shall pass through a single control panel. Three individual hoses shall be used for the following connections: From control panel to pneumatic plugs for inflation; from control panel to sealed line for introducing the low pressure air; from sealed line to control panel for continually monitoring the air pressure rise in the sealed line.
 2. All pneumatic plugs shall be seal tested before being used in the actual test installation. One length of pipe shall be laid on the ground and sealed at both ends with the pneumatic plugs to be checked. Air shall be introduced into the plugs to 25 psig (172.3689 Kpa). The sealed pipe shall be pressurized to 5 psig (34.47378 Kpa). The plugs shall hold against this pressure without bracing and without movement of the plugs out of the pipe.
 3. After a manhole to manhole reach of pipe has been backfilled and cleaned, and the pneumatic plugs are checked by the above procedure, the plugs shall be placed in the line at each manhole and inflated to 25 psig (172.4 Kpa). Low pressure air shall be introduced into this sealed line until the internal air pressure reaches 4 psig (27.579 Kpa) greater than the average back pressure of any groundwater that may be over the pipe. At least two minutes shall be allowed for the air pressure to stabilize.
 4. After the stabilization period (3.5 psig (24.1317 Kpa) minimum pressure in the pipe), the air hose from the control panel to the air supply shall be disconnected. The portion of line being tested shall be termed "Acceptable" if the time required in minutes for the pressure to decrease from 3.5 to 2.5 psig (24.1317 to 17.2369 Kpa) (greater than the average back pressure of any groundwater that may be over the pipe) is not less than the time shown for the given diameter in the following table.

Pipe Diameter	Specification Time for Length Shown (min: sec)			
	<u>Inches</u>	<u>100 ft.</u>	<u>200 ft.</u>	<u>300 ft.</u>
6	5:40	5:40	5:40	5:42
8	7:34	7:34	7:36	10:08
10	9:26	9:26	11:52	15:49
12	11:20	11:24	17:05	22:47
15	14:10	17:48	26:42	35:36
18	17:00	25:38	38:27	51:16
21	19:50	34:54	52:21	69:48
24	22:47	45:34	68:22	91:10

5. In areas where groundwater is known to exist, the Design-Builder shall install a 1/2 inch (1.27cm) diameter capped pipe nipple, approximately 10 inches long, through the manhole wall adjacent to one of the sewer lines entering the manhole. This shall be done at the time the line is installed. Immediately prior to the performance of the Line Acceptance Test, the groundwater shall be determined by removing the pipe cap, blowing air through the pipe nipple into the ground so as to clear it, and then connecting a clear plastic tube to the nipple. The hose shall be held vertically and a measurement of the height in feet of water over the invert of the pipe shall be taken after the water has stopped rising in this plastic tube. The height in feet shall be divided by 2.3 to establish the pounds of pressure that will be added to all readings. (For example, if the height of water is 11 1/2 feet, then the added pressure will be 5 psig. This increases the 3.5 psig to 8.5 psig, and the 2.5 psig to 7.5 psig. The allowable drop of one pound and the timing remain the same). In no case shall the starting pressure exceed 9.0 psig.
6. If the Design-Builder is unable to pass a pressure test because lines are “live”, the Design-Builder shall perform closed circuit television inspections of the lines at no additional cost to the MBTA. The MBTA must be able to witness the tests and must be provided with a video recording of each test for further inspection.
7. Test Failure: If the section of pipe fails to pass the leakage and pressure test, or if there is any visible leakage, the Design-Builder shall locate, uncover and repair or replace the defective pipe fitting or joint and retest all at his own expense. Pipe will be considered passing only when the leakage does not exceed the above standard. Passing the test does not absolve the Design-Builder from his responsibility if leaks develop later within the period of warranty.

C. RCP and Box Culverts:

1. Leakage Tests: Leakage tests will be required by the Authority for all pipe and manhole installations. Tests shall meet all requirements of this paragraph. Leakage into or from the piping and structures, except storage tanks, will be determined respectively by infiltration tests or by exfiltration tests, as specified herein and as directed. The maximum allowable amount of infiltration into the piping or exfiltration from the piping as determined respectively by the infiltration tests or by the exfiltration tests, including manholes, shall be at a rate of not greater

than 150 gallons (567.8 l) per inch of pipe diameter per mile of pipe per 24 hours, and there shall be no gushing or spurting streams of water into or from the piping or manholes. The phrase, "per mile of pipe" shall refer to the total length of pipe measured through manholes. Where the groundwater level can be maintained at a height of not less than one foot (304.8 mm) above the top of the pipe for the full length of the section of pipe being tested for leakage, the leakage into the piping and manholes shall be determined as specified under "Infiltration Tests." Where the groundwater cannot be maintained at a level of not less than one foot (304.8 mm) above the top of the pipe for the full length of the section of pipe being tested, the leakage from the piping and manholes shall be determined as specified under "Exfiltration Tests". Perform all work, provide all necessary weirs or such other measuring devices as required, do all pumping and furnish all equipment necessary for the proper performance of leakage tests at no additional cost to the MBTA. Leakage testing of piping shall be satisfactorily performed in sections as the work progresses, and as directed.

2. Infiltration Tests: The tests shall be conducted at such times as the groundwater level is at a height of not less than one foot (304.8 mm) above the top of the pipe for the full length of the section of the pipe being tested. The groundwater leakage into the pipe will be measured by the Authority at such point or points as he may direct. Construct such weirs or other means of measurement as required and pump as necessary for the tests to be properly made.
3. Exfiltration Tests: Where exfiltration tests are required, the section of pipe to be tested shall be subjected to an internal pressure. The lower end of the section of pipe to be tested shall be closed and the entire section of the pipe, including manholes, shall be filled with clean water so as to obtain a minimum head of 2 feet (0.6096 m) above the top of the pipes; the length of the section of pipeline being tested shall be such that with the head of water 2 feet (0.6096 m) above the top of pipe at the upper end of the section of the pipeline being tested will not exceed 8 feet (2.4384 m). The rate of leakage from each section of the pipe being tested will be determined by the MBTA by measuring the amount of water required to maintain the minimum head of 2 feet (0.6096 m) above the top of the pipe for the full length of each section of the pipes being tested.
4. Should the infiltration or exfiltration test on any section of the pipelines, including manholes, show a rate of leakage into or from the pipeline exceeding the maximum allowable rate of infiltration or exfiltration specified herein, locate, repair, or replace defective joints and work in a manner satisfactory to the MBTA and retest at no additional cost to the MBTA until the rate of infiltration into or exfiltration from each section of the pipeline being tested does not exceed the rate specified herein for infiltration or exfiltration.
5. The completed pipe and joints shall be visually inspected by the MBTA. If the Design-Builder is unable to pass a pressure test because lines are "live", the Design-Builder shall perform closed circuit television inspections of the lines at no additional cost to the MBTA. The MBTA must be able to witness the tests and must be provided with a video recording of each test for further inspection.

D. Ductile Iron Force Mains:

1. Pressure Testing: All pipe and appurtenances installed shall be hydrostatically tested in accordance with ANSI/AWWA C600, latest version unless stated otherwise herein. Test pressure, expressed in terms of feet of water, applied at any point in pipe equals arithmetic difference between specified test pressure plane elevation and elevation of horizontal center line of pipe at selected location. Multiply value by 0.433 to obtain pounds per square inch. Ensure pressure gauges are accurately calibrated. Do not attempt pressure testing until all air has been vented from the mains. All new force mains that shall become the property of the MBTA shall be pressure tested at a minimum of 150 psi for a continuous period of two hours.

2. Leakage Testing: Conduct leakage testing in conjunction with pressure tests. Ensure that joints in piping are watertight and free from visible leaks during leakage test.
 3. Leakage Test Pressure: Maintain specified normal operating line pressure for pressure testing of reach during leakage test. Maintain hydrostatic pressure within plus or minus 5 percent during entire time of leakage measurements.
 4. Leakage Measurement: Do not attempt measurement of leakage until trapped air has been vented and constant test pressure has been established. Measure leakage by means of an approved water meter installed in the pressure piping on discharge of the pump. Ensure that water meter is accurately calibrated.
 5. Allowable Leakage: Ensure that pipe reach does not exceed the allowable leakage rate. Calculate allowable leakage with following formula:
 - a. $Q = 0.0075 \text{ DLN}$ where
 - b. Q = allowable leakage in gallons per hour
 - c. D = nominal diameter of pipe in inches
 - d. L = length of section tested in thousand feet (1,000-foot maximum)
 - e. N = square root of avg test pressure in psi (12.25)
 6. Calculate allowable leakage separately for each diameter and add resulting allowable leakage rates to obtain total allowable leakage for entire reach.
- E. Drainage and Sanitary Structures and Catch Basins, Leakage Tests:
1. The manholes shall be made as nearly watertight as practicable.
 2. The Design-Builder shall perform leakage tests on each manhole installed using an approved low air pressure testing system. This type of test shall be used only immediately after assembly of the manhole and only prior to backfilling. The manhole to pipe connection should only be a flexible connector. All lift holes shall be plugged with a non-shrinking mortar. For this test, each manhole shall be tested under 10-inch Hg vacuum. The test shall pass if the vacuum remains at 10-inch Hg or drops no lower than 9-inch Hg after 60 seconds for 4 or 5 foot manholes from 0 to 10 feet deep, 75 seconds for 4 or 5 foot manholes from 10 to 15 feet deep, or 90 seconds for 4 or 5 foot manholes from 15 to 25 feet deep. A volume equivalent shall be calculated for larger diameter manholes to determine the testing length based on these parameters.
- F. Fiberglass Reinforced Pipe
1. Low Pressure Air Test: Each joint / coupling is to be air tested with air pressure (max 5 psi). The joint passes the test if there is no pressure drop through the pipe or pipe joints for 4 minutes.
 2. The Design-Builder shall furnish manufacturer's test data that substantiates pipe joints will not leak (into the pipe) with a 25-foot head of water above the top of pipe.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Materials used to manufacture storm drainage products (pipe, structures and their appurtenances) are specified in the following paragraphs of this Part. For portions of the storm drainage system to be

installed that are tributary to and downstream of the Washington Street Pump Station (WSPS) the following additional requirements specified in this Paragraph apply. The storm drainage facilities in these areas require protection from chlorinated volatile organic compounds (CVOC) that have been reported in the groundwater. These additional requirements shall pertain to all drainage facilities within the railroad corridor as determined by the designated Project LSP and generally between the Washington Street Pump Station (WSPS) and just north of Cross Street (NH-T1 Sta. 103+50), the Washington Street underpass roadway drainage collection and conveyance system, the WSPS discharge force main piping from the pump station to force main piping Station 68+00 and the end seals of the casing pipe for the force mains which begins at approximately force main piping Station 68+00. The previous design measures are provided herein and listed below as a general reference only. Subsequent findings and final recommendation of the designated Project LSP shall govern.

1. Joint sealing material and gaskets for all piping and drainage structures shall be the fluorocarbon type, and at a minimum, be constructed of Viton. This shall also include all flexible pipe connector devices used to connect piping to drainage structures and the WSPS. Gasket material shall be in accordance with ASTM D2000.
 2. Cement concrete used to manufacture precast reinforced concrete pipe (RCP) and drainage structures shall include an additive to provide a waterproofing system. Concrete waterproofing system shall be of the integral crystalline type, defined by the ACI 212.3R – 10 Report on Chemical Admixtures for Concrete as a “PRAH” type hydrophilic admixture. It shall react such that it chemically controls and permanently fixes a non-soluble crystalline structure throughout the capillary voids of the concrete. The system shall cause the concrete to become sealed against the penetration of liquids from any direction, and shall protect the concrete from deterioration due to harsh environmental conditions. Admixture shall be a product produced by Kryton International Inc., Xypex Chemical Corporation or an approved equal. Design-Builder shall submit product literature and mix designs demonstrating compliance with the intent of these specifications and indication of precaster acceptance of use of the additive.
 3. Plastic drain and underdrain shall be polyvinylidene fluoride (PVDF) piping, as shown on the Plans.
- B. Products used at interface with utility companies shall conform to the requirements of connected utility companies.

2.2 PIPE AND FITTINGS

- A. Clay Pipe and Fittings:
1. Pipe: ASTM C 700, except crushing strength shall be in accordance with National Clay Pipe Institute Specification ER4, salt or ceramic glazed, bell and spigot except where plain ends are indicated.
 2. Joints and Gaskets: ASTM C 425.
- B. Plain Concrete Pipe:
1. Unperforated: ASTM C14, class as indicated, bell and spigot.
 2. Perforated: ASTM C 444, type as indicated, and all applicable requirements of ASTM C 14, class as indicated.
- C. Reinforced Concrete Pipe (RCP) and Box Culverts (preferred for all gravity flow drainage systems):

1. Circular Section: ASTM C 76; ends, class, and wall as indicated. All RCP on MBTA property shall utilize Class 5 with a Wall C. RCP that is to be jacked shall be minimum Class 5.
 2. Elliptical Section: ASTM C 507; ends and class as indicated.
 3. Box Culvert Section: ASTM C 1433; ends, class, and wall as indicated.
- D. Joints and Gaskets for Circular Concrete Pipe: ASTM C 443.
- E. Steel Casing Pipe for Jacking or Open-Cut Installations: Casing pipe shall be designed for the earth and/or pressure present, and for railroad live load. The dead load of earth shall be considered 120 pounds per cubic foot. Railroad live load shall be Cooper E-80 with 50% added for impact. The minimum yield strength for steel pipe shall be 35,000 psi.
- F. Ductile Iron Pipe for Gravity and Force Mains:
1. Refer to Section 02615 for Ductile Iron Pipe and Fittings for Stormwater Pump Stations.
 2. Ductile iron pipe shall be that of a United States manufacturer who can demonstrate at least 5 years of successful experience in manufacturing ductile iron pipe. The pipe shall be equipped with push on type, restrained joint, or mechanical joints, as required.
 3. All ductile iron pipe shall conform to ANSI/AWWA C 151/A21.51 and ASTM A 746.
 4. The ductile iron pipe shall be, at a minimum, Class 52 or as determined considering the trench load and internal pressure separately in accordance with ANSI/AWWA C150/A21.50. Ductile iron pipe shall be H2 Sewer Safe Pipe (Sewer Coat lined).
 5. The ductile iron pipe shall be asphalt coated on the outside and inside with a minimum of 1 mil bituminous paint according to ANSI/AWWA C151/A21.51 Section 51-8.1. Prior to the lining, the inside and outside of the spigot end shall be coated with a minimum of 8 mil of epoxy. The inside of the bell end including the gasket cavity shall also be coated with 8 mil of epoxy.
 6. The ductile iron pipe lining shall be as manufactured by Lafarge Calcium Aluminates or approved equal. The coating shall be a calcium aluminate mortar consisting of calcium aluminate cement and fused calcium aluminate aggregates. A seal coat shall be applied to the lining. The thickness of the lining shall be 0.125-inch for 6-inch through 12-inch pipe and 0.1875-inch for 14-inch through 24-inch pipe.
 7. Ductile iron pipe shall be encased in polyethylene film, conforming to the requirements of AWWA C105.
 8. Gasket Materials: Push-on and mechanical joint gaskets shall be Nitrile (NBR) (Acrylonitrile Butadiene) or equal gasket acceptable for use in an environment which will handle fats, oils and greases unless otherwise noted or approved.
 9. Fittings: Fittings shall be compact ductile iron Class 350 Mechanical Joint, conforming to ANSI Specification A21.53 (AWWA C 153), latest edition, for pipe sizes 16 inches and smaller, and Class 350 standard Mechanical Joint fittings conforming to AWWA C110/ANSI A21.10, latest edition except as specified, for pipe sizes 16 through 24 inches, unless specifically stated otherwise in the specifications or on the drawings. Fittings shall be suitable for use with restraints as specified hereinafter. Fittings shall be manufactured in the United States. Fittings shall be of the same material and have the same lining and coating as the pipe specified above. All fittings shall be marked with the weight and shall have distinctly cast upon them the pressure rating, the manufacturer's identification, nominal diameter of openings and the number of degrees or fraction of the circle on all bends.

- a. Caps and plugs installed in all new work as indicated on the drawings shall be provided with a threaded corporation or bleeder valve so that air and water pressure can be relieved prior to future connection.
- b. Solid sleeve couplings shall be ductile iron with 350 psi rating. Sleeves shall conform to ANSI/AWWA C 219.

G. Polyvinyl Chloride Pipe (PVC):

1. All PVC pipe shall be continuously and permanently marked with the manufacturer's name, pipe size, and pressure rating or stiffness in psi (kpa).
2. The Design-Builder shall also require the manufacturer to mark the date of extrusion on the pipe. This dating shall be done in conjunction with records to be held by the manufacturer for 2 years, covering quality control tests, raw material batch number, and other information deemed necessary by the manufacturer.
3. Pipe:
 - a. All PVC pipe shall be joined by compression joints unless otherwise shown or specified, and shall conform to the following requirements:
 - b. Non Perforated Polyvinyl chloride pipe (PVC) shall conform to the requirements of ASTM D 3034, Class SDR 35. Material for PVC pipe shall conform to the requirements of ASTM D 1784 for Class 12454-B or 12454-C as defined therein. All diameters shall be as specified on the Contract Drawings.
 - c. Perforated PVC pipe shall conform to the requirements of ASTM D 3034, Class SDR 35. Material for perforated PVC pipe shall conform to the requirements of ASTM D 1784 for Class 12454-B or 12454-C as defined therein. The pipe shall have 3/8-inch perforations, 6 inch on center and 4 holes per row. The pipe shall be 6 inch diameter unless otherwise specified on the Contract Drawings.
 - d. Elastomeric seals for compression type joints for PVC pipe and fittings shall conform to the requirements of ASTM D 3212.
 - e. Service pipes for storm services shall be minimum of 8-inch and shall match diameter of existing services for reconnections. Service pipes for sanitary services shall be minimum of 6-inch and shall match diameter of existing, services for reconnections.
4. Fittings:
 - a. All fittings shall conform to the requirements of ASTM D 3034 or ASTM F 679. The ring groove and gasket ring shall be compatible with PVC pipe ends. The flanged fittings shall be compatible with cast-iron or ductile iron pipe fittings.
 - b. The strength class of the fittings shall be not less than the strength class of any adjoining pipe.
 - c. PVC pipe fittings shall be full-bodied, either injection molded or factory fabricated.
5. Connections:
 - a. Sanitary services shall be connected to new, parallel or replacement sanitary sewer lines with full bodied tees or wye fittings.

- b. Storm services shall be connected to new, parallel, or replacement storm sewer lines with full bodied tees or wye fittings for all pipes up to 18-inch in diameter. Connections to pipes larger than 18-inch in diameter or odd sizes shall be made with saddle tap connections, as approved by Owner.
 - c. Connections of storm and sanitary service lines to existing storm and sanitary main lines shall be made with full bodied tees or wye fittings wherever possible for existing lines less than 18-inch in diameter and with tapping saddles as approved by Owner for existing lines greater than 18-inch in diameter and in odd sizes.
6. Gaskets: Flexible elastomeric rings conforming with ASTM F 477.

H. Perforated High Density Polyethylene (HDPE) Pipe:

- 1. Perforated high density polyethylene pipe and fittings for use as underdrain pipe shall be corrugated profile-wall pipe with a smooth interior wall. HDPE underdrain pipe shall meet the requirements of AASHTO M294 and ASTM F2306. Virgin material for pipe and fitting production shall be high-density polyethylene conforming with the minimum requirements of ASTM D3350, except that carbon black content should not exceed 4%.
- 2. Pipe joints shall comply with the requirements of AASHTO M294 and ASTM F2306. Pipe joints shall be watertight meeting the requirements of ASTM D3212. The joint gaskets shall comply with ASTM F477.
- 3. Perforations shall be Class 2 type slots.

I. Solid Wall High Density Polyethylene (HDPE) Pipe:

- 1. The HDPE pipe shall be manufactured from a high density, high molecular weight polyethylene resin, which conforms to ASTM D-1248 and meets the requirements for Type III, Class B, Grade P34, Category 5, and has a PPI rating of PE 3408, when compounded. The pipe produced from this resin shall have a minimum cell classification of 345434C or D under ASTM D 3350.
- 2. The wall thickness of the HDPE pipe shall be as determined by the Design-Builder for the minimum thickness required to meet the structural requirements listed under Design Criteria below, and shall meet the following:
- 3. Minimum Wall Thickness: 0-12 feet depth, minimum wall thickness SDR 26; over 12 feet depth, SDR 21 minimum wall thickness.
- 4. All pipes shall be made of virgin material. No re-work, except that obtained from the manufacturer's own production of the same formulation shall be used.
- 5. The pipe shall be homogenous throughout and shall be free of visible cracks, holes, foreign material, blisters, or other deleterious faults.
- 6. The interior surface of the HDPE pipe shall not be dark or non-reflective in nature that could inhibit proper television inspection.
- 7. The finished HDPE pipe shall be continuous over the entire length of an insertion run between the insertion pit and reception pit. The HDPE pipe shall be impervious and free of any leakage from the rehabilitated host pipe to surrounding ground, or from the surrounding ground to the inside of the pipe.
- 8. The manufacturer of the pipe shall supply the AUTHORITY with certificates of compliance indicating conformance for all material and testing requirements furnished under these Specifications.

9. Each standard pipe unit shall be clearly and permanently marked with the date of manufacture, class, production code, and manufacturer's trademark.
10. The Design-Builder and manufacturer shall exercise extreme care during transportation, handling, storing, and installation of the HDPE pipe to ensure that the pipe is not gouged or otherwise damaged in any way. The Design-Builder shall store the pipe with a cover to block ultraviolet light in accordance with the manufacturer's recommendations. If the HDPE pipe becomes gouged or otherwise damaged, before or during installation, it shall be replaced or repaired by the Design-Builder at no additional cost to the Authority.

J. Fiberglass Reinforced Pipe (FRP):

1. General: Workmanship and methods shall be in accordance with the best practices of modern shops for this type of work and shall be the product of a manufacturing firm having at least five years of experience in the manufacture of this type of pipe. Pipe shall have a smooth and even interior surface free from roughness or irregularities. Prior to fabrication of pipe, submit shop drawings showing lengths of pipe, pipe joint details, construction details and tolerances as required by the Authority. Each pipe shall be marked with the date of manufacture, mark or trademark of the manufacturer, and the class, wall thickness of the pipe, and serial number. No slurry mix shall be used on interior of pipe.
2. Resin Systems: The manufacturer shall use only polyester resin systems with a proven history of performance in this particular application. The historical data shall have been acquired from a composite material of similar construction and composition as the proposed product.
3. Glass Reinforcements: The reinforcing glass fibers used to manufacture the components shall be of highest quality commercial grade E-glass filaments with binder and sizing compatible with impregnating resins.
4. Silica Sand: Sand shall be minimum 98% silica with a maximum moisture content of 0.2%.
5. Additives: Resin additives, such as curing agents, pigments, dyes, fillers, thixotropic agents, etc., when used, shall not detrimentally effect the performance of the product.
6. Elastomeric Gaskets: Gaskets shall be supplied by qualified gasket manufacturers and be suitable for the service intended.
7. Pipes, Joints, and Fittings:
 - a. Pipe shall be manufactured by a casting process that results in a dense, nonporous, corrosion-resistant, consistent composite structure. Pipe shall comply with ASTM D3262.
 - b. Actual outside diameter (18-inch to 48-inch) of the pipes shall be in accordance with ASTM D 3262. For other diameters, OD's shall be per manufacturer's literature.
 - c. The minimum pipe stiffness class shall be 72 psi unless otherwise noted or manufacturer demonstrates another class is adequate. Minimum wall thickness shall be the stated design thickness.
 - d. Pipe ends shall be square to the pipe axis with a maximum tolerance of 1/8-inch.
8. Unless otherwise specified, the pipe shall be field connected with fiberglass sleeve couplings or bell-spigot joints, "flush" or "non-flush", that utilize elastomeric sealing gaskets as the sole means to maintain joint watertightness. The joints must meet the performance requirements of ASTM D 4161. Joints at tie-ins, when needed, may utilize fiberglass, gaskets-sealed closure couplings.
9. Flanges, elbows, reducers, tees, wyes, laterals, and other fittings shall be capable of withstanding all operating conditions when installed. They may be contact molded or manufactured from

mitered sections of pipe joined by glass-fiber-reinforced overlays. Properly protected standard ductile iron, fusion-bonded epoxy-coated steel and stainless steel fittings may also be used.

- K. Polyvinylidene Fluoride Pipe (PVDF) (as may be recommended by the Project LSP in areas of existing or suspected areas of soil/groundwater contamination):
1. All PVDF pipe shall be continuously and permanently marked with the manufacturer's name, pipe size, and pressure rating or stiffness in psi (kpa).
 2. The Design-Builder shall also require the manufacturer to mark the date of extrusion on the pipe. This dating shall be done in conjunction with records to be held by the manufacturer for 2 years, covering quality control tests, raw material batch number, and other information deemed necessary by the manufacturer.
 3. Pipe:
 - a. All PVDF pipe shall be joined by compression joints unless otherwise shown or specified.
 - b. Polyvinylidene fluoride shall conform to the requirements of ASTM F1673, SDR 21. Pipe diameters shall be as shown on the Contract Drawings.
- L. Galvanized Steel Pipe (must meet all Stray Current and Corrosion Control requirements as described in the Technical Provisions subsection 8 Right of Way Structures and Specification Section 16451 Corrosion Control and Stray Current Mitigation):
1. Steel Pipe: ASTM A53 / A53M, Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless, standard weight (Schedule 40), unless another weight is indicated.
 2. Pipe fittings shall be minimum standard weight (Schedule 40).
 3. Joints: grooved-ends conforming to ANSI / AWWA C606.
 4. Mechanical coupling method for joining pipe. Manufactured in two segments of cast ductile iron, conforming to ASTM A-536, Grade 65-45-12. Gaskets shall be pressure responsive synthetic rubber, grade compatible with railroad track bed stormwater runoff, conforming to ASTM D2000.
 5. All hardware and fasteners shall be hot-dip galvanized.

2.3 STRUCTURAL STEEL FOR SITE ERECTION

- A. Corrugated: AASHTO M 167.
- B. Flat: AASHTO M 218.

2.4 UNDERDRAIN FILTER

- A. Filter Material: Narrowly graded mixture of natural or crushed gravel, or crushed stone and natural sand; ASTM D 448; coarse-aggregate grading Size 67; with 100 percent passing a 1-inch sieve and 0 to 5 percent passing a No. 4 sieve.

2.5 DRAINAGE AND SANITARY STRUCTURES

- A. Precast Concrete Structures shall be manufactured in accordance with ASTM C478 (circular structures) and ASTM C913 (rectangular structures) and all applicable associated ASTM standards. Design loading for all structures installed within MBTA Railroad Property influenced by the track live load shall be

Cooper E-80, unless noted or approved otherwise. Design loading for other areas shall conform to AASHTO-HS20.

- B. Precast Sections (for non-load bearing drainage structures other than manholes): ASTM C 139 for Concrete Masonry Units for Catch Basins and Manholes.
- C. Pipe openings in the structure shall be the minimum size required to receive the pipe, with either a flexible connector or mortared in place, and shall be accurately set to conform to the required line and grade.
- D. Drain pipe shall be joined to the wall of the concrete manholes or catch basins with flexible manhole connectors complying with ASTM C923.
- E. Precast manhole and catch basin structures shall have eccentric cone sections. Where depth to inlet/outlet piping is limited, a flat top type of structure may be used.
- F. Manhole bases shall be either precast or cast-in-place. When cast-in-place, the base shall be shaped by means of an accurate bell-ring to conform to the barrel sections.
- G. The exterior surfaces of all sanitary manholes shall be coated with two (2) coats of Super Service Black by Koppers or an equivalent product by Mobil, Tnemec, or equal. The final thickness shall be 20-24 mils dry.
- H. Preformed flexible joint sealant, conforming to ASTM Designation C990 shall be used to seal joints between precast sections.
- I. Manhole steps shall be fabricated of a minimum 1/2-inch Grade 60 circular steel reinforcement core, with a bonded outer shell of Copolymer Polypropylene plastic, and shall be cast into the manhole sections(s). Steps shall comply with the applicable provisions of ASTM A615, C478 and D4101.

2.6 DRAINAGE AND SANITARY STRUCTURES REMODELED

- A. The work to be done under this item shall conform to the relevant provisions of Section 220 of the MassDOT Standard Specifications, Construction Standards. The work shall include the removal and resetting of the casting to the proposed line and grade and the removal and replacement, in kind, of the masonry which, in the judgment of the MBTA, shows signs of deterioration.

2.7 BRICK

- A. ASTM C32, Grade SS, 2-1/4 inches by 3-3/4 inches by 8 inches.

2.8 CONCRETE

- A. Concrete, General: Section 03300 - CAST-IN-PLACE CONCRETE.
- B. Cradles and Cradle-Arches: Class 4,000-3/4.
- C. Manholes and Other Load-Bearing Drainage Structures: Class 4000-3/4.

2.9 CEMENT MORTAR

- A. One part Portland cement, two parts sand by volume with sufficient water to form a workable mixture, mortar minimum strength of 3,000 psi.

2.10 FRAMES AND COVERS

- A. Drain Manhole Frames shall meet the requirements set forth by MassDOT.
- B. Drain Manhole Covers shall meet the requirements set forth by MassDOT.
- C. Iron castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow-holes and other defects affecting the strength and value for the service intended. The finished coating shall be tough and tenacious when cold and not brittle or with any tendency to scale off under reasonable temperature changes.
- D. Frames and Covers shall be Cast Iron, minimum Class 25 conforming to ASTM A 48, and as follows: Castings to be free from scale, lumps, blisters and sandholes. Machine contact surfaces to prevent rocking. Thoroughly clean and hammer inspect.
- E. Frames and covers shall meet the requirements set forth by MassDOT. Frames and covers shall be capable of withstanding AASHTO H-20 loading unless otherwise indicated or specified.
- F. The Design-Builder shall furnish all manhole frames and covers conforming to the details shown on the drawings, or as herein specified. Frames and covers shall be of cast iron with diamond cover surface design. Manhole covers shall be machined to fit securely and evenly on the frame.
- G. Covers for all structures shall have the word "DRAIN", "SEWER" or other appropriate designation cast upon them.
- H. Track underdrain cleanout ring and cover shall meet the requirements set forth by MassDOT.
- I. Combination inlet castings shall be an integral curb inlet with double grates, shall meet the requirements set forth by MassDOT.

2.11 FRAMES

- A. Single Catch Basin Frames shall meet the requirements set forth by MassDOT.

2.12 GRATES

- A. Single Catch Basin Grates shall meet the requirements set forth by MassDOT.

2.13 LOCKING FRAMES AND COVERS

- A. Locking Frames and Covers shall meet the requirements set forth by MassDOT.

2.14 HOODS

- A. Catch Basin Hoods shall meet the requirements set forth by MassDOT.

2.15 NO DUMP CURB MARKERS

- A. No-dump markers shall be installed on all existing-to-remain or proposed catch basins and inlets within the project area. Curb markers shall be 4-inch diameter, 0.090 mil. thick, PVC laminate, with urethane dome. The Design-Builder shall obtain and utilize the most current maker requirements from the respective municipality at the time of the installation.

2.16 FLEXIBLE MANHOLE SEALS

- A. Flexible manhole seals shall meet the requirements set forth by MassDOT. Field applied seals shall meet the requirements set forth by MassDOT. Manhole sleeves, gaskets and sealants shall be furnished complete with lubricants, stainless steel stops, inserts, clamps, etc.

2.17 FILTER FABRIC

- A. Filter fabric for lining PVC drain and underdrain trenches shall meet the requirements set forth by MassDOT. Refer to other paragraphs in this Section and in Earthwork, Section 02300, for other applications of filter fabric for piping.

2.18 PIPE BEDDING

- A. Bedding Course for Ductile Iron Pipe: Naturally or artificially graded mixture of natural or crushed gravel, crushed stone, and natural or crushed sand; ASTM D 2940; except with 100 percent passing a 1-inch sieve and not more than 8 percent passing a No. 200 sieve.
- B. Sand Borrow: Sand borrow shall be used as pipe bedding for all pipe with the exception of Reinforced Concrete Pipe and Ductile Iron Pipe, placed between 6 inches below pipe invert to 6 inches above pipe crown.
- C. Crushed Stone: Crushed stone meeting the requirements of ASTM D2490 shall be used as Ductile Iron, Reinforced Concrete, Fiberglass Reinforced and PVC Pipe bedding between 12 inches below pipe invert to 6 inches above pipe crown and initial 12 inches of backfill under structures, as a working mat or as a filter around perforated drain pipe. Crushed stone shall be wrapped in filter fabric, placed in maximum 6-inch thick layers, loose measure, and compacted with a minimum of four passes of a vibratory plate or roller compactor. The crushed stone shall be uniformly blended.
- D. Controlled Density Fill: For use as flowable fill for pipe bedding material at locations noted, shown or as specified. This controlled density fill shall be the excavatable type, complying with the material requirements of the Massachusetts DOT Highway Division Standard Specifications, Section M4.08.00, Type 2E, flowable (excavatable).

2.19 POLYETHYLENE ENCASEMENT

- A. The polyethylene film used for encasing ductile iron pipe shall be manufactured in accordance with the formulation, physical tests, thickness and dimensional requirements specified in AWWA/ANSI Standard C105/A21.5 (*Standard for Polyethylene Encasement of Ductile Iron Pipe Systems*) and ASTM A674.

2.20 STOP LOGS

- A. Stop logs for all drainage structures for all locations within the project shall be constructed of the same material and furnished by the same manufacturer. Stop logs shall be either aluminum or fiberglass reinforced plastic.
- B. Stop logs constructed of extruded aluminum shapes shall have a minimum thickness of 5/16-inch.
 - 1. Maximum bending stress shall not exceed 7600 psi at the maximum operating head.
 - 2. Adequate drainage shall be provided for each stop log. Logs shall be self-draining and shall not retain water.
 - 3. Two slots shall be provided in the top of each stop log for removal and installation via the stop log lifter.
 - 4. A mill finish on aluminum surfaces shall be required. All aluminum in contact with concrete shall be shop coated with a heavy coat of bitumastic paint. Welds on aluminum shall be cleaned to provide a uniform finish.
- C. Stop logs constructed of fiberglass reinforced plastic shapes shall have a minimum thickness of 1/4-inch on the front and back facings and 3/4-inch on the remaining perimeter.
 - 1. Maximum fiber stress shall not exceed 2.5 times the working stress at the maximum operating head.
 - 2. Stop log shall be fabricated by a steel internal matrix being fully encased by thermoset plastic, no less than 1/4-inch thick on all sides, so as to totally encapsulate the internal frame. Steel shall be sandblasted and coated with vinyl ester resin immediately prior to vacuum infusion in order to ensure complete bonding with external barrier.
 - 3. Surface resin shall be at a depth between 0.010 and 0.020 inches and reinforced with C-glass or polymeric fiber surfacing material. Resin shall also include an added ultraviolet stabilizing pigment to provide long term protection.
 - 4. Per ASTM D2563-0 allowable surface defect tolerances are as follows: No cracks, blisters, chips, pits, dry spots, fish eyes, burned areas, pinholes, foreign matter or exposed glass or exposed cut edges shall be acceptable. Scratches shall be acceptable up to 0.002-inch in depth. Winkles shall be acceptable up to 1/8-inch. If any stop log exceeds these requirements it shall not be installed.
 - 5. Adequate drainage shall be provided for each stop log. Logs shall be self-draining and shall not retain water.
 - 6. Two slots shall be provided in the top of each stop log for removal and installation via the stop log lifter.
- D. Each stop log shall be outfitted with a continuous resilient lip seal along the bottom and both sides to restrict leakage in accordance with the requirements listed in this specification.
 - 1. The continuous lip seal shall be constructed of urethane or neoprene rubber and shall be mechanically attached to the log.
 - 2. Seal shall be activated by a combination of the weight of the stop log and the differential water pressure, which will push the seal against the inside of the lip groove assembly.
 - 3. Stop logs that utilize rubber “J” seals or “P” seals are not acceptable.

- E. One stop log lifter shall be provided for each different guide frame width.
 - 1. The lifter shall be constructed of aluminum and shall be outfitted with Ultra High Molecular Weight Polyethylene (UHMW) guide bars and stainless steel fasteners.
 - 2. The lifter shall be provided with lifting hooks designed to automatically engage in the slots in the top of the stop logs and stay engaged until manually released. Lifter shall be fitted with eye bolts for the attachment of lifting cables.
 - 3. The lifter shall be capable of installing and removing all stop logs of the same width whether they are installed or at the operating floor level.

- F. Storage racks shall be provided to house stop logs while they are not in use.
 - 1. Storage racks shall be constructed of aluminum and shall be mounted on the interior wall of the valve chamber rooms at the Red Bridge Pump Station and the Washington Street Pump Station..
 - 2. A latch or locking mechanism shall be required on rack to hold logs in place while being stored.

- G. Anchor bolts shall be provided by the stop log manufacturer for mounting the guide frames and storage racks (if applicable).
 - 1. Quantity and location shall be determined by the stop log manufacturer.
 - 2. If epoxy type anchor bolts are provided, the stop log manufacturer shall provide the studs and nuts.
 - 3. Anchor bolts shall have a minimum diameter of ½-inch.

2.21 INLINE CHECK VALVE

- A. Inline check valve shall be installed at the end of the 12-inch discharge pipe from the proposed viaduct infiltration system into the outlet control structure for the detention basin at Red Bridge.
 - 1. No mechanical parts
 - 2. Operates on differential pressure
 - 3. Low headloss
 - 4. Self-draining
 - 5. Silent, non-slamming
 - 6. Less than 1” of head pressure opens the valve, eliminating standing water
 - 7. 100% elastomer durable construction
 - 8. Simple installation
 - 9. Maintenance free except for periodic inspection

- B. Inline check valve shall be Tideflex CheckMate or approved equal.

2.22 AREA DRAINS

- A. Area drain catch basins shall be nine inch (9”) square structural-foam polyolefin structures with ultraviolet (UV) light inhibitors.

- B. Square tapered polypropylene drain risers with UV inhibitors shall be used where necessary and cut to height to achieve the correct rim and invert elevations. Design-Builder shall not stack more than five (5) risers between the catch basin and grate per structure.
- C. Drain grate shall be square cast iron grate with powdered coating. Grate shall meet ADA spacing requirements of openings no greater than one-half inch (1/2") wide in one direction and be able to meet AASHTO H-20 loading requirement.

2.23 SPLASH PADS

- A. Splash pads for protection of site surfaces at downspout outlet discharges and other locations, as directed by the Owner, shall be precast concrete items manufactured of Class 4,000 psi concrete and 5% to 9% air entrained. The splash pad shall be configured to form a trough, with trough minimum inside dimensions of 18" wide and 48" long, unless site constraints restrict dimensions. The trough bottom shall be sloped slightly and its minimum depth shall be 4". All corners shall be rounded over, 3/16" radius, and all edges rounded over, 1/16" radius.

PART 3 - EXECUTION

3.1 GENERAL

- A. Excavation. Excavate trenches as specified in Section 02300 - EARTHWORK.
- B. Bedding. Classes of bedding are defined in ASTM C12. Use class of bedding indicated; prepare trench and bedding as specified in ASTM C12. Place concrete for encasement against undisturbed soil. Where noted, shown or as specified bedding material shall be a controlled density fill.
 - 1. Bedding for Drainage Pipes
 - a. Place and compact bedding course on trench bottoms and where indicated. Shape bedding course to provide continuous support for bells, joints, and barrels of pipes and for joints, fittings, and bodies of conduits. Sand borrow bedding shall be placed by hand shovels, in layers not more than 4-inch thick in loose depth, and each layer shall be thoroughly and evenly compacted by tamping on each side of the pipe to provide uniform support and around the pipe, free from voids. Crushed stone bedding material shall be placed in layers not more than 6-inch thick in loose measure, and compacted with at least 4 passes using a vibratory plate or roller compactor.
 - 2. Bedding for Underdrains
 - a. Place subsurface drainage geotextile around perimeter of subdrainage trench. Place a 6-inch course of filter material on subsurface drainage geotextile to support subdrainage pipe. Encase subdrainage pipe in a minimum of 12 inches of filter material, placed in compacted layers 6 inches thick, and wrap in subsurface drainage geotextile, overlapping sides and ends at least 6 inches.
 - 1. Compact each filter material layer to 90 percent of maximum dry unit weigh according to ASTM D 1557.
- C. Pipe Laying. Lay all pipe in accordance with the manufacturer's written instructions. Additional requirements for specific types of pipe are included in subsequent articles herein.

- D. Structures. Construct manholes, junction chambers, inlets, wingwalls, and other related drainage structures in connection with the installation of pipe. Install or cut pipe flush with the inside face of structure walls.
- E. Protection
 - 1. Protect joint materials from the air and sun to prevent drying and other deterioration.
 - 2. Take precautions to prevent flooding of trench prior to backfilling.
 - 3. Do not allow free water to come in contact with pipelines until Portland cement joint and sealing materials have set for at least 24 hours.
- F. Backfill. Backfill trenches as specified in Section 02300 - EARTHWORK.
- G. Interfacing with existing pipeline
 - 1. Existing pipeline shall be cleaned at the locations as directed by the Owner.
 - 2. The Design-Builder is required to comply with all requirements of MassDOT Interim Supplemental Specifications, Section 227 DRAINAGE SYSTEM SEDIMENT.
 - 3. Design-Builder shall propose means and methods to the Owner for review and approval.
 - 4. Design-Builder shall be responsible for the characterization of the sediment in the pipe. If the sedimentation is characterized as oil and hazardous materials (OHM), Design-Builder shall handle and transport the sediments in accordance with the specification Section 02081 – HAZARDOUS MATERIALS ABATEMENT.

3.2 CRADLES

- A. Where gravel, crushed stone, or concrete cradles are indicated, provide bell holes in subgrade to permit uniform cradle depth beneath entire pipe length.

3.3 JACKING PIPE

- A. At locations where the Design-Builder proposes to jack reinforced concrete pipe, steel casing pipe or fiberglass reinforced pipe into place, jacking operations shall be performed on a continuous basis, 24 hours per day, 7 days per week. All MBTA requirements shall be strictly adhered to. Railroad operations shall be maintained at all times.
- B. Strength, reinforcement, and gauge of pipe designated to be jacked will be determined for vertical loads only. Provide additional reinforcement or higher strength or heavier gauge pipe as necessary to withstand jacking pressure, at no additional expense to the Authority.
- C. Excavate for jacking pipe not more than 0.1 foot wider than outside limits of pipe. When material tends to cave beyond that limit, use a shield ahead of the first section of pipe. Backfill caving and excavation beyond that limit with sand or grout to fill voids.
- D. Sluicing and jetting will not be permitted.
- E. Design-Builder shall submit proposed jacking plan for Owner's review and approval. The plan must be specific as to:

1. Size and material of casing pipe, casing spacers and end seals
 2. Size and material of carrier pipe
 3. Location and dimensions of jacking pits shall be shown with details of their sheeting and shoring.
 4. Temporary track support structures
- F. Casing pipe shall be installed in accordance with the most current edition of the American Railway Ownering Association specifications, "Jacking Culvert Pipe Through Fills". Design-Builder shall install signage at the ends of all casing pipes in accordance with the requirements of the MBTA Railroad Operations Specifications. The Design-Builder shall seal casing ends, including provisions for drainage if leakage occurs within the casing pipe, also in accordance with these Specifications. At locations identified on the Plans, end seals shall be constructed to be chemically resistant to the potential contaminants identified to be present in the groundwater.
- G. Design-Builder shall execute jacking and conduct geotech and surface monitoring conforming to the Authority's requirements for pipe jacking operations as specified in the MBTA Railroad Operations Specifications. Design-Builder shall conduct ground stabilization also in accordance with these Specifications.

3.4 INSTALLATION OF REINFORCED CONCRETE PIPE AND BOX CULVERTS

- A. Placement: Lay pipe upgrade with bell or groove end uphill. Place circular pipe having elliptical reinforcement with minor axis of the reinforcement in vertical position.
- B. Backfilling: Except where an exfiltration/infiltration test is to be performed, backfill of culvert-pipe and siphon-pipe trenches may be completed while joint mortar is still plastic. Should joint mortar become set before placing backfill, do not commence backfilling within 16 hours of joining pipe sections.

3.5 INSTALLATION OF DUCTILE IRON PIPE

- A. Handling Pipe: The Design-Builder shall take care not to damage pipe by impact, bending, compression, or abrasion during handling, and installation. Joint ends of pipe especially shall be kept clean. Pipe shall be stored above ground at a height no greater than 5 feet, and with even support for the pipe barrel. Only nylon protected slings shall be used for handling the pipe. No hooks or bare cables will be permitted. Gaskets shall be shipped in cartons and stored in a clean area, away from grease, oil, heat, direct sunlight and ozone producing electric motors.
- B. Alignment and Placement of Pipe: Jointing of ductile iron pipe and fittings shall be done in accordance with the printed recommendations of the manufacturer and as specified. The last 8 inches of the outside of the spigot end of pipe and the inside of the bell end of pipe shall be thoroughly cleaned. The joint surfaces and the gasket shall be painted with a lubricant just prior to making up the joint. The spigot end shall then be gently pushed home into the bell. The position of the gasket shall be checked to insure that the joint has been properly made and is watertight. Care shall be taken not to exceed the manufacturer's recommended maximum deflection allowed for each joint.
- C. Installation and jointing of push-on ductile iron pipe shall be in accordance with AWWA C 600 Sections 9b and 9c, latest revision, as applicable. Mechanical joints shall be installed with Mega-Lug, Uni-Flange or MJR restraints. Restraints shall be installed in full accordance with the manufacturers' instructions. All bolt heads on Mega-Lugs or Uni-flanged shall be tightened sufficiently so that they shear off to provide indication that proper tightening torque was achieved. MJR systems shall be installed with ductile iron locking ring, tapered MJ gland and a symmetrical locking ring. Restrained push on joints

shall be installed with specified gasket joint restraints. Restraints shall be installed in full accordance with the manufacturers' instructions.

- D. Piping Support: Furnish and install supports to hold piping at lines and grades indicated or specified. Support pipe and appurtenances connected to equipment to prevent any strain imposed on equipment.
- E. Pipe and Fittings: Remove and replace defective pieces. Clear of all debris and dirt before installing and keep clean until accepted. Lay accurately to lines and grades indicated or required. Provide accurate alignment, both horizontally and vertically. Provide firm bearing along entire length of buried pipelines.
- F. Appurtenances: Set valves, fittings and appurtenances as indicated.
- G. Push-on Joints: Insert gasket into groove bell. Apply thin film of nontoxic gasket lubricant over inner surface of gasket in contact with spigot end. Insert chamfered end into gasket. Force pipe past it until it seats against socket bottom. Where required install restraint and secure in accordance with manufacturer's instructions.
- H. Mechanical Joints: Wire brush surfaces in contact with gasket and clean gasket. Lubricate gasket, bell, and spigot with soapy water. Slip gland and gasket over spigot, and insert spigot into bell until seated. Seat gasket and press gland firmly against gasket. After bolts inserted and nuts made finger-tight, tighten diametrically opposite nuts progressively and uniformly around joint by torque wrench. Torque bolts to values specified above.
- I. Testing: Clean of all dirt, dust, oil, grease and other foreign material, before conducting pressure and leakage tests.

3.6 INSTALLATION OF PVC AND PVDF PIPE

- A. Piping shall be installed per the requirements of ASTM D2321. Each pipe unit shall be inspected before being installed. No single piece of pipe shall be laid unless it is generally straight. The centerline of the pipe shall not deviate from a straight line drawn between the centers of the openings at the ends of the pipe by more than 1/16-inch per foot of length. If a piece of pipe fails to meet this requirement for straightness, it shall be rejected and removed from the site. Any pipe unit or fitting discovered to be defective, either before or after installation, shall be removed and replaced with a sound unit.
- B. No pipe or fitting shall be permanently supported on saddles, blocking, or stones. Crushed stone shall be as specified in Section 02300 - EARTHWORK.
- C. Suitable bell holes shall be provided, so that after placement, only the barrel of the pipe receives bearing pressure from the supporting material. Special care shall be taken to hold the trench width at the crown of the pipe to the maximum indicated on the Trench Detail included in the Details Section of these specifications.
- D. All pipe and fittings shall be cleared of all debris, dirt, etc., before being installed and shall be kept clean until accepted in the completed work.
- E. Pipe and fittings shall be installed to the lines and grades indicated on the Drawings. Care shall be taken to ensure true alignments and gradients.
- F. Before any joint is made, the previously installed unit shall be checked to assure that a close joint with the adjoining unit has been maintained and that the inverts are matched and conform to the required

grade. The pipe shall not be driven down to the required grade by striking it with a shovel handle, timber or other unyielding object.

- G. All joint surfaces shall be cleaned. Immediately before jointing the pipe, the bell or groove shall be checked to see that the rubber ring is properly seated. Apply lubricant to the spigot end only, paying particular attention to the bevel, in accordance with the manufacturer's recommendation. Each pipe unit shall then be carefully pushed into place without damage to pipe or gasket. Suitable devices shall be used to force the pipe units together so that they will fit with minimum open recess inside and outside and have tightly sealed joints. Care shall be taken not to use such force as to wedge apart and split the bell or groove ends. Joints shall not be "pulled" or "cramped" unless permitted by the Owner.
- H. Where any two pipe units do not fit each other closely enough to enable them to be properly jointed, they shall be removed and replaced with suitable units and new gaskets.
- I. Details of gasket installation and joint assembly shall follow the directions of the manufacturers of the joint materials and of the pipe, all subject to review by the MBTA. The resulting joints shall be watertight and flexible.
- J. All premolded gasket joint polyvinyl chloride or polyvinylidene fluoride pipe of a particular manufacturer may be rejected if there are more than five unsatisfactory joint assembly operations or "bell breaks" in 100 consecutive joints, even though the pipe and joint conform to the appropriate ASTM Specifications as hereinbefore specified. If the pipe is unsatisfactory, as determined above, the Design-Builder shall, if required, remove all pipe of that manufacturer of the same shipment from the work and shall furnish pipe from another manufacturer which will conform to all of the requirements of these specifications.
- K. Open ends of pipe and branches shall be closed with polyvinyl chloride or polyvinylidene fluoride stoppers, as applicable, secured in place in an acceptable manner.
- L. After each pipe has been properly bedded, enough crushed stone shall be placed between the pipe and the sides of the trench, and thoroughly compacted, to hold the pipe in correct alignment. Bell holes, provided for jointing, shall be filled with crushed stone and compacted, and then crushed stone shall be placed and compacted to complete the pipe bedding.
- M. The Design-Builder shall take all necessary precautions to prevent flotation of the pipe in the trench. At all times pipe installation is not in progress, the open ends of the pipe shall be closed with temporary watertight plugs, or by other acceptable means.
- N. If water is in the trench when work is to be resumed, the plug shall not be removed until suitable provisions have been made to prevent water, earth, or other substances from entering the pipe. Pipelines shall not be used as conductors for trench drainage during construction. Install PVC pipe and fittings in accordance with manufacturer's printed instructions.
- O. Allowable Pipe Deflection: Pipe provided under this Specification shall be so installed as to not exceed a maximum deflection of 5.0 percent. Such deflection shall be computed by multiplying the amount of deflection (nominal diameter less minimum diameter when measured) by 100 and dividing by the nominal diameter of the pipe. Upon completion of a section of pipe, including placement and compaction of backfill, the Design-Builder shall measure the amount of deflection by pulling a specially designed gage assembly through the completed section. The gage assembly shall be in accordance with the recommendations of the pipe manufacturer, and be reviewed by the Owner. The section of pipe must be placed and backfilled for a minimum of 90 days before the deflection can be measured. Should

the installed pipe fail to meet this requirement, the Design-Builder shall do all work to correct the problem without additional compensation.

- P. Cleaning: Care shall be taken to prevent earth, water and other materials from entering the pipeline. As soon as possible after the pipe and manholes are completed, the Design-Builder shall clean out the pipeline and manholes being careful to prevent soil, water and debris from entering any existing pipe.

3.7 INSTALLATION OF HIGH DENSITY POLYETHYLENE (HDPE) PIPE

- A. All requirements specified for the installation of PVC pipe shall also pertain to the installation of HDPE pipe.
- B. The Design-Builder shall take all necessary precautions to prevent flotation of the pipe in the trench.
- C. Installation shall be in strict compliance with ASTM D2321 and with the manufacturer's installation guidelines. HDPE pipe bedding and initial backfill materials shall be a Class I type material as defined by ASTM D2321.
- D. The minimum depth of cover over the pipe, or minimum distance between bottom of railroad cross-tie and the top of pipe, shall be 2 feet.

3.8 INSTALLATION OF FIBERGLASS REINFORCED PIPE (FRP)

- A. General: Installation of pipe shall comply with the applicable provisions of ASTM D2321 and ASTM F1668. Installation of pipe and fittings shall be in accordance with the project plans and specifications and the manufacturer's requirements. In addition, installation of piping shall be in accordance with governing authorities having jurisdiction, except where more stringent requirements are indicated.
- B. Handling Pipe: Textile slings, other suitable materials or a forklift shall be used in the handling of pipes. Use of chains or cables is not recommended. Each pipe unit shall be handled into its position in the trench only in such manner and by such means, as the Owner accepts as satisfactory. The Design-Builder will be required to furnish suitable devices to permit satisfactory support of all parts of the pipe unit when it is lifted.
- C. Laying Pipe: Except where a concrete cradle or envelope is required, all pipe shall be laid in crushed stone. In trenches, no blocking or supporting of the piping by concrete, stones, bricks, wooden wedges, or method other than bedding the pipe on crushed stone will be permitted. Each length of pipe shall be shoved home against the pipe previously laid and held securely in position. Joints shall not be "pulled" or "cramped" without approval of the Owner. The Design-Builder shall take all necessary precautions to prevent flotation of the pipe in the trench.
- D. Jointing Pipe: After the pipe are aligned in the trench and are ready to be jointed, the following shall be performed: Ends of pipe and coupling components shall be cleaned. Joint lubricant shall be applied to pipe ends or bell interior surfaces and the elastomeric seals. Only lubricants approved by the pipe manufacturer shall be used. Suitable equipment and end protection to push or pull the pipes together shall be used. Recommended forces by the manufacturer for joining or pushing pipe shall not be exceeded. Pipes shall be joined in straight alignment and then deflected to required angle. Deflection angle shall not exceed the deflection permitted by the manufacturer.
- E. Alignment and Placement: All pipe shall be laid with extreme care as to grade and alignment. Each pipe shall be so laid as to form a close joint with the next adjoining pipe and bring the inverts continuously to the required grade.

- F. Cleaning: Care shall be taken to prevent earth, water and other materials from entering the pipeline. As soon as possible after the pipe and manholes are completed, the Design-Builder shall clean out the pipeline and manholes being careful to prevent soil, water and debris from entering any existing Drain. Place plugs in end of uncompleted conduit at end of day or whenever work stops. Flush lines between manholes if required to remove collected debris.
- G. The manufacturer shall supply a qualified field representative to be present periodically during the installation of the pipe.

3.9 INSTALLATION OF GALVANIZED STEEL PIPE

- A. As shown and detailed on the Plans, install galvanized steel stormwater drainage piping on bridge and viaduct structures and their respective piers and columns.
- B. Pipe ends shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove for proper gasket sealing.
- C. Install the piping system in accordance with the manufacturer's latest recommended practices and installation instructions.

3.10 CONCRETE ENCASEMENT

- A. If pipe is to be entirely or partly embedded in concrete or controlled density fill or if pipe is within 10' and above existing or proposed water piping,, support and brace pipe in a manner that will prevent movement or displacement of pipe during placement, consolidation and curing of the concrete and fill mixes, and during testing.
- B. Place concrete as specified in Section 03300 - CAST-IN-PLACE CONCRETE, being careful to tamp concrete under and around pipe without displacing pipe.
- C. Do not use earth form.

3.11 INLINE CHECK VALVE

- A. Install inline check valve at the locations indicated or as may be required as part of the Design-Builder's proposed design.
- B. Install in accordance to the manufacture's recommendations.

3.12 BACKFILL

- A. Partial Backfill Before Testing
 - 1. Deposit and compact backfill in four inch layers around bottom half of pipe and for full width of trench, leaving top half of pipe exposed.
 - 2. Deposit and compact additional backfill between joints, to a depth of 12 inches above top of pipe, leaving joints exposed.
- B. Final Backfill After Testing
 - 1. Backfill and compact as specified in Section 02300 - EARTHWORK, flush with finished grade. If permitted by the Owner, surface of backfill may be slightly convex.

2. Restore surface to its original condition or as required.

3.13 LEAKAGE TOLERANCES

- A. Gravity Lines. Maximum allowable leakage for any section or sections, or for the total lengths of pipe lines: 200 gallons per inch of diameter per mile per 24 hours.
- B. Force Mains: Zero leakage in 30 minutes at 150 percent of the maximum pressure that pump or ejector is capable of developing.

3.14 ABANDONED FACILITIES

- A. When abandoned facilities are to be left in place, plug, or cap or bulkhead the ends of conduits and pipes, as indicated. Pipe or conduit greater than 15-inch diameter shall be completely filled with Controlled Density Fill per Section 02221 - DEMOLITION. Remove abandoned utility manholes, junction boxes, and similar structures to a minimum depth of two feet below finish grade and fill the remaining void with sand or select fill, as specified in Section 02300 – EARTHWORK, after the plugging, or capping, or bulkheading of conduits and pipes has been completed. Puncture or break the bottom slabs of manholes and similar structures to provide drainage. Backfill and compact excavations resulting from removal of utility facilities, as required.
- B. Bulkheads for pipes greater than 15-inch diameter shall be constructed of solid concrete masonry bricks or solid concrete masonry blocks with full mortar joints. The bulkhead shall be watertight. Recess the bulkhead ½-inch and seal with non-shrink grout.
- C. Refer to Section 02650 – EXISTING SITE UTILITIES for abandonment of existing storm drain.

3.15 AREA DRAINS

- A. Install area drain catch basins in accordance with manufacturer’s instructions at locations indicated and/or required by the Design-Builders proposed design.. Each structure shall be inspected before being installed.
- B. Area drain catch basins and grates shall be installed level and to proper elevation per the plan set. Risers shall be installed between catch basin and grate to achieve the correct elevation. Grate shall be recessed 1/8 inch below finish grade listed on plan set.
- C. Area drain catch basins shall be installed on top of compacted gravel or crushed stone and encased with a 4-inch collar of concrete as indicated on the drawings. Crushed stone shall be as specified in Section 02300 - EARTHWORK.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02401

STORMWATER PUMP STATION CONTROLS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Provide complete pump control panel and appurtenances including operator interface, enclosures, level control devices and transmitters, and auxiliary items, as indicated and as specified, to provide a complete pump control system at each stormwater pump station. The stormwater pump stations are identified as: Red Bridge Pump Station (RPS); Washington Street Pump Station (WPS) and the Gilman Square Pump Station (GPS). The RPS and WPS stormwater pump stations are equipped with three 100-Hp high flow pumps that operate with variable frequency drives and two 20-Hp low flow pumps that operate at constant speed. The Gilman Square Pump Station (GPS) is equipped with two 10-Hp constant speed pumps.
- B. Construction of the Red Bridge and Washington Street pump stations (RPS and WSP, respectively) was initiated under IGMP-03, a previous GLX construction contract. That work was advanced to near completion of the basic structure. The pumps, variable frequency motor controllers, communication programmable logic controllers, and pump station controls were not (or may not have been) completed, however certain items of that equipment were procured by the Owner and will be provided to the Design-Builder. The Design-Builder shall complete the construction of these two pump stations in full compliance with the specifications. The Design-Builder shall complete all work within this Section and all related work, to provide complete operable pump station facilities.
- C. The specifications relative to the WPS and RPS pump stations, including all operating parameters, control logic and other parameters, shall not be modified in any way.
- D. The Design-Builder may elect to adapt these specifications, if appropriate, to any pump station it may propose at Gilman Square.
- E. Certain work under this Section was, or may have been, completed by the previous GLX contractor. The Design-Builder shall be responsible for making its own assessments and evaluations as to the exact scope and limits of the completed and the uncompleted work. The Design-Builder shall complete any and all work associated with this Section and all Related Sections, including any and all uncompleted and/or partially completed work. The Design-Builder shall coordinate all related work, to provide complete and operable stormwater pumping facilities.
- F. The terms and meaning of “Manufacturer’s Services Engineer”, “Startup/Testing Engineer”, “Factory Trained Service Engineer” and “Service Engineer” (collectively, “Startup, Testing and Service Engineers”) as used in this Section shall all remain unchanged and any remaining work required of these Startup, Testing and Service Engineers shall be the responsibility of the Design-Builder. Likewise, the services of a Structural Engineer as required herein shall be the responsibility of the Design-Builder unless that work was completed by the previous Contractor.
- G. The use of the word “Contractor” has been retained in this Section; however, it shall be interpreted to mean the Design-Builder for any and all work remaining to be completed. Likewise, the word “Engineer” has been retained; however, it shall be interpreted to mean the Owner for any and all work remaining to be completed.

- H. Pump control panels can be supplied by the Contractor or by the pump manufacturer at the Contractor's option. The pump control system must be an integrated package to provide a complete operating system.
- I. Pump control panels and devices shall be manufacturer's current standard technology and in production for a minimum of 5 years.
- J. Installation and integration of the control panel and devices shall be the responsibility of the Contractor. All electrical work shall be performed by a licensed electrician in accordance with UL 508A and Article 409 of the National Electrical Code (NEC).
- K. **Related Work:** The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 11306 – SUBMERSIBLE SOLIDS HANDLING PUMPS AND APPURTENANCES
 - 2. Section 16260 - VARIABLE FREQUENCY MOTOR CONTROLLERS FOR STORMWATER PUMP STATIONS (Note: Gillman Square PS does not incorporate a VFD, only a soft start.)
 - 3. Section 16790 - COMMUNICATION PROGRAMMABLE LOGIC CONTROLLERS

1.2 SUBMITTALS

- A. Shop drawings, brochures and samples shall be submitted for all items to be furnished in accordance with the provisions of Section 01300 - SUBMITTALS.
- B. The Contractor shall coordinate the submittals for this section with the Related Work to confirm coordinated and integrated controls and operation review.
- C. Submittals required with the section, but are not limited to the following:
 - 1. Shop Drawings, including all equipment and components shall be provided in a concise organized three-ring binder for review including:
 - a. Manufacturer's brochures and/or catalogue cuts for all equipment and appurtenances.
 - b. Complete master wiring diagrams and elementary or control schematics, including required coordination with other electrical control devices operating in conjunction with the pumping equipment. Due to the complexity of the control functions, it is imperative the above drawings be clear and carefully prepared to facilitate interconnections with other equipment. Standard preprinted sheets or drawings simply marked to indicate applicability to this contract will not be acceptable.
 - c. Panel layout and front view drawings.
 - d. Enclosure drawings and details showing all dimensions and construction details for all installed devices.
 - e. Other submittals specified herein.
 - 2. Performance Test Reports shall be submitted to the Engineer upon completion of installed system and include all shop and field tests performed to prove compliance with specified performance criteria.

3. Operation and Maintenance (O&M) Manuals shall be submitted to the Engineer for approval within 30 days of equipment approval. The O&M manual shall include a table of contents for all components of the integrated pumping system, control panel and related devices, and provide a clear explanation of the operation and maintenance of the equipment with a cross-referenced index. The manual shall include, but not necessarily be limited to the following information:
 - a. Contact and order information for all components.
 - b. Recommended spare parts for one year's operation.
 - c. Preventive maintenance schedule and instructions.
 - d. Operating instructions including reprogramming level and alarm settings.
 - e. Troubleshooting and fault isolating procedures for on-site repair.
 - f. Complete copy of O&M on compact disk with updated as-built working drawings.

1.3 PRODUCT HANDLING

- A. All materials and equipment shall be shipped, stored, handled, and installed in such a manner as not to degrade quality, serviceability, or appearance. The equipment shall be stored in a clean, dry location free from construction dust, precipitation, and excess moisture. If stored for more than two weeks, the equipment shall receive all maintenance considerations required by the manufacturer for proper storage of the equipment.

1.4 DESIGN CRITERIA

- A. The materials and equipment covered by this specification are intended to be standard materials and equipment of proven ability as manufactured by reputable concerns. Equipment shall be designed and constructed in accordance with the best practice of the industry and shall be installed in accordance with the manufacturer's recommendations and the Contract Documents. The specifications call attention to certain features but do not purport to cover all details entering into the construction of the equipment. All work shall conform to the requirements of Section 01600 – MATERIALS AND EQUIPMENT.

1.5 QUALITY ASSURANCE

- A. Provide in accordance with Section 01400 - QUALITY ASSURANCE and as specified.
- B. Ensure that conduit size and wire quantity, size and type are suitable for the equipment supplied. Coordinate all design information with the Electrical Contractor. Review the proper installation with the equipment supplier prior to installation.
 1. Services of Service Engineer, specifically trained on type of equipment specified. Person-day requirements listed exclusive of travel time and are for each pump station location.
 - a. Assist in location of devices, methods of mounting, field erection, etc.
 - b. 1 person-day

1.6 WARRANTY AND SERVICE

- A. Guarantee components, parts and assemblies supplied against defects in materials and workmanship for a period of 24 months after acceptance, and in this time period include onsite, parts and labor warranty. All labor to be performed by trained service technicians.

PART 2 - PRODUCTS

2.1 CONTROL PANEL

- A. For each stormwater pump station, the pump manufacturer shall provide a completely self-contained NEMA 12 motor control panel. A 460 V three phase power supply and 120 VAC control power supply shall be provided to the panel.
 - 1. The RBP and WPS control panel will interface to three 100-Hp motor/VFDs (high flow pumps) and include a PLC based level control system, operator interface, two circuit breakers and two 20-Hp SSRV starters (low flow pumps) and all required control for integrated pumping control system. Operation of the high flow pumps (RPS-1, RPS-2, RPS-3 and WPS-1, WPS-2, WPS-3) shall be independent of the low flow pumps (RPS-4, RPS-5 and WPS-4, WPS-5) as described herein.
 - 2. The GPS control panel will interface to two (2) 10-Hp motors and include a PLC based level control system, operator interface, two circuit breakers and two 10-Hp SSRV starters and all required control for integrated pumping control system
- B. Pump motor protection shall be provided for all pumps including a moisture sensing circuit to detect water leakage into the cavity of each pump. The circuit shall latch through a contact, de-energize the motor, and energize a pilot light indicating a seal failure. A pushbutton shall be provided to reset the circuit after the seal failure has been corrected. A motor over-temperature sensor shall also be provided to detect abnormal and detrimental motor temperature, de-energize the motor, and energize a pilot light indicating over temperature alarm. A pushbutton shall be provided to reset circuit after the over-temperature condition has been corrected.
- C. The control panels shall conform to National Electrical Manufacturer's Association (NEMA), Joint Industry Council (JIC), and National Electrical Code (NEC) specifications, and shall be Underwriters' Laboratories (UL) listed and labeled. The panel shall be factory wired and tested.
- D. Alternator
 - 1. An alternator shall be provided to alternate the lead pump duty between the three 100 Hp high flow pumps on successive pump cycles. The alternator shall be integral to the pump controller.
 - 2. A separate alternator shall be provided to alternate pump duty between the two 20 Hp low flow pumps on successive pump cycles. The alternator shall be integral to the pump controller.
 - 3. The Gilman Square PS alternator shall be provided to alternate the lead pump duty between the two 10 Hp pumps on successive pump cycles. The alternator shall be integral to the pump controller.
- E. Selector Switches

1. A hand-off-automatic selector switch shall be provided for each pump at the Main Control Panel. Selector switches shall be of oil-tight construction. Toggle switch types shall not be considered equal. Selector switch contacts shall be heavy duty, double-break, and silver.

F. Relays

1. Heavy duty relays shall be 600 volt industrial control type. Intrinsically safe relays shall be furnished for interconnection of each wet well float switch with the control panel.

G. Terminal Blocks

1. Terminal blocks shall be provided for all external connections to the control panel and for all connections between the component mounting plate and enclosure mounted components to allow for easy removal of the component mounting plate if required for service. Terminal blocks shall consist of individual snap together contact sections mounted on a common mounting channel. Terminal block sections shall have tubular screw contacts mounted in a nylon housing to resist breakage; phenolic or other rigid, brittle materials shall not be considered equal. Plain screw contacts requiring lugs to be installed on wires shall not be considered equal.

H. Control Circuit

1. The control circuit of the motor control panel shall operate at 120 VAC and be fuse protected.

I. Elapsed Time Meters

1. Provide a non-reset meter for each pump to indicate elapsed time of operation from 0 to 99,999.9 hours.

J. Indicating Lights

1. In addition to the aforementioned indicating lights, a green "pump running" light and red "pump off" light shall be provided for each pump. All indicating lights shall be transformer type, oil-tight, press-to-test with colored lens and legend plate.

K. Alarm System

1. The control panel shall be furnished with an alarm system consisting of separate red indicating lights for each alarm condition, alarm lock-in relays, alarm acknowledge/silence pushbutton and alarm reset button. Each individual alarm shall energize two auxiliary contacts. One of these auxiliary contacts shall illuminate the respective alarm light; the second shall be a spare. The alarm light shall remain "steady" illuminated until the alarm condition is corrected and the reset pushbutton depressed.
2. The RPS and WPS alarm system shall be energized by up to 48 alarm points, including, but not limited to the following alarm conditions that shall be provided to the Alarm Dialer:
 - a. High Wet well level (HWL)
 - b. Low Wet Well Level (LWL)
 - c. Primary Level Device Failure
 - d. Pump Running (each)
 - e. Pump Failure (each)

- f. VFD fault (each)
 - g. Power Failure
 - h. Generator Run
 - i. Generator Failure
 - j. Control Building Intrusion
 - k. Wet Well Intrusion (each)
 - l. High Level at Red Bridge Detention Basin
 - m. High Level at Storage Chamber Outlet Control
3. The GPS alarm system shall be energized by up to 24 alarm points, including, but not limited to the following alarm conditions that shall be provided to the Alarm Dialer:
 - a. High Wet well level (HWL)
 - b. Low Wet Well Level (LWL)
 - c. Primary Level Device Failure
 - d. Pump Running (each)
 - e. Pump Failure (each)
 - f. Soft start fault (each)
 - g. Power Failure
 - h. Pump Station Intrusion
 4. Each of the above alarm conditions shall be monitored and transmitted by the alarm dialer for remote indication of pump station trouble at the 45 High Street Control Center operated by the MBTA.
 5. The RPS and WPS dialer shall continuously monitor the presence of AC power and the status of up to 48 contact closure inputs. The GPS dialer shall continuously monitor the presence of AC power and the status of up to 24 contact closure inputs. AC power failure shall cause the unit to go into alarm status and begin dial-outs. Alarms are acknowledged by either pressing a touch tone “9” as the call is received, or by calling the dialer back after receiving an alarm call.
 6. The dialer shall be the Verbatim as manufactured by RACO Manufacturing or equal as approved by the Engineer.

2.2 PUMP OPERATION

A. Red Bridge and Washington Street Pump Station Control Description

1. The pump controls shall be located in the Pump Control Panel and shall operate the pumps to maintain the liquid level between adjustable operating limits. The stormwater pump stations are each designed to meet two pumping conditions.

- a. For short duration and/or low intensity stormwater flows into the station, the 20 Hp low flow pumps (RPS-4, RPS-5 and WPS-4, WPS-5) are intended to alternate operation (lead/back-up) on constant speed, based on programmed set points/wet well level settings as specified herein.
 - b. The 100 Hp high flow pumps (RPS-1, RPS-2, RPS-3 and WPS-1, WPS-2, WPS-3) shall operate when the low flow pump capacity is exceeded and the wet well level continues to rise to the established elevation settings for the high flow pumps. The three high flow pumps are intended to operate (lead/lag/back-up) with VFD control within certain operating levels as specified herein.
2. Starting and stopping of each stormwater pump shall be accomplished by a level sensor for primary start and stop levels. Float type mercury switches serve as backup level set-points for alarm notification and shall be capable of pump start/stop control in the event of the main controller fault.
 3. Refer to Table 02401-1 at the end of this section for a listing of Elevation IDs and the corresponding wet well elevations and pump operation settings for each of the stormwater pump stations. The following narrative references the Elevation ID as measured by the primary level sensor (primary device) and transmitted to the Pump Control Panel.
 - a. Low Flow Pumps - RPS-4 and RPS-5 or WPS-4 or WPS-5
 1. As the influent stormwater fills the wet well and reaches Elevation K the lead pump will start and operate at full speed after a soft-start. If the wet well level drops to Elevation L, the lead pump will shut down. If the pump fails to shut down and the wet well level reaches Elevation M, the low level float will initiate a LWL alarm and shut down the pump. This alarm will indicate that the primary level device failed to signal for the pump to shut down and that a Low Wet Well Level condition exists in the wet well.
 2. If the lead pump fails to start an alarm will indicate lead pump failure. If the wet well level continues to rise and reaches Elevation I, the standby pump will start and operate at full speed after a soft-start. If the wet well level drops to Elevation L, the pump will shut down. If the pump fails to shut down and the wet well level reaches Elevation M, the low level float will initiate a LWL alarm and shut down the pump. This alarm will indicate that the primary level device failed to signal for the pump to shut down and that a Low Wet Well Level exists in the wet well.
 3. The "lead" and "standby" pump shall alternate with each pump cycle. The automatic alternator shall alternate the pump sequence after each pump cycle. The lead pump selector switch shall be used for manually bypassing the alternator and setting any of the pumps in automatic mode as the lead pump. In the "Hand" mode, the pump selected shall immediately operate, bypassing all automatic controls.
 - b. High Flow Pumps - RPS-1, RPS-2 and RPS-3 or WPS-1, WPS-2 and WPS-3
 1. If the wet well level continues to rise and reaches Elevation D, the lead high flow pump will start until it reaches full speed (100%) using a 0 to 120 second timer. At the same Elevation D, the low flow pump(s) will shut down with a 0 to 60 second time delay. As the wet well level drops to Elevation E, Elevation F, Elevation G, and Elevation H, the high flow pump shall decrease in speed as specified herein. When the wet well level reaches Elevation I, the lead low flow pump will start and operate at full speed after a soft-start and the high flow pump shall shut down with a 0 to 120 second timer. If the high flow pump(s) fail to shut down and the wet well continues to fall to Elevation J, the

back-up float will initiate an alarm and shut down the pump(s) with a 0 to 120 second timer. This alarm will indicate that the primary level device failed to signal for the pump(s) to shut down. If the low flow pump(s) fail to shut down and the wet well level reaches Elevation M, the low level float will initiate a LWL alarm and shut down the pump(s).

2. If the wet well continues to rise and reaches Elevation C, the lag high flow pump will start until it reaches full speed (100%) using a 0 to 120 second timer. The alarm condition will indicate that the lag high flow pump is operating. As the wet well level drops to Elevation E, Elevation F, Elevation G, and Elevation H, the high flow pumps shall decrease in speed as specified herein. When the wet well level reaches Elevation I, the low flow pump will start and operate at full speed after a soft-start and the high flow pump(s) shall shut down with a 0 to 120 second timer. If the pump(s) fail to shut down and the wet well level reaches Elevation L, the low level float will initiate a LWL alarm and shut down the pump(s). This alarm will indicate that the primary level device failed to signal for the pump(s) to shut down and that a Low Wet Well Level condition exists in the wet well.
 3. If the wet well continues to rise and reaches Elevation B, the primary level sensor will initiate a High Water Level Alarm condition. The alarm condition will indicate pump failure and/or that the storm event exceeds the capacity of the pumps operating.
 4. If the wet well continues to rise and reaches Elevation A, the back-up float shall initiate a High High Water Level. The alarm condition will indicate that the primary level device failed or that the storm event exceeds the capacity of the pumps operating.
 5. The "lead", "lag", and "standby" pumps shall alternate with each pump cycle. The automatic alternator shall alternate the pump sequence after each pump cycle. The lead/lag/standby pump selector switch shall be used for manually bypassing the alternator and setting any of the pumps in automatic mode as the lead pump. In the "Hand" mode, the pump selected shall immediately operate, bypassing all automatic controls.
- c. At the Red Bridge Pump Station, the pump control panel shall include a contact and alarm indication for Detention Pond High Level (float) in the Outlet Structure (Sheets 000-C-2068 and 000-C-8022). Upon activation, an alarm shall be initiated and the low flow pumps shall shut down and that high flow pumps shall shut down using a 0 to 120 second timer.
 - d. At the Red Bridge Pump Station, the pump control panel shall include a contact and alarm indication for indication of High Water Level (float) at the twin storage pipe Storage Chamber outlet control structure (Sheets 000-C-2007 and 000-C-8024). Upon activation, an alarm shall be initiated for the need of maintenance at the Storage Chamber outlet control structure.

B. Gilman Square Pump Station Control Description

1. The pump controls shall be located in the Pump Station Control Panel and shall operate the pumps to maintain the liquid level between adjustable operating limits. The pump station is designed to meet pumping conditions.
 - a. The pump Station shall operate when the operator selects the pump to run during dry weather conditions within the limits set by the high and low level set points.

2. Starting and stopping of each pump shall be accomplished by a manual hand-off-automatic (H-O-A) selector switch. Float type mercury switches serve as backup level set-points for alarm notification and shall be capable of pump start/stop control in the event of the main controller fault.
3. Refer to Table 02401-2 at the end of this section for a listing of Elevation IDs and the corresponding wet well elevations and pump operation settings for the pump station. The following narrative references the Elevation ID as measured by the primary level sensor (primary device) and transmitted to the Pump Control Panel.

a. GPS Pumps

1. When the pump operator switches the H-O-A switch to Automatic the lead pump will start and operate at full speed after a soft-start. If the wet well level drops to Elevation B, the lead pump will shut down. If the pump fails to shut down and the wet well level reaches Elevation C, the low level float will initiate a LWL alarm and shut down the pump. This alarm will indicate that the primary level device failed to signal for the pump to shut down and that a Low Wet Well Level condition exists in the wet well.
2. If the lead pump fails to start an alarm will indicate lead pump failure and the “standby” pump will start.
3. The "lead" and “standby” pump shall alternate with each pump cycle. The automatic alternator shall alternate the pump sequence after each pump cycle. The lead pump selector switch shall be used for manually bypassing the alternator and setting any of the pumps in automatic mode as the lead pump. In the "Hand" mode, the pump selected shall immediately operate, bypassing all automatic controls.

C. Wet Well Level Sensors

1. Ultrasonic Level Transmitter (LE, LIT)

- a. Level transmitter shall be a Milltronics Mini Ranger Plus non-contacting ultrasonic meter or approved equal.
- b. Unit shall include two (2) form ‘C’ SPDT relays, 110VAC, 5amp non-inductive contacts assignable as alarms.
- c. Transmitter output to be milliamp current loop into 750 Ohms +/-0.1% resolution, 4-20 mA. Transmitter shall be wall-mounted.
- d. Transducer shall have built- in temperature sensor, including a minimum 125 feet of cable or as indicated on the drawings. Transducer shall be suitable for this application.
- e. Power supply to transmitter to be 120V, 60Hz. Transmitter to come complete with digital display to show level (feet, inches), loss of echo, shorted or open cable, or transducer incorrectly wired.
- f. Transmitter enclosure to be polycarbonate CSA type 4 NEMA, IP65 rated enclosure.
- g. Mounting hardware shall be furnished by the probe manufacturer and all metal components shall be made of stainless steel.

2. Float type switches, each encapsulated within a solid polyurethane float ball shall be provided as back-up to the level sensor and to signal alarm conditions. Float switches shall be provided with individual weights. A mounting bracket shall be provided near the access opening to allow

adjustment of the control/alarm levels as shown on the drawings. Each float switch shall be furnished with cable lengths to suit the installation without splices (control panel is remotely mounted). A properly rated electrical cable shall connect the float switches to the control panel with no splices or terminations within the electrical junction box in the wetwell.

D. Operator Interface Device

1. Provide a color touchscreen as manufactured by Red Lion or approved equal including the following:
 - a. 10.4-INCH TFT 32K VGA 640x480 Pixel LCD (G310CI/A2)
 - b. Configuration and Firmware shall be Stored in 8MB of Non-volatile FLASH Memory
 - c. Resistive Analog Touchscreen
 - d. Dedicated MENU Key
 - e. Up to 5 RS-232/422/485 Serial Ports
 - f. UL Listed NEMA 4X I IP66 Front Panel
2. At a minimum, the Operator Interface Device shall include operator screens for station status, station pump set points, speed control, and alarms. Screen shots to be provided for review and approval with control system submittal.
3. Control system operation shall be coordinated with the variable frequency motor controllers and motor starters in accordance with the pumping operation as specified in Table 02401-01 – Wet Well Elevation ID Schedule for Pump Controls.
4. Provide PLC system for all pump control and alarm functioning.
 - a. A microprocessor-based automatic pump and alarm control system shall be provided for each pumping station incorporating an industrial-grade, 32-bit CMOS microcomputer and associated elements suitable for achieving performance as hereinafter described. The PLC will incorporate the following:
 - 1) Internal diagnostics
 - 2) Real time clock calendar
 - 3) Floating-point data file
 - 4) Battery back up
 - 5) Non-proprietary RTU communication
 - 6) PID loops
 - 7) 6K memory
 - 8) Expansion 110 options (up to 6 modules discrete/analog)
 - 9) Data file download protection
 - 10) 20kHz high-speed counter
 - 11) Advanced communication options (SCADA/RTU networks, DH-485, DeviceNet, and EtherNet/IP)

- 12) Capability of a DF1-Full Duplex device
 - b. The system shall incorporate U.L. 508 Industrial Control Panel approved elements as required of all components of these project panels and be furnished with all necessary hardware and software to accomplish level-responsive pump and alarm operation with software specifically suited to this project.
 - c. All of the discrete 110 circuitry of the computer-based system shall be built to the IEEE 472 (1974) Surge Withstand Capability Standards. The automatic pump and alarm control system computer shall be the standard product of the control system manufacturer and specifically suited for this type of industrial control panel service. All job connections shall be a UL recognized clamp type barriered screw terminals accepting up to two AWG 14 conductors per terminal.
 - d. The drive equipment shall be programmed to respond to variations in the wet well in a manner wherein the hydraulic requirement will be accommodated in the pumping program using simple menu-related operator interface routines.
 - e. The controller must use Microsoft Windows latest compatible software. The software shall utilize a ladder logic language for programming and shall be open architecture.
 - f. The PLC shall be manufactured by Allen Bradley, Series 1400 MicroLogix or approved equal to be coordinated with the MBTA operations.

2.3 REMOTE MONITORING TERMINAL POINTS AND CONNECTIONS

- A. The Red Bridge and Washington Street PS contractor shall furnish and install remote I/O terminals for monitoring pump control alarms from the pump controller located at each stormwater pump station. Dry contacts closures shall be labeled on the terminals for up to 16 points including the following Red Bridge and Washington Street PS general alarms:
 1. Main Power Fail
 2. Generator Running
 3. Generator Fail
 4. Pump Running
 5. Pump Fail
 6. High Wet Well Level
 7. Low Wet Well Level
 8. Control Building Intrusion
 9. Wet Well Intrusion
 10. High Level at Red Bridge (from RPS only)
 11. High Level at Stormwater Storage Outlet Structure (from RPS only)
- B. The Gilman Square PS contractor shall furnish and install remote I/O terminals for monitoring pump control alarms from the pump controller located at the pump station. Dry contacts closures shall be labeled on the terminals for up to 16 points including the following Gilman Square PS general alarms:
 1. Main Power Fail
 2. Pump Running

3. Pump Fail
 4. High Wet Well Level
 5. Low Wet Well Level
 6. Wet Well Intrusion
 7. Control Panel Intrusion
- C. The I/O terminals shall be integrated to the future station Communications Programmable Logic Controllers (CPLC). See Section 16790 - COMMUNICATION PROGRAMMABLE LOGIC CONTROLLERS for remote system monitoring at the 45 High Street Control Center Operated by the MBTA.

2.4 SPARE PARTS

- A. All spare parts indicated are for each stormwater pumping station.
- B. Spare parts for each Control Panel:
 1. One control interface
 2. Two (2) spare timing relays of each type
 3. One panel board of each type
 4. One box of fuses of each size used (each box shall have a minimum of 6 fuses)
 5. Two boxes of pilot lights (each box shall have a minimum of 6 bulbs)
 6. Two PLC power supplies
 7. Ten percent (minimum of one each) of each type I/O Module
- C. Provide one (1) spare ultrasonic level transducer with cable length as specified.
- D. Provide two (2) spare float switches with cable length as specified.
- E. Spare parts shall be identical to and interchangeable with parts installed.

PART 3 - EXECUTION

3.1 VERIFICATION OF CONDITIONS

- A. Before the start of the work of this Section, verify that the project is ready for this work.
- B. Verify that field measurements are as shown on approved shop drawings and/or manufacturer's instructions.
- C. Verify that the equipment or material is in conformance with the approved shop drawings and specifications and resolve any deviations at no additional cost to the owner.
- D. Notify subcontractors involved or affected by this work and coordinate the work with them.

3.2 GENERAL REQUIREMENTS

- A. All materials and equipment shall be installed in a neat, workmanlike manner.
- B. All wiring of the equipment shall be as specified under DIVISION 16 - ELECTRICAL of these specifications.

3.3 MANUFACTURER'S FIELD SERVICES

- A. At each of pump station location, a minimum of two days shall be provided for services during installation and startup.

3.6 MANUFACTURER'S TRAINING

- A. At each pump station location, a minimum of two days shall be provided for manufacturer's training on the pump station control and operation performed.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

See

TABLE 02401-1 - WASHINGTON AND RED BRIDGE PS WET WELL ELEVATION ID SCHEDULE FOR PUMP CONTROLS

TABLE 02401-2 - GILMAN SQUARE PS WET WELL ELEVATION ID SCHEDULE FOR PUMP CONTROLS

**TABLE 02401-1
WASHINGTON AND RED BRIDGE PS WET WELL ELEVATION ID SCHEDULE FOR PUMP CONTROLS**

ELEV. ID	RPS ELEVATION (feet)	WPS ELEVATION (feet)	NUMBER AND SPEED OF HIGH FLOW PUMPS OPERATING		NUMBER AND SPEED OF LOW FLOW PUMPS OPERATING		NOTES	
			Wet Well Level		Wet Well Level		Wet Well Level	
			Increasing	Decreasing	Increasing	Decreasing	Increasing	Decreasing
A	1.5	6.5	2@ 100%	---	---	---	High-High Level Alarm	---
B	1.0	6.0	2@ 100%	---	---	---	High Level Alarm	---
C	0.0	5.0	2@ 100%	---	---	---	Lag High Flow Pump On (w/0 to 120 second timer)	---
D	-1.0	4.0	1@ 100%	---	1@ 100%	---	Lead High Flow Pump On (w/0 to 120 second timer) and Low Flow Pump Off (w/0 to 60 Second Delay Timer)	---
E	-1.5	3.5	---	90%	1@ 100%	---		Speed of Each High Flow Pump Decreasing
F	-2.0	3.0	---	80%	1@ 100%	---	---	Speed of Each High Flow Pump Decreasing
G	-2.5	2.5	---	70%	1@ 100%	---	---	Speed of Each High Flow Pump Decreasing
H	-3.0	2.0	---	60%	1@ 100%	---	---	High Flow Pumps Off (w/0 to 120 Second)
I	-3.5	1.5	---	50%	1@ 100%	1@ 100%	Standby Low Flow Pump On ¹	High Flow Pumps Off and Lead Low Flow Pump On
J	-5.0	0.0	---	---	---	---	---	High Flow Pumps Off (w/0-120 second timer)
K	-8.0	-2.5	---	---	1@ 100%	1@ 100%	Lead Low Flow Pump On	---
L	-12.0	-7.0	---	---	---	---	---	Pumps Off
M	-12.5	-7.5	---	---	---	---	---	LWL Alarm

Notes: 1. Standby Low Flow Pump On only after Lead Low Flow Pump Fail or in Manual
2. Elevations are based on NAVD 88

TABLE 02401-2
GILMAN SQUARE PS WET WELL ELEVATION ID SCHEDULE FOR PUMP CONTROLS

ELEV. ID	Gilman PS ELEVATION (feet)	Wet Well Level Alarms	
A	29.0	High Wet Well Level Alarm	(HWL)
B	14.5	Low Wet Well Level	(pumps off)
C	14.0	Low Wet Well Level Alarm	(LWL)

Note: Elevations are based on NAVD 88

SECTION 02402

STORMWATER TREATMENT AND DISPOSAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies construction of stormwater treatment and disposal facilities. Design-Builder shall furnish all labor, equipment and materials necessary to install the stormwater treatment and disposal systems, complete and operable as designed and as specified herein, in accordance with the requirements of all contract documents. The Design-Builder shall provide and install all pre-manufactured stormwater treatment and disposal systems that it proposes to use, in conformance with all manufacture's requirements.
- B. The project has been designated as a Redevelopment Project by MADEP under their Stormwater Management Standards and Policy. Accordingly, only certain Stormwater Management Standards are required to be met on the Project and those, to the maximum extent practical. The Design-Builder shall make all reasonable attempts to comply with the full Standards. The Owner shall be made aware of any instance where an applicable Standard cannot reasonably be fully met, including site-specific information of what prevents compliance. It is recognized that site conditions may make it difficult to install some systems, for example, high groundwater and/or unfavorable soil conditions may preclude the use of infiltration type stormwater disposal systems at some locations.
- C. The Design-Builder may propose for consideration, alternative stormwater treatment and disposal systems that otherwise meet the design intent of these specifications, including compliance with all regulatory requirements and permits as specified herein and/or elsewhere in related specifications. Such systems, if proposed by the Design-Builder, shall meet all performance requirements required herein and/or by regulatory requirements. If alternative designs are accepted by the Owner, the Design-Builder shall be responsible demonstrating compliance with these specifications and for completing any and all additional permitting requirements.
- D. Stormwater treatment systems shall generally consist of flow-through underground water quality devices to remove fine-grained sediment, nutrients and oils to achieve a higher water quality.
- E. Two types of stormwater treatment systems are generally to be constructed as part of the work. Systems with their discharge in the City of Cambridge, Massachusetts shall be a filtration type system, preceded by a pre-treatment device. All systems in Cambridge must meet their phosphorous standard. At the Vehicle Maintenance and Storage Facility (VMSF) site and in all other areas of the Project the systems shall generally be the hydrodynamic separation type, referred to as water quality structures (WQS).
- F. Stormwater disposal systems for the detention and recharge of stormwater shall generally be a standard design modular chamber system installed in a horizontal field of crushed stone.
- G. All stormwater treatment and disposal systems, including any proposed alternative designs, shall be of a type that have been installed and in use successfully for a minimum of five (5) or more years.
- H. The sizing of all treatment and disposal systems shall be based on the Design-Builder's hydraulic calculations including flow rates and volumes, as approved by the Owner, for each location. The requirements of MADEP Stormwater Management Standards and related design manuals/guidelines, along with any municipal requirements and/or permit requirements which may be more stringent, shall

apply. The manufacturer shall establish the actual size, configuration, model and particular installation requirements for each treatment system to be installed. Sizing of stormwater disposal systems shall consider soil investigations, findings and data conducted earlier and/or that may be conducted by the Design-Builder.

1.2 RELATED WORK IN OTHER SECTIONS:

1. Section 02240 - DEWATERING
2. Section 02260 - EXCAVATION SUPPORT AND PROTECTION
3. Section 02282 - HANDLING, TRANSPORT AND DISPOSAL OF EXCAVATED MATERIALS
4. Section 02300 - EARTHWORK
5. Section 02400 - DRAINAGE AND SEWER SYSTEMS
6. Section 02632 - WASTEWATER BYPASS PUMPING SYSTEMS
7. Section 03300 - CAST-IN-PLACE CONCRETE

1.3 SUBMITTALS

- A. Shop Drawings. Include details of stormwater treatment and disposal facilities, including relationship to other systems; true position and details of interfaces, connections, inlets, cleanouts, manholes, alignment, grade, changes of direction, offsets, bedding, protection, materials and other pertinent data.
- B. Product data: Submit copies of manufactures' printed product data, specifications, standard details, installation instructions, use limitations and recommendations for each material used. Provide certifications that materials and systems comply with specified requirements.
- C. Manufacturer's Performance Certificate. The manufacturer shall submit to the Owner a "Manufacturer's Performance Certification" certifying that each device is capable of achieving the specified removal efficiencies listed in these specifications. The certification shall be supported by independent third-party research
- D. Warranty: The manufacturer shall guarantee the stormwater treatment and disposal systems components against all manufacturer originated defects in materials or workmanship for a period of twelve (12) months from the date the installed components are accepted by the Owner. The Design-Builder and manufacturer shall, upon determination of a defect, repair, correct or replace any manufacturer originated defects advised in writing to the Design-Builder/manufacturer within the referenced warranty period.
- E. Operation and Maintenance Manual: Furnish two full-size paper hard-copies bound in a three-ring binder and one electronic copy in PDF format.

1.4 PERMITS AND LICENSES

- A. The Design-Builder is required to submit permit applications required and pay the associated fees to the Cities of Cambridge, Medford and Somerville to obtain permits for the construction of the facilities.

- B. The Design-Builder is required to apply for and obtain Licenses from the Cities of Cambridge, Medford and Somerville.
- C. The Design-Builder is required to comply with all requirements of 520 CMR 14.00: Excavation and Trench Safety, which has established standards to prevent unauthorized access to the unattended trenches.

1.5 QUALITY CONTROL INSPECTION

- A. The quality of materials, the process of manufacture, and the finished systems shall be subject to inspection by the Owner. Such inspection may be made at the place of manufacture, or on the work site after delivery, or at both places. The systems shall be subject to rejection at any time if material conditions fail to meet any of the specification requirements, even though sample sections may have been accepted as satisfactory at the place of manufacture. Sections rejected after delivery to the site shall be marked for identification and shall be removed from the site at once. All sections, which have been damaged beyond repair during delivery, will be rejected and, if already installed, shall be repaired to the Owner’s acceptance level, if permitted, or removed and replaced, entirely at the Design-Builder's expense.

PART 2 - PRODUCTS

2.1 STORMWATER TREATMENT AND DISPOSAL SYSTEMS

- A. Stormwater Treatment System, Filtration Type
 1. The filtration type stormwater treatment system shall consist of a pre-treatment device to pre-treat the incoming stormwater, followed by a stormwater filter system. The pre-treatment device shall be a hydrodynamic separation (WQS) device as specified herein, unless the pre-treatment device is manufactured integral to the filtration device.
 2. All system internal components including piping, filter media, flow spreader, energy dissipater and pre-treatment devices shall be provided by the manufacturer of the stormwater filter.
 3. Removal Efficiencies: The systems shall be capable of removing up to 80% total suspended solids, 95% total petroleum hydrocarbons and 80% phosphorus on a net annual basis.
 4. System Capacities: The stormwater filtration system shall be capable of capturing and storing petroleum hydrocarbons and sediment in the volumes as determined by the manufacturer for each treatment system to be installed. The system shall be able to convey a peak hydraulic flow rate and a water quality filtration rate as determined by the Design-Builders hydraulic calculations, as approved by the Owner, for each treatment system to be installed.
 5. Alternative designs which otherwise meet these specifications, including the performance criteria for removal efficiencies and system capacities, may be submitted for consideration.
 6. The treatment structure shall be designed and manufactured to withstand all loads, including lateral soil loads and AASHTO HS-20 vehicle loadings. All structures shall be designed to resist flotation assuming the structure is empty and the groundwater elevation is at finished grade.

- B. Stormwater Treatment System, Hydrodynamic Separation Type (Water Quality Structure)

1. The hydrodynamic separation type stormwater treatment system shall consist of single treatment device. The treatment system structure shall be capable of accommodating multiple inlet pipes and be able to be used at an angle point in the storm drain system alignment.
2. The separator should be equipped with an internal high flow bypass that regulates the flow rate into the treatment chamber and conveys high flows directly to the outlet so the scour and/or re-suspension of material previously collected in the separator does not occur. External bypasses are not acceptable. The bypass area must be physically separated from the separation area to prevent mixing with the separator circular and constructed from either fiberglass or precast concrete risers.
3. Removal Efficiencies: The separator shall remove oil and sediment from storm water during frequent wet weather events. It shall treat a minimum of 75 to 90 percent of the annual runoff volume and be capable of removing 50 to 80 percent of the total suspended sediment load as well as more than 90 percent of floatable free oil. The separator shall be capable of trapping silt and clay size particles, in addition to large particles
4. System Capacities: The hydrodynamic separation treatment system shall be capable of capturing and storing petroleum hydrocarbons and sediment for the volumes as determined by the manufacturer for each treatment system to be installed. The system shall be able to convey a peak hydraulic flow rate and a water quality filtration rate based on the Design-Builders hydraulic calculations, as approved by the Owner, for each treatment system to be installed.
5. The treatment structure shall be precast concrete, designed and manufactured in accordance with ASTM C-478. The concrete gasketed joints shall be oil resistant, water tight and meet the design criteria according to ASTM C-443. A fiberglass insert, bolted and sealed watertight to the inside of the bypass chamber, shall divert low to normal stormwater flows into the treatment chamber. A minimum of 12 inches of oil storage shall be lined with fiberglass to provide secondary containment of any hydrocarbon materials.
6. Alternative designs which otherwise meet these specifications, including the performance criteria for removal efficiencies and system capacities, may be submitted for consideration.
7. For stormwater treatment structures proposed to be constructed in the vicinity of the Washington Street Pump Station refer to Section 02400, Paragraph 2.1 A. for additional requirements that shall pertain to the manufacture of these structures.
8. The treatment structure shall be designed and manufactured to withstand all loads, including lateral soil loads and AASHTO HS-20 vehicle loadings. All structures shall be designed to resist flotation assuming the structure is empty and the groundwater elevation is at finished grade.

C. Stormwater Disposal System, Detention and Recharge Fields

1. The Detention and Recharge Fields shall meet municipality and MassDEP standards.
2. Each chamber shall be provided with discharge holes in the sidewall to promote lateral conveyance of water into the surrounding stone media. Holes shall not be drilled or bored in the modules by the Design-Builder unless specifically allowed by the system manufacturer and the Owner.
3. Underground stormwater disposal systems, including all chambers and appurtenances shall be designed and manufactured to withstand all soil loads and AASHTO HS-20 vehicle loadings at the proposed depth of bury. All components of the system, including chambers, headers, cleanouts, interconnecting pipe, special fittings and flush mounted frames and covers, shall be of a type suitable for use in paved areas

4. Alternative designs which otherwise meet these specifications may be submitted for consideration.

2.2 DESIGN-BUILDER PROVIDED COMPONENTS

All Design-Builder provided components shall meet the requirements of this section, related other specifications and contract documents. In the case of conflict, the more stringent specification shall apply.

- A. Crushed rock base material shall be six-inch minimum thick layer of ¾-inch minus rock. Compact undisturbed sub-grade materials to 95% of maximum density at +/-2% of optimum moisture content. Unsuitable material below sub-grade shall be replaced to Owner's approval.
- B. Concrete shall have an unconfined compressive strength at 28 days of at least 4,000 psi, with ¾-inch round rock, a 4-inch slump maximum, and shall be placed within 90 minutes of initial mixing.
- C. Silicone Sealant shall be pure RTV silicone conforming to Federal Specification Number TT S001543A or TT S00230C or Owner approved.
- D. Grout shall be non-shrink grout meeting the requirements of Corps of Engineers CRD-C588. Specimens molded, cured and tested in accordance with ASTM C-109 shall have minimum compressive strength of 6,200 psi. Grout shall not exhibit visible bleeding.
- E. Backfill material shall be ¾-inch minus crushed rock, or approved equal.
- F. Crushed stone used in the detention / recharge disposal fields shall be 1-2 inch double-washed clean stone.
- G. Filter fabric to encapsulate the crushed stone detention and recharge fields and separate them from surrounding in-situ soil as well as backfill material shall be a product recommended by the chamber manufacturer. Filter fabric shall be used along the leveled subgrade below the field, along the sidewalls and along the top of the leveled crushed stone placed over the chamber system.
- H. Polyliner to protect the field at inlet pipe locations, manifolds and feed connectors which may be part of the chamber system, shall be a product recommended by the chamber manufacturer.

PART 3 - EXECUTION

3.1 GENERAL

- A. Stormwater Treatment Systems, including filtration type and hydrodynamic separation types: The Manufacturer shall be responsible for delivering the Stormwater Treatment Systems to the site. The system includes the pretreatment unit with all internal components and service access riser to surface, the filtration chamber with all internal components, service access risers to surface, filter media, pipe coupling between the pretreatment unit and filter chamber, and manhole frames and covers.
- B. Stormwater Disposal Systems, including detention and recharge chambers and appurtenances: The Manufacturer shall be responsible for delivering the Stormwater Disposal Systems to the site. The system may include pre-formed HDPE chambers, all internal and external manufactured components,

service access riser to surface, pipe coupling, and manhole frames and covers that are part of the completed system.

- C. The Design-Builder shall install all Stormwater Treatment and Disposal Systems in accordance with the Contract Documents and all manufacturers recommended installation instructions.
- D. Stormwater Treatment Systems: The Design-Builder shall be responsible for preparing the site for the treatment system installation including, but not limited to, temporary shoring, excavation, cutting and removing pipe, new pipe, bedding, and compaction. The Design-Builder shall be responsible for furnishing the means to lift the system components off the delivery trucks. The Design-Builder shall be responsible for providing any concrete anti-floatation/anti-creep restraints, anchors, collars, etc. with any straps or connection devices required. The Design-Builder shall be responsible for field cutting/adjusting, if necessary, service access risers to grade. The Design-Builder shall be responsible for sealing the pipe connections to the Stormwater Treatment System, backfilling and furnishing all labor, tools, and materials needed.
- E. Stormwater Disposal System: The Design-Builder shall be responsible for preparing the site for the chamber system, including a prepared level subgrade, installing filter fabric materials to line the bottom of the field and encapsulate the crushed stone surrounding the chambers. The Design-Builder shall install crushed stone and the component parts of the chamber system in accordance with the manufacturer's recommendations. After the modular system has been installed and accepted by the Owner and the site prepared, crushed stone shall be placed between, around and above the chamber system to the elevations and dimensions consistent with the Design-Builders approved final design. Design-Builder shall level the top layer of crushed stone field, place filter fabric above it and place and compact backfill above the crushed stone field. Final surface treatment shall be as described elsewhere in the Contract Documents.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection with the work are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02444

CHAIN-LINK FENCE AND GATES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the furnishing and installation of chain-link fence and gates, of the following types:
1. Type I: Galvanized Steel
 2. Type II: Aluminum-Coated Steel Fabric with Galvanized Steel Posts, Hardware, and Fittings
 3. Type III: (not used)
 4. Type IV: Colored PVC-Coated Steel Fabric with Galvanized and PVC-Coated Steel Posts, Hardware, and Fittings
- B. Related Work:
1. Section 02100 – SITE PREPARATION
 2. Section 03300 - CAST-IN-PLACE CONCRETE
 3. Section 05500 - MISCELLANEOUS METALS
 4. Section 09900 – PAINTING
 5. Section 16060 – GROUNDING AND BONDING
 6. Section 16702 – ELECTRONIC ACCESS CONTROL SYSTEMS (for panic bar and alarm on emergency egress gates)

1.2 SUBMITTALS

- A. Shop Drawings:
1. Include cross sectional dimensions of posts, braces, rails, fence fabric, fittings, accessories and gate frames and details of all gate hardware.
 2. Include a layout drawing showing the spacing of posts and location of all gates; abrupt changes in grade; and all corner, gate, anchor, end, and pull posts.
- B. Certificates: Submit certified test reports giving results of tests specified herein for zinc and vinyl coatings.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. General: Comply with AASHTO M181, with the additions and modifications specified herein.
1. Aluminum alloy line, end, and corner posts, and top rail, may be substituted for galvanized steel at the Design-Builder's option.

2. Aluminum Alloy: ASTM B221 for shapes, and B429 for pipe, Alloy 6061-T6. Pipe dimensions specified are the nominal pipe sizes per ASTM B429 Schedule 40. Coat portions of posts to be embedded in concrete with two coats of an accepted coal-tar mastic, allowing 24 hours drying time between coats.
3. Steel pipe dimensions and weights: ASTM A120, Schedule 40. Dimensions specified are the nominal pipe sizes.
4. Dimensions and weights specified herein are subject to a tolerance of plus or minus five percent.
5. Zinc Coating: Minimum 2.0 ounces per square foot except where specified otherwise.
6. Provide posts with accepted tops of same material as posts, so designed as to fit securely over post and carry top rail or cable; the base of top fitting shall carry an apron around outside of post.

B. Line Posts

1. Steel, Five Feet and Shorter: 1-1/2 inch pipe; or 1.625 by 1.875 inch H column weighing 2.70 pounds per foot; or 1.625 by 1.875 inch C column weighing 2.20 pounds per foot.
2. Aluminum, Five Feet and Shorter: 1.625 by 1.875 inch H column weighing 1.03 pounds per foot.
3. Steel, Over Five Feet: 2 inch pipe; or 1.95 by 2.25 inch H column weighing 4.10 pounds per foot; for 1.70 by 2.25 inch C column with a weight of 2.66 pounds per foot.
4. Aluminum, Over Five Feet: 2 by 2.25 inch H column weighing 1.24 pounds per foot.

C. Gate Posts: Steel, minimum 3-1/2 inch pipe, except as otherwise specified in the Contract Documents .

D. End and Corner Posts

1. Steel, Five Feet and Shorter: 2 inch pipe, or 3.5 inch square C column weighing 5.163 pounds per foot.
2. Aluminum, Five Feet and Shorter: 2 inch pipe.
3. Steel, Over Five Feet: 2.5 inch pipe, or 3.5 inch square C column weighing 5.163 pounds per foot.
4. Aluminum, Over Five Feet: 2.5 inch pipe.

E. Top Rail, Cables, and Spring Tension Wire

1. Top Rail
 - a. Steel: 1-1/4 inch pipe, or 1.25 x 1.625 inch C section weighing 1.262 pounds per foot.
 - b. Aluminum: 1.25 inch pipe.
 - c. Couplings and Expansion Sleeves: Outside sleeve type, minimum six inches long.
2. Cable: ASTM A475, 3/8 inch, seven-strand, common grade, Class A galvanizing.
3. Cable attachments
 - a. Shoulder Eye Bolts: 5/8 inch diameter, of sufficient length to fasten to the post used.

- b. Turnbuckles: Shackle end type, 1/2 inch diameter, with six-inch standard take-up and 3/8 inch diameter pins.
 - c. Thimbles: lightweight wire rope for use with 3/8 inch diameter cable.
 - d. Wire Rope Clips: U-bolt diameter of 7/16 inch for use with 3/8 inch diameter cable.
 - e. Anchor Shackles: 3/8 inch diameter, 11/16 minimum distance between eyes, 7/16 inch in diameter.
 - f. Seizing: 0.0181 inch diameter galvanized annealed iron wire.
4. Spring Tension Wire: Coil spring steel, 0.1770 inch diameter; base metal having a minimum tensile strength of 80,000 psi, galvanized with 1.6 ounces per square foot; or aluminum coated with 0.4 ounces per square foot.
- F. Braces and Tension Rods
- 1. Compression Braces: Same type and size as top rail.
 - 2. Tension Rods: 3/8 inch round rods with drop-forged turnbuckles or other approved type of adjustment.
- G. Fence Fabric
- 1. Type I, Galvanized Steel: ASTM A392, Size 9, Class 2 coating.
 - 2. Type II, Aluminum-Coated Steel: ASTM A491, Size 9.
 - 3. Type IV, PVC-Coated Steel: ASTM A392, Size 9, except with PVC coating in lieu of galvanizing.
 - 4. Selvages, all Types
 - a. Fabric 60 inches high and under: knuckled at both selvages.
 - b. Fabric over 60 inches high: knuckled at one selvage and twisted and barbed at the other.
- H. Fabric Band and Stretcher Bars
- 1. Fabric Band: Minimum 1/8 by 3/4 inch section.
 - 2. Stretcher Bars: Minimum 1/4 by 3/4 inch section.
 - 3. Aluminum Alloy Items: ASTM B221, 6061-T6.
- I. Tie Wire and Miscellaneous Items
- 1. Tie Wire: Galvanized or aluminum-coated 0.148 inch steel wire, or aluminum alloy conforming to ASTM B211, 1100-H14.
 - 2. Hog Rings: Galvanized or aluminum-coated 0.120 inch steel wire, or aluminum conforming to ASTM B221, 6061-T6. Aluminum coating: minimum 0.24 ounces per square foot.
 - 3. Post Clips: Galvanized or aluminum-coated 0.192 inch steel wire, or aluminum alloy conforming to ASTM B211, 1100-H14. Aluminum coating: minimum 0.30 ounces per square foot.
- J. Barbed Wire and Extension Arms
- 1. Barbed Wire: ASTM A121, 12-1/2 gauge, 4-point round barbs, Class 3 coating.

2. Extension Arms: Projecting at an angle of approximately 45 degrees, fitted with clips or other means of attaching three strands of barbed wire, the top outside wire approximately 12 inches from the fence line and the other wires spaced uniformly between the top outside wire and the fence fabric.

K. Gates

1. General: Swing Gates: per ASTM F900 Sliding Gates: per ASTM F1184 type.
2. Furnish gates complete with necessary hinges, latches, rollers and roller track, and drop bar locking devices; corners shall be welded or fastened and reinforced with suitable fittings.
3. Gates Frames, Six Feet and Under: 1-1/4 inch steel pipe or aluminum tubing.
4. Gate Frames, Over Six Feet: 1-1/2 inch steel pipe or aluminum tubing.
5. Cross-Trussing: 3/8 inch galvanized iron adjustable rods.
6. All gates shall be equipped with a positive type latching device with a means for padlocking. Latches shall be arranged for padlocking so that padlock will be accessible from both sides of the gate regardless of the latching arrangement. The double gate shall be equipped with a center plunger, rods, catch and semi-automatic outer catches to secure the leaves in open position. Hinges shall be heavy duty and designed to permit easy and trouble free operation.

L. Concrete: Section 03300 - CAST-IN-PLACE CONCRETE

M. Vinyl Coating

1. Vinyl color shall be black. All fabric, posts and fittings shall comply with the Munsell Color System as indicated: Black N.1.1.7/0.
2. The vinyl coating shall be continuously bonded (not sprayed or dipped) over the galvanized steel by the Extrusion Bonding process under pressure of 5,000 psi to insure a dense and impervious covering free of voids, having a smooth and lustrous surface appearance. The coating thickness over the galvanized steel shall be in accordance with U.S. Gov't Spec. RR-F-191/1A, Type V. The wire mesh shall be vinyl-clad before weaving and shall be free and flexible at all joints.
3. Plasticized Polyvinyl Chloride (PVC) with low temperature (-20 degrees C) plasticizer, no filler, extenders or extraneous matter, other than the necessary stabilizers and pigments shall be used. Colors will be stabilized and have a light fastness that shall withstand a minimum WEATHER-O-METER exposure of 1,5000 hours without any deterioration (Test Equipment Operating Light and Water Exposure Apparatus Carbon - Arc Type ASTM D1499.E42 Type E). The vinyl covering shall, in addition, resist attack from prolonged exposure to dilute solutions of most common mineral acids, sea water and dilute solutions of most salts and alkali.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Fence, post and gate installation including all manufactured parts shall adhere to municipal and agency standard requirements.

B. Gates:

1. Install gates plumb, level, and secure for full opening without interference.
2. Install ground set items in concrete for anchorage.
3. Adjust hardware for smooth operation and lubricate where necessary.
4. Install gates according to manufacturer's instructions, plumb, level, and secure.
5. Where panic bars and alarms are required they shall be installed per Section-16702 ELECTRONIC ACCESS CONTROL SYSTEMS.

C. Grounding: Refer to Section 16060 - GROUNDING AND BONDING.

3.2 TOUCH-UP AND REPAIR WORK

- A. Remove and replace fencing which is improperly located, damaged or is not true to line, grade and plumb within tolerances as indicated.
- B. Repair damaged vinyl-coated components as recommended by the manufacturer.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection with the work are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02451

GUARD RAIL

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing and installing steel beam type highway guardrail with steel posts and steel guard rail with posts as locations shown on the Contract Documents.

1.2 SUBMITTALS

- A. Product Data: Provide manufacturers' literature complete describing products.
- B. Shop Drawings:
 - 1. Include cross sectional dimensions of posts, rail elements, and terminal sections.
 - 2. Include layout drawing showing spacing of posts; abrupt changes in grade; and all rail and terminal sections.
- C. Certificates: Provide certificate certifying compliance of materials with standards designated.

1.3 QUALITY ASSURANCE

- A. Erect guardrail true to line and grade and to dimensions conforming to Contract Documents and manufacturers' instructions and recommendations.

PART 2 - PRODUCTS

2.1 STEEL POSTS

- A. Fabricated from ASTM A36 steel "H" sections and channels as indicated; hot-dip galvanized per ASTM A123, and stamped with the ASTM number and the weight of the zinc coating in ounces per square foot.

2.2 RAIL ELEMENT AND TERMINAL SECTIONS

- A. Steel Rail: AASHTO M180, Class A, Type 2. Fit each end of the rail, for each stretch of guard, with a terminal section as indicated, using the same splice detail as for the rail. Provide shapes and profiles indicated on the Drawings.

2.3 BOLTS, NUTS, WASHERS

- A. ASTM A307, galvanized per ASTM A153.

2.4 TOUCH-UP PAINT

- A. Provide touch-up paint meeting requirements of paint as specified in Section 09900 - PAINTING.

2.5 FABRICATION

- A. Fabricate all metal work in the shop. Do not punch, cut, or weld in the field. Where holes are required to be made in the field, drill such holes.
- B. Galvanize components of bolted assemblies separately before assembly. When necessary to straighten sections after galvanizing, perform such work without damage to the zinc coating.

PART 3 - EXECUTION

3.1 ERECTION

- A. Posts:
 - 1. Post installation shall meet MassDOT standard requirements.
- B. Rail:
 - 1. Rail installation shall meet MassDOT standard requirements.
- C. Touch-Up of Damaged Surfaces: Touch-up damaged galvanized surfaces in accordance with requirements of Section 09900 - PAINTING.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection with the work are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02470

SITE IMPROVEMENTS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installation of miscellaneous site improvements including the following:
1. Benches (Community Path & Skilton Avenue)
 2. Trash Receptacles (Community Path)
 3. Signs and Sign Support Structures: Wayfinding, Warning, and Regulatory (Community Path)
 4. Solar-Powered Emergency Call Boxes (Community Path)
 5. Steel Bollards - Fixed (Community Path)
 6. Steel Bollards – Removable (Community Path)
 7. Cobblestone (Community Path)
 8. Inlaid Preformed Thermoplastic Asphalt Pavement Marking System
 9. Low Mow Seed Mix
 10. Parking Bumper Curbs
 11. Low Retaining Walls (Maintenance Facility site)
 12. Shelter (Skilton Avenue)
 13. Barrier Free Fountain (Skilton Avenue)
 14. Dog Waste Station (Skilton Avenue)
 15. Pet Shower (Skilton Avenue)
 16. Tree Guard (Skilton Avenue)
 17. Lighted Bollard (Skilton Avenue)
- B. Concrete, concrete reinforcement, miscellaneous metals, and incidentals thereto shall conform to the applicable requirements of Section 03300 - CAST-IN-PLACE CONCRETE and Section 05500 - MISCELLANEOUS METALS.
- C. Related Work specified elsewhere:
1. Section 02300 – EARTHWORK
 2. Section 02359 – MODULAR PRECAST BLOCK RETAINING WALLS
 3. Section 02513 – BITUMINOUS CONCRETE PAVEMENT
 4. Section 02525 – GRANITE CURBS
 5. Section 02526 – DETECTABLE WARNING STRIPS

6. Section 02577 – PAVEMENT MARKING
7. Section 02784 – SITE FURNISHINGS; for benches, trash receptacles, bollards at stations.
8. Section 02920 – SEEDED LAWN
9. Section 02930 - PLANTING
10. Section 02932 – PLANTING SOILS
11. Section 02970 – LANDSCAPE MAINTENANCE
12. Section 03300 - CAST-IN-PLACE CONCRETE; for concrete, reinforcement, and incidentals pertaining thereto.
13. Section 05500 – MISCELLANEOUS METALS
14. Section 09900 – PAINTING
15. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK
16. Section 16145 – LIGHTING CONTROL DEVICES
17. Section 16521 – EXTERIOR LIGHTING

1.2 REFERENCES

A. Comply with applicable requirements of:

1. Commonwealth of Massachusetts, Standard Specifications for Highways and Bridges, MassDOT, latest edition, Boston, Massachusetts.
2. ASTM: American Society for Testing and Materials.
3. AASHTO: American Association of State Highway and Transportation Officials.
4. Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Rights of Way (7/26/11. Access Board): Sections R304 and R305).
5. Federal Highway Administration (FHWA).
6. AISC - American Institute of Steel Construction Manual of Steel Construction.
7. AWS - American Welding Society.
8. LEED - Leadership in Energy and Environmental Design.
9. OSHA – Occupational Safety and Health Administration Steel Erection Standard 29 CFR 1926 Subpart R-Steel Erection.
10. PCI - Powder Coating Institute.
11. SSPC – The Society for Protective Coatings.
12. IBC 2009 – International Building Code 2009
13. ADAAG – Americans with Disabilities Act Accessibility Guidelines
14. MAAB – Massachusetts Architectural Access Board
15. MUTCD – Manual on Uniform Traffic Control Devices for Streets and Highways, latest edition

1.3 SUBMITTALS

- A. Submit product data, shop drawings, samples, certificates, and other submittals in accordance with requirements of General Conditions, Supplementary Conditions, and Section 01300 - SUBMITTALS
1. Product Data: Submit manufacturer's specifications, installation, and maintenance instructions for:
 - a. Benches
 - b. Trash Receptacles
 - c. Emergency Call Boxes
 - d. Steel Bollards, fixed and removable
 - e. Inlaid Preformed Thermoplastic Asphalt Pavement Marking System
 - f. Cobblestone Pavers
 - g. Shelter
 - h. Barrier-Free Fountain
 - i. Dog Waste Station
 - j. Pet Shower
 - k. Tree Guard
 - l. Lighted Bollard
 2. Certificates: Submit material certificates signed by material producer and Design-Builder. Provide certifications stating materials comply with requirements.
 3. Shop Drawings: Submit shop drawings for the following components showing attachment methods, fabrication, casting, and hardware:
 - a. Benches
 - b. Trash Receptacles
 - c. Signs (Include span lengths, post heights, and vertical and horizontal clearances)
 - d. Sign Posts
 - e. Chain Link Fence Sign Support Frame for Overhead Sign Mount
 - f. Emergency Call Boxes
 - g. Steel Bollards, fixed and removable
 - h. Lighted Bollard
 - i. Parking Bumper Curbs
 - j. Shelter
 - k. Barrier-Free Fountain
 - l. Dog Waste Station
 - m. Pet Shower
 - n. Tree Guard

4. Samples: Full Size Sample: Provide full size sample of one unit of the following for the Owner's approval prior to fabrication of remaining units:
 - a. Benches (Community Path)
 - b. Trash Receptacles
 - c. Steel Bollards, fixed and removable
 - d. Cobblestone Paver

5. Submit manufacturer's samples of materials, finishes, and colors for the following:
 - a. Benches (Skilton Avenue)
 - b. Shelter
 - c. Barrier-Free Fountain
 - d. Dog Waste Station
 - e. Pet Shower
 - f. Tree Guard
 - g. Lighted Bollard

6. Shelter:
 - a. Design Requirements: The building shall meet the following design requirements and as specified by the manufacturer:
 1. Building Code: IBC 2009.
 2. Ground Snow Load (Pg):50.
 3. Basic Wind Speed (V): 110.
 4. Design: See drawings.

 - b. Calculations and Submittal drawings shall include, at a minimum:
 1. Calculations:
 - a. References to building codes and design manuals used for calculations.
 - b. Identification of lateral force resisting system.
 - c. Formulas used for determining snow, wind, and seismic loads to specific project location.
 - d. Three dimensional modeling input, model geometry, and analysis results.
 - e. Member design results and controlling load combinations.
 - f. Connection design for structural bolts, welds, plate thicknesses, and anchorage to the foundation.
 - g. Foundation designs shall include the required combinations of gravity and lateral loads.

 2. Submittal Drawings:

- a. Anchor bolt layout.
 - b. Foundation design.
 - c. Three dimensional views of frame.
 - d. Member sizes and locations.
 - e. Structural connection details, including bolt sizes and plate thicknesses.
 - f. Roof trim and connection details for installation clarity.
- c. Foundation Design:
- 1. The shelter shall be set on foundations designed by manufacturer.
 - 2. Foundation materials shall be provided by the Design-Builder.
 - 3. Owner shall provide manufacturer with complete information about the site including soil bearing capacity and lateral load capacity.
 - 4. If soil data is not available in this area, foundations shall be designed to the minimum values
- d. Anchor Bolts:
- 1. Anchor bolts shall be provided by the manufacturer.
7. Emergency Call Boxes: Shop drawings for Emergency Call Boxes on viaduct shall include pole mounting attachment detail to parapet and special side mounting detail of call box attachment to pole. Provide dimension height of call box from deck surface or finished grade. In addition, shop drawings for both at-grade call boxes and those on the viaduct shall adequately detail the mounting location and orientation of the solar panel on the pole to ensure that there are no conflicts with adjacent fence or other surrounding elements.
8. Inlaid Preformed Thermoplastic Asphalt Pavement Marking System: Shop drawings for crosswalks shall include detailed plans of the pattern specific for each of the crossings, showing overall dimensions of the crosswalk length and width as well as dimensioning of the pattern changes. Template layout drawings shall be submitted to illustrate proper template placement to create the specified pattern.
9. No Mow/Low Grow Seed Mix: At least 30 days prior to ordering, the Design-Builder shall submit to the Owner seed packing certificates with source and date. No material shall be ordered until submittals have been approved by the Owner. Delivered materials shall match approved materials.
10. Maintenance Recommendations: Provide maintenance recommendations from the equipment manufacturers for the records of the Owner and the City of Somerville.

1.4 QUALITY ASSURANCE

- A. Source: For each type of material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.

- B. Accessibility: The ADAAG and the MAAB regulations are pertinent to the design and installation of items covered under the work of this Section. When guidelines conflict, the guidelines giving greater access shall be applicable.
- C. The approved manufacturer shall have experience in the type of work required, shall have a reputation for doing satisfactory work on time and shall have recently successfully completed similar work.
- D. The Design-Builder is responsible for the proper engineering of all items. The internal structure, dimensions and specifications for all items shall be indicated in the Design-Builder's shop drawings. Sign Design-Builder to engineer signs to proper level to withstand abuses of their environment.
- E. Coordination: The work of this Section shall be completely coordinated with the work of other Sections. Verify dimensions and work of other trades that adjoin materials of this Section before the installation of items herein specified. Cooperate with such trades to assure the steady progress of all work under this Contract.
- F. Inlaid Preformed Thermoplastic Asphalt Pavement Marking System
 - 1. The manufacturer must be ISO 9001:2008 certified for design, development and manufacturing of preformed thermoplastic, and provide proof of current certification.

G. SHELTER

- 1. Manufacturer's Qualifications:
 - a. Minimum of (10) years in the shelter construction industry.
 - b. Full time on-staff Licensed Engineer.
 - c. Full time on-staff AWS Certified Associate Welding Inspector.
 - d. Full time on-staff Quality Assurance Manager.
 - e. All welders AWS Certified.
 - f. Manufacturer owned and controlled finishing system to include shot blast, pretreatment, primer, and top coat.
 - g. Published Quality Management System.
 - h. Annual audit of Quality System and Plant Processes by Third Party Agency.
 - i. Annual audit of powder coat finish system by Third Party Agency (PCI).
- 2. Manufacturer's Certifications:
 - a. PCI 4000 S Certified, Certification thru Powder Coating Institute for original equipment manufacturers (OEMs) to evaluate process on entire finish system to add powder coat over steel.
- 3. Manufacturer's Warranty
 - a. Shelter must have a (10) ten year limited warranty on steel frame members.
 - b. Shelter must have a (10) ten year limited warranty on paint system.
 - c. Pass through warranty of Metal Roof manufacturer shall be provided upon request.

H. Inlaid Preformed Thermoplastic Asphalt Pavement Marking System

1. The manufacturer must be ISO 9001:2008 certified for design, development and manufacturing of preformed thermoplastic, and provide proof of current certification.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. All materials under this Section shall be delivered, stored, and handled so as to prevent damage and deterioration. Products stored on site shall be stored above the ground.
- B. Preformed Thermoplastic Material: Shall be vacuum sealed in protective plastic film with cardboard stiffeners to prevent damage in transit. The cartons in which standard preformed thermoplastic patterned sheets are packed shall be non-returnable and shall not exceed 25 in. in length and 25 in. in width. The cartons shall be labeled for ease of identification. The weight of an individual carton must not exceed fifty (50) pounds. The carton must be wrapped with a protective film to protect the material from rain or premature aging.
- C. Shelter: Protect building products after arrival at destination from weather, sunlight, and damage. Installer shall store product elevated to allow air circulation and to not introduce mold, fungi decay or insects to the product. Product must be handled with protective straps or padded forks if lifting with mechanical equipment. Use of chain or cable to lift product into place will not be accepted and may void manufacturer's warranty.

PART 2 - PRODUCTS

2.1 BENCHES (COMMUNITY PATH)

- A. Park Bench with back, 6'-0" Ribbon Bench, Model No. CFPB-018, as manufactured by Custom Fabrication, Inc., C/O Marturano Recreation Company, PO Box 106, Spring Lake, NJ 07762. Contact: Brian Killmeier. Phone: (732) 320-5254, email: BKillmeier@MRCREC.com, or approved equal.
 1. Bench shall be six (6) feet in length; seat height shall be 17 inches; overall depth shall be 25 ¾"; overall height shall be 31 ½".
 2. Arms: Cast Iron Ends with integrated armrests.
 3. Seat Surface Shape: contoured or dished. Frame shall be fabricated of (2) 2" schedule 40 (2-3/8" OD) steel pipes and 1 ½" x ¼" steel bars. (1) ¾" schedule 40 (1.05" OD) steel pipe connecting integrated armrest/legs.
 4. All steel parts shall be phosphate washed, primed with zinc rich primer, and painted with exterior grade polyester powder coat, color shall be black. Final coating shall be a minimum of 4 mils thick on all surfaces.
 5. All assembly hardware shall be stainless steel.
 6. Bench shall be surface mounted on concrete pad. For flush surface anchoring, use flat head coated stainless steel bolt 8" long minimum, anchored to concrete pad.

- B. Park Bench (Backless), 6'-0" Ribbon Bench, Model No. CFPB-033, as manufactured by Custom Fabrication, Inc., C/O Marturano Recreation Company, PO Box 106, Spring Lake, NJ 07762. Contact Brian Killmeier. Phone: (732) 320-5254, email: BKillmeier@MRCREC.com, or approved equal.
1. Bench shall be six (6) feet in length and shall be installed on the viaduct as per the contract documents and approved shop drawings.
 2. Seat Surface Shape: contoured or dished. Frame shall be fabricated of (2) 2" schedule 40 (2-3/8" OD) steel pipes and 1 1/2" x 1/4" steel bars. (1) 3/4" schedule 40 (1.05" OD) steel pipe connecting integrated armrest/legs.
 3. All steel parts shall be phosphate washed, primed with zinc rich primer, and painted with exterior grade polyester powder coat, color shall be black. Final coating shall be a minimum of 4 mils thick on all surfaces.
 4. All assembly hardware shall be stainless steel.
 5. Bench shall be surface mounted on concrete deck of viaduct. For flush surface anchoring, use flat head coated stainless steel bolt 8" long minimum, anchored to concrete pad.
- C. Bench concrete pad shall be 6 inches of 4,000 psi concrete with 12 inches of compacted gravel base. Concrete pad shall be reinforced with 6 x 6 – W4 x W4 Welded Wire Mesh.
- D. Concrete for bench concrete pad specified under Section 03300 – CAST-IN-PLACE CONCRETE.
- E. Stone Base for bench concrete pad specified under Section 02300 – EARTHWORK.

2.2 BENCHES (SKILTON AVENUE)

- A. "Plainwell" Bench, 73-1/4 inches with back, no center arm, surface mount, as manufactured by Landscape Forms, Inc., 431 Lawndale Ave., Kalamazoo, MI 49048 (contact Nadene Worth. Phone 800-430-6206 x 1325. Email: nadenew@landscapeforms.com), or approved equal.
- B. Style:
1. Backed
 - a. Depth: 24 inches
 - b. Overall Height: 33 inches
 - c. Arm height: 27-3/8 inches
 - d. Length: 73-1/4 inches
 2. Mounting:
 - a. Surface mount
- C. Materials:
1. Seat and Back Panels:

- a. Aluminum: ASTM B221 extruded aluminum boards have end caps. Aluminum boards and end caps are clear anodized (202-R1) and powder coated to match the frame color.
2. Frame:
- a. End supports with integral armrests are sand-cast aluminum. Seat straps and back straps are sand-cast aluminum. Leg section is 1-1/2" x 2" oval shape. End supports are connected by two A36 steel channels 1-1/2" x 9/16" x 3/16" fasted with black Magni-coated steel cap screws.
3. Bench shall be surface mounted on concrete pad with corrosion resistant anchor bolts.
- D. Finishes:
- 1. Primer: Rust inhibitor on ferrous supports.
 - 2. Topcoat: Thermosetting TGIC polyester powder coat. UV, chip, and flake resistant.
 - 3. Test Results: "Pangard II".
 - a. Gloss consistency, Gardner 60 Degrees, ASTM D 523: Plus or minus 5 percent from standard.
 - b. UV Resistance, Color and Gloss, ASTM G 155, Cycle 7: Delta E less than 2 at 2.0 mils and less than 20 percent loss.
 - c. Cross-hatch Adhesion, ASTM D 3359, Method B: 100 percent pass.
 - d. Flexibility Test, Mandrel, ASTM D 522: 3 mm at 2 mils.
 - e. Erichsen Cupping, ISO 1520: 8 mm.
 - f. Impression Hardness, Buchholz, ISO 2815: 95.
 - g. Impact Test, ASTM D 2794: 60 inch-pounds at 2.5 mils.
 - h. Pencil Hardness, ASTM D 3363: 2H minimum.
 - i. Corrosion Resistance, 1500-Hour Test, ASTM B 117: Max undercutting 1 mm.
 - j. Humidity Resistance, 1500-Hour Test, ASTM D 2247: Max. Blisters 1 mm.
 - 4. Color: Mercury
- E. Bench concrete pad shall be 6 inches of 4000 psi concrete with 12 inches of compacted gravel base. Concrete pad shall be reinforced with 6 x 6 – W4 x W4 Welded Wire Mesh.
- F. Concrete for bench concrete pad specified under Section 03300 - CAST-IN-PLACE CONCRETE.
- G. Stone Base for bench concrete pad specified under Section 02300 – EARTHWORK.

2.3 TRASH RECEPTACLES (COMMUNITY PATH)

- A. Trash Receptacle, Part No. CFTR-003, as manufactured by Custom Fabrications, Inc., C/O Marturano Recreation Company, PO Box 106, Spring Lake, NJ 07762. Contact: Brian Killmeier, Phone (732) 320-5254, email: BKillmeier@MRCREC.com, or approved equal.

1. Trash receptacle shall have Hinged Lockable Side Door, welded down Bonnet Style lid, and 32-gallon Rubbermaid liner.
 2. All steel parts shall be phosphate washed, primed with zinc rich primer, and painted with exterior grade polyester powder coat, color shall be black. Final coating shall be a minimum of 4 mils thick on all surfaces.
 3. Mounting: Provide stainless steel vandal proof Anchor Bolts (2) minimum.
 4. Lids and Tops: Bonnet Style Steel Lid permanently secured.
 5. Receptacle Height: 36"
 6. Overall Width: 23 ¼"
 7. Inner Container: 32-gallon Rubbermaid Container, capacity not less than 32 gallon.
 8. Service Access: Side access with inner container.
- B. Trash Receptacle concrete pad shall be 6 inches of 4,000 psi concrete with 12 inches of compacted gravel base. Concrete pad shall be reinforced with 6 x 6 – W4 x W4 Welded Wire Mesh.
- C. Concrete for trash receptacle concrete pad specified under Section 03300 – CAST-IN-PLACE CONCRETE.
- D. Stone Base for trash receptacle concrete pad specified under Section 02300 – EARTHWORK,

2.4 SIGNS (COMMUNITY PATH)

- A. Signs:
1. All signs on the community path shall be constructed and erected in accordance with the latest edition of the “Manual on Uniform Traffic Control Devices for Streets and Highways” (MUTCD) with all revisions.
- B. Sign Posts for free-standing signs
1. Sign Posts shall be 2-inch tubular steel for all free-standing signs along the Community Path and shall have a black powder-coat finish.
 2. Sign Posts for signs on the roadway at path intersections shall be Type P5.
- C. Sign Supports for overhead signs
1. Signs on the viaduct shall be mounted on overhead supports and centered over the path as shown on the drawings.
 2. Frames for the sign supports shall match, and attach to, the security fence mounted on the sides of the viaduct structure. Color shall be black to match fence.

2.5 SOLAR-POWERED EMERGENCY CALL BOXES (COMMUNITY PATH)

A. General

1. Emergency Call Boxes shall be located at locations shown on the drawings. The City of Somerville's standard Signal Communications Solar Powered Radio Fire Alarm Box shall be used at all locations, both at-grade and on viaduct. On the viaduct section of the community path, the mounting poles shall be mounted on top of the parapet. The height of the mounting poles on the viaduct shall be shorter to accommodate the height of the parapet and the security fence.
2. Emergency Call Boxes shall be Signal Communications Solar Powered Radio Fire Alarm Box DTS L1R1 – P104 (DTX Solar Powered Radio Box) as supplied by L.W. Bills Company, 7-9 Park Street, PO Box 7, Georgetown, MA 01833-0007, Phone: (800) 892-0275, Email: lwbills@comcast.net, or approved equal. This is the City of Somerville's standard emergency call box.
 - a. Three Button Box: FIRE/POLICE/MEDICAL
 - b. Stickers: EMERGENCY
3. Call Boxes shall meet all ADA requirements.

B. Emergency Call Boxes At-Grade

1. Mounting Pole: 11 ½ foot long aluminum pole mounted on 18 inch diameter x 4 foot deep concrete base. Standard City of Somerville emergency call box assembly.
2. Concrete foundation for call boxes shall be designed to meet MassDOT requirements. Concrete shall be as specified under Section 03300 – CAST-IN-PLACE CONCRETE.

C. Emergency Call Boxes on Viaduct

1. Mounting Pole: 6 ½ foot long aluminum pole mounted to the top of the 30 inch parapet wall for a total height of 9 feet above deck.
2. Call Box shall be side mounted on mounting pole. Call box shall not extend into the path. There shall be breaks in the railing where the call boxes are to be located. Coordinate with railing installation.

2.6 STEEL BOLLARDS (COMMUNITY PATH)

A. Steel Bollards specified under this section are for bollards located within or adjacent to the community path as shown on the community path plans.

B. Steel Bollards - Fixed

1. Bollard shall be 5 ¾ inch diameter, schedule 40, galvanized steel pipe. Length of pipe shall be 6 feet and it shall extend 39 inches above finished grade. Steel shall conform to ASTM A36 and shall be galvanized in accordance with relevant sections of ASTM A123 or ASTM A386 to assure proper bonding of paint to steel surface exposed to the weather.

2. A six inch diameter cast iron cap shall be welded to the top of the bollard. All welds shall be ground smooth.
3. Two white reflectors, square in shape, shall be bolted to each side of the bollard. Submit shop drawings detailing method of connection to the pipe bollard.

C. Steel Bollard – Removable

1. Bollard shall be 5 ¾” diameter, schedule 40, galvanized steel pipe. Length of pipe shall be 6 feet and it shall extend 39” above finished grade. Steel shall conform to ASTM A36 and shall be galvanized in accordance with relevant sections of ASTM A123 or ASTM A386 to assure proper bonding of paint to steel surface exposed to the weather.
2. A six inch diameter cast iron cap shall be welded to the top of the bollard. All welds shall be ground smooth.
3. Two white reflectors, square in shape, shall be bolted to each side of the bollard. Submit shop drawings detailing method of connection to the pipe bollard.

D. Finish and welding of bollards shall be as specified in Section 05500 – MISCELLANEOUS METALS.

E. Finish: Bollards shall be phosphate washed, primed with zinc rich primer, and painted with exterior grade polyester powder coat; color shall be yellow, RAL #1016. Final coating shall be a minimum of 4 mils thick on all surfaces.

F. Concrete for footing foundation as specified under Section 03300 – CAST-IN-PLACE CONCRETE.

G. Crushed Stone and Gravel Borrow base for footing specified under Section 02300 – EARTHWORK.

2.7 COBBLESTONE (COMMUNITY PATH)

A. Characteristics and Quality

1. Cobblestone units shall be sound stock, and free from defects impairing strength, durability or appearance, such as cracks, seams, starts, holes, flaws or imperfections which have been patched or filled.
2. Units shall be uniformly consistent in color, value, graining texture, and other features to the extent inherent in each stone type.
3. Units shall be clean, used, split-faced cobbles, 4” deep, and with 4”x8” face sizes.
4. Stone shall be cut to sizes, shapes, dimensions, and details shown on the drawings or as per approved shop drawings and as directed by the Owner.
5. Exposed surfaces and edges of stone units shall be free from cracks, broken corners, chipped edges, scratches, or defects affecting appearances. No patching or hiding of defects will be permitted
6. Shop Cutting, Drilling and Fitting: Include all cutting, drilling, and fitting of stone required to accommodate the work of other trades and to fit conditions on-site. In cutting and fitting,

carefully cut and grind edges to a neat, tight fit. Cutting shall be in such a manner so as not to impair strength or appearance.

B. Mortar

1. All mortar mixes shall be in accordance with ASTM C270. Portland Cement, Type I ASTM C150, White Portland Cement. Cement shall be in accordance with ASTM C91, not more than 0.30 percent water-soluble alkali. Hydrated Type S Lime for Masonry Purposes, ASTM C207. Do not use air entrained lime. Aggregate shall be well graded sharp bagged mason's mortar sand in accordance with ASTM C144. Water shall be clean and free from deleterious materials. Only potable water shall be used. Mortar pigment color shall be approved by the Owner. Design-Builder shall submit samples. Do not exceed pigment to cement ratio by weight of 1 to 7. Proportion specification for mortar materials shall be:

Type S Mortar

Portland Cement	1 Part by volume
Hydrated Lime	½ Parts by volume
Sand	4 Parts by volume (as measured damp)

2.8 INLAID PREFORMED THERMOPLASTIC ASPHALT PAVEMENT MARKING SYSTEM

A. Inlaid Prefomed Thermoplastic Asphalt Pavement Marking System

1. Purpose: This is a durable preformed thermoplastic asphalt pavement marking system that is inlaid just below the asphalt pavement surface to create colorized patterns within the asphalt for streetscape and traffic calming purposes on public roads.
2. The preformed thermoplastic is inlaid into asphalt pavement using infrared heating equipment designed specifically to elevate the temperature of the asphalt without it being adversely affected. A specialized template is imprinted into the heated asphalt pavement to create depressions to match the desired pattern. The preformed thermoplastic, precut by the material manufacturer to match the imprinted pattern, is laid to fit within the depressions and melted into place using the infrared heater.
3. The top of the inlaid preformed thermoplastic lies slightly below the surface level of the surrounding asphalt pavement allowing the pavement to absorb the physical effects of the traffic. When applied in accordance with the manufacturer's application guidelines by an applicator certified by the manufacturer, the inlaid preformed thermoplastic will wear at a similar rate as the surrounding asphalt pavement. Therefore, the life of the inlaid preformed thermoplastic is dependent upon using a long lasting, durable and stable asphalt pavement to prevent premature wear.
4. The pattern and color of the inlaid preformed thermoplastic at all designated community path crosswalks shall be as shown on the drawings and approved shop drawings. The primary pattern shall be created using precut preformed thermoplastic sheets that are 24 inches x 24 inches. The precut patterned border pieces shall measure either 8 inches or 12 inches wide x 24 inches long. These sizes ensure the specified patterns are created with a minimal number of seams between the preformed thermoplastic sheets. The use of individual preformed thermoplastic strips inlaid into standard imprinted patterns to create the design shall not be allowed.

5. The inlaid preformed thermoplastic is manufactured without glass beads. The inlaid preformed thermoplastic material must be a resilient preformed thermoplastic product, which contains intermixed anti-skid/anti-slip elements with a minimum hardness of 6 (Mohs scale), and where the top surface contains factory applied anti-skid/anti-slip elements with a minimum hardness of 8 (Mohs scale).
6. **Preformed Thermoplastic Material:** Must be composed of an ester-modified rosin impervious to degradation by motor fuels, lubricants, etc. in conjunction with aggregates, pigments, binders, and anti-skid/anti-slip elements. Pigments and anti-skid/anti-slip elements must be uniformly distributed throughout the material. The thermoplastic material shall conform to AASHTO designation M249, with the exception of the relevant differences due to the material being supplied in a preformed state, being non-reflective, and potentially being of a color from white or yellow.
 - a. **Pigments:**
 1. **White:** The material shall be manufactured with sufficient titanium dioxide pigment to meet FHWA Docket No. FHWA-99-6190 Table 5 and 6 as revised and corrected.
 2. **Other Colors:** The pigment system must not contain heavy metals, nor any carcinogen as defined in 29 CFR 1910.1200 in amounts exceeding permissible limits as specified in relevant Federal Regulations.
 - b. **Skid Resistance:** The surface of the preformed thermoplastic material shall contain factory applied anti-skid material with a minimum hardness of 8 (Mohs scale). Upon application the material shall provide a minimum skid resistance value of 60 BPN when tested according to ASTM E 303.
 - c. **Slip Resistance:** The surface of the preformed thermoplastic material shall contain factory applied anti-skid material with a minimum hardness of 8 (Mohs scale). Upon application the material shall provide a minimum static friction of coefficient of 0.6 when tested according to ASTM C 1028 (wet and dry), and a minimum static coefficient of friction of 0.6 when tested according to ASTM D 2047.
 - d. **Thickness:** The material must be supplied at a minimum thickness of 90 mil (2.3 mm).
 - e. **Environmental Resistance:** The material must be resistant to deterioration due to exposure to sunlight, water, salt or adverse weather conditions and impervious to oil and gasoline.
 - f. **Storage Life:** The material may be stored for 12 months, if stored indoors and protected from the elements.
 - g. **Transverse Lines for Inlaid Preformed Thermoplastic Crosswalk Application:** Supplied as white, retroreflective preformed thermoplastic linear striping material in 90 mil (2.3 mm) or 125 mil (3.2 mm) thickness, material is available in 6 in., 8 in., or 12 in. widths. This material may be supplied and applied by the certified applicator in conjunction with the inlaid preformed thermoplastic system and is available from the inlaid preformed thermoplastic manufacturer. (Consult the manufacturer's published application instructions for the preformed thermoplastic linear striping material selected for proper application methods.)

7. Specialized Application Equipment

- a. Stamping Templates: Designed and constructed for imprinting the specified pattern into the asphalt pavement, templates are supplied by the inlaid preformed thermoplastic manufacturer in 150 mil (3.81 mm) thickness. Standard patterned templates are designed to create crosswalks ranging from 6 feet to 20 feet wide, in 2 feet increments. Template layout drawings shall be supplied by the inlaid preformed thermoplastic manufacturer to illustrate proper template placement to create the specified pattern. Certain templates may be field assembled as needed using the manufacturer supplied template assembly kit.
- b. Heating Equipment: The inlaid preformed thermoplastic manufacturer shall distribute reciprocating infrared heating equipment designed specifically to elevate the temperature of the asphalt pavement without adversely affecting it, as well as the inlaid preformed thermoplastic material. The primary asphalt heating unit must employ a bank of propane-fired infrared heaters, mounted on a track device that allows the heater bank to reciprocate back and forth over a designated area, thereby allowing the operator to monitor the temperature of the asphalt pavement and the inlaid preformed thermoplastic at all times during the pavement heating process.
 1. A smaller, mobile infrared heater distributed by the inlaid preformed thermoplastic manufacturer is designed specifically to heat areas such as borders and narrow areas that are inaccessible to the primary heater. This secondary heater also allows the operator to monitor the temperature of the asphalt pavement and the inlaid preformed thermoplastic at all times during the heating process.
 2. An approved hand-held propane heat torch distributed by the inlaid preformed thermoplastic manufacturer shall be used to heat isolated areas of the asphalt pavement or inlaid preformed thermoplastic.
- c. Hand Held Finishing Tool: Enables the applicator to complete the imprinting of the asphalt pavement in areas around permanent structures, such as curbs and manhole covers, which may be inaccessible to the stamping template. The hand held finishing tools are distributed by the inlaid preformed thermoplastic manufacturer.
- d. Vibratory Plate Compactor (700-900 lb./318-408 kg.): Shall be used for pressing the stamping template into the heated asphalt to create the specified pattern. The inlaid preformed thermoplastic manufacturer does not supply vibratory plate compactors.

B. Granite Curb flush with pavement as per Section 02525, Granite Curbs.

C. Asphalt Roadway Surface as per Section 02513, Bituminous Concrete Pavement.

2.9 LOW-MOW SEED MIX

- A. Low-Mow Seed Mix shall conform to the relevant provisions of Section 02920 – SEEDING and the following:
- B. The intent of this specification is to establish a healthy stand of a Low-Mow species. Low mow species are slow growing and require more attention during establishment than typical lawn mixes. The steps specified herein are strongly recommended for best establishment and shall be followed unless otherwise recommended by the supplier.

- C. Seed Mix: Seed mix shall be Pure Live Seed and shall be comprised of a No Mow or Low Mow mix from one of the following suppliers or an equal approved by the Owner:
 - 1. No mow Lawn Mix, Prairie Nursery, Inc., Westfield, WI (800) 476-9453.
 - 2. Sun-Shade Ultra Low Maintenance Mix, Pearls Premium, Wayland, MA (508) 521-9940.
 - 3. Lo-Mo Mix, North Country Organics, Bradford, VT (802) 222-4277.
- D. Hay Mulch: Hay Mulch shall consist of mowed and properly cured grass, clover or other acceptable plants. No salt hay shall be used.

2.10 PARKING BUMPER CURBS

- A. Parking bumper curbs shall be of the dimensions and configuration as shown on the Plans. They shall be precast concrete items manufactured of Class 4,000 psi concrete and 5% to 9% air entrained. Steel for concrete reinforcement and anchor / tie-down rods shall be ASTM A615, 60 KSI. Longitudinal reinforcement shall include at least two #3 bars. Anchor rods shall be minimum 18-inch long #6 bars each, embedded flush with the top of the bumper curb.

2.11 LOW RETAINING WALLS (MAINTENANCE FACILITY SITE)

- A. Low retaining walls shall comply with the requirements of Section 02359, MODULAR PRECAST BLOCK RETAINING WALLS.

2.12 SHELTER (SKILTON AVENUE)

- A. Description
 - 1. Multi-Rib Metal Roof “R” Panel, size and shape as shown on the plans, or approved equal.
 - 2. Roof Slope: 5/12
 - 3. Minimum Clearance Height (MCH): 7.5 ft. Minimum clearance height under the structure indicates the lowest height of a member from finish grade for clearance under the structure. This is generally the clearance under roof eave or frame, whichever is lower.
- B. Shelter System and Materials
 - 1. Manufacturer:
 - a. The product shall be designed, produced, and finished at a facility operated and directly supervised by the supplier who has a minimum of (10) years in the business of making pre-manufactured shelters.
 - 2. Product Requirements and Materials:
 - a. General: The pre-engineered package shall be pre-cut unless otherwise noted and pre-fabricated which will include all parts necessary to field construct the shelter. The shelter shall be shipped knocked down to minimize shipping expenses. Field labor will be kept to a minimum by pre-manufactured parts. Onsite welding is not necessary.

- b. Reinforced Concrete:
 - 1. Concrete shall have minimum 28-day compressive strength of 3,000 psi and slump of 4" (+/- 1"), unless otherwise noted on the drawings.
 - 2. Reinforcing shall be ASTM A615, grade 60.
- c. Steel Columns
 - 1. Hollow structural steel tube minimum ASTM A500 grade B with a minimum wall thickness of 3/16" or approved equal.
 - 2. Unless columns are direct buried, columns shall be anchored directly to concrete foundation with a minimum of four anchor rods to meet OSHA requirement 1926.755(a)(1).
- d. Structural Framing:
 - 1. Hollow Structural Steel tube minimum ASTM500 grade B. "I" beams, tapered columns, or open channels shall not be accepted for primary beams. Frame will have a STANDARD POLI-5000 finish.
- e. Compression Members:
 - 1. Compression rings of structural channel or welded plate minimum ASTM A36 or compression tubes or structural steel tube minimum ASTM A500 grade B shall only be used.
- f. Connection Requirements:
 - 1. Anchor bolts shall be ASTM F1554 (Grade 36) unless otherwise noted.
 - 2. Structural fasteners shall be zinc plated ASTM A325 high strength bolts and A563 high strength nuts.
 - 3. Structural fasteners shall be hidden within framing members wherever possible.
 - 4. No field welding shall be required to construct the shelter.
 - 5. All welds shall be free of burrs and inconsistencies.
 - 6. Exposed fasteners shall be powder coated by manufacturer prior to shipment to match frame or roof colors as applicable.
 - 7. Manufacturer shall provide extra structural and roofing fasteners.
- g. Roofing Materials:
 - 1. Primary Roof Deck of "R" Panel Metal Roofing (MR):
 - a. Roofing shall be 24 gauge ribbed galvalume steel sheets, with ribs 1 3/16" high and 12" on center.
 - b. Roof surface shall be painted with per manufacturer's specifications to the City's standard color.
 - c. Ceiling surface shall be a "wash coat" primer.

- d. Roof panels shall be factory pre-cut to size and angled to provide ease of one-step installation.
 - e. Metal roofing trim shall match the color of the roof and shall be factory made of 26 gauge painted steel.
 - f. Trim shall include panel ridge caps, hip caps, eave trim, splice channels, rake trim, roof peak cap, and corner trim as applicable for model selected. Trim may need to be cut to length and notched. Installation drawings shall have detailed information on how to cut and affix roof trim.
 - g. Ridge, hip, and valley caps shall be pre-formed with a single central bend to match the roof pitch and shall be hemmed on the sides.
 - h. Roof peak cap shall be pre-manufactured.
 - i. Manufacturer shall supply painted screws and butyl tape.
- h. Finishes:
- 1. Coat Base Coat Finish:
 - a. Entire building under durable polyester TGIC powder coat shall have a base coat.
 - b. Steel shall be shot blasted in-house to SSPC-SP10 near-white blast cleaning prior to adding base coat. SSPC-SP2 hand tool cleaning will not be an acceptable alternative.
 - c. Top powder coat system durable TGIC powder coat which includes epoxy primer shall be applied.

2.13 BARRIER FREE FOUNTAIN (SKILTON AVENUE)

- A. Drinking fountain shall be Murdock model M-43A-PFS. Unit shall be furnished with one fountain bowl mounted on an arm and one fountain pet bowl mounted on the pedestal. Pedestal and arm shall be heavy duty iron castings and base of pedestal shall have four mounting holes. Pedestal and arm shall be furnished with a heavy grade of oil based enamel. Access cover shall be secured with vandal-resistant stainless steel screws. Murdock Manufacturing, P.O. Box 3527, City of Industry, CA 91744-0527. 800-591-9880, www.murdockmfg.com.
- B. Pet Bowl shall be round, case aluminum alloy with matte finish and two 3/8" holes for draining.
- C. Valves shall be self-closing, pushbutton operated, incorporating a replaceable cartridge and requiring less than 5 pounds of force to operate. Valves shall include an adjustable stream regulator controlling the water.
- D. Bubblers shall be stainless steel and operate on a water pressure range of 30 - 105 psig.
- E. Spigot shall be constructed of cast brass with a rough chrome plated finish and pushbutton operated. Supply line shall be lead free brass piping with 1/2" NPT connection.
- F. All solid brass castings shall conform to ASTM standards B61 and B62. Unit shall conform to ANSI A117.1, 2010 ADA Standards for Accessible Design, ANSI/NSF 61-9, and Public Law 111-380.

Spigot valve conform to lead-free requirements of NSF61, Section 9, 1997 and Federal Public B61 and B62. Law 111-380.

G. Pedestal Color:

1. Black

2.14 DOG WASTE STATION (SKILTON AVENUE)

A. Pet Waste Station as detailed on the plans and shall include the following:

1. 7 ft. U-Channel Post
2. Bag Dispenser
3. 10-Gallon Non-Locking Can
4. Sign and Sign Brackets. Heavy-gauge, rust-proof aluminum
5. Commercial-Grade Post, 2 lb./ft. steel. Powder coated.

B. Color:

1. Powder coated: Black

2.15 PET SHOWER (SKILTON AVENUE)

A. Pet Shower as detailed on the plans and shall include the following:

1. Pet Shower to be rectangular and have Push Button Activation. Unit shall be pre-piped and hydrostatically tested.

B. Materials:

1. Valves shall have internally mounted metering valve, pushbutton operated and requiring less than 5 pounds of force to activate. Timing shall be adjusted from 5 to 60 seconds.
2. Shower heads shall be chrome plated brass with 2.5 gpm flow restrictor and include an adjustable spray pattern from a coarse stream to a fine mist.
3. Unit shall be constructed of heavy duty 14 gauge type 304 stainless steel polished to a corrosion and scratch resistant stain finish with vandal resistant fasteners and shall include a ¼” thick stainless steel bottom plate, providing secure mounting for shower.

C. Color:

1. Powder coated Black

2.16 TREE GUARD (SKILTON AVENUE)

A. Materials:

1. Cast components will be of 100% recycled aluminum: ASTM B261

2. Castings will be squared and flat, free of burrs, slag, air pockets, blow holes, flashing, and grinding or welding on exposed surfaces. Excessive warping or shrinkage is not acceptable.
3. Fabricated components will be mild carbon steel, ASTM A36
4. Fabrication will be true to square, or diameter and sized within 1/8"

B. Finishes:

1. All visible welds to be ground smooth on outside edges.
2. Finish to be powder coat, Black, and applied per UA specifications.

2.17 LIGHTED BOLLARD (SKILTON AVENUE)

A. Materials:

1. Flat Top Cap: One-piece sand-cast, secured to louvers by concealed allen screws in keyhole slots. For relamping access, allen screws shall not require complete removal.
2. Louvers: Aluminum die-cast.
3. Shaft: One-piece extruded aluminum, .with a heavy cast aluminum twist-lock anchor base concealed within the shaft. Concealed set screws shall lock shaft onto the cast anchor base.
4. Electronic Module: All electrical components are either UL or ETL recognized, mounted on a single plate and factory prewired with quick disconnect plugs. Driver is rated for -40°F starting and has a 0-10V dimming interface for multi-level illumination options.
5. Optical Module: Each LED equipped with a directional optic for maximum beam angle projecting through louver stack spacing. LED boards to be mounted to an anodized interlocking heat sink extrusion. (Type I) two 5-LED boards for a total of 10-LED. (Type III) three 5-LED boards for a total of 15-LED. (Type V) four 5-LED boards for a total of 20-LED. Available in 580nm Amber, 3000K, 4200K and 5100K color temperatures.
6. Anchor Bolts: Four C" x 10" + 2" zinc plated L-hooks, each with two nuts, washers and a rigid pressed board template.

B. Finishes

1. Fade and abrasion resistant, polyester powdercoat finish.

C. Color

1. Dark Bronze

PART 3 - EXECUTION

3.1 BENCHES (COMMUNITY PATH)

- A. Community Path Benches shall be installed in accordance with the contract drawings, as per manufacturer's instructions and approved shop drawings.
- B. The concrete pad for benches shall slope at a ½ percent slope or crown from the center to the edges to eliminate any wet spots. The pad shall have a brushed finish.
- C. Benches shall be surface mounted to the concrete pad with anchor bolts as per manufacturer's recommendations and approved shop drawings.

3.2 BENCHES (SKILTON AVENUE)

- A. Examination:
 - 1. Examine areas to receive benches.
 - a. Verify that substrates are stable and capable of supporting the weight of items covered under this section.
 - b. Verify that substrates have been adequately prepared to securely anchor those items that will be surface mounted.
 - c. Notify Owner of conditions that would adversely affect installation or subsequent use.
 - d. Do not begin installation until unacceptable conditions are corrected.
- B. Installation:
 - 1. Install benches in accordance with manufacturer's instructions at locations indicated on the Drawings.
 - 2. Install benches level.
 - 3. The concrete pad for benches shall slope at a ½ percent slope or crown from the center to the edges to eliminate any wet spots. The pad shall have a brushed finish.
 - 4. Benches shall be surface mounted to the concrete pad with anchor bolts as per manufacturer's recommendations and approved shop drawings.
- C. Adjusting:
 - 1. Finish Damage: Repair minor damages to finish in accordance with manufacturer's instructions and as approved by the Owner.
 - 2. Component Damage: Remove and replace damaged components that cannot be successfully repaired as determined by the Owner.
- D. Cleaning:
 - 1. Clean benches promptly after installation in accordance with manufacturer's instructions.
 - 2. Do not use harsh cleaning materials or methods that could damage finish.

- E. Protection:
 - 1. Protect installed benches to ensure that, except for normal weathering, benches will be without damage or deterioration at time of Substantial Completion.

3.3 TRASH RECEPTACLES (COMMUNITY PATH)

- A. Community Path Trash Receptacles shall be installed in accordance with the contract drawings, as per manufacturer's instructions and approved shop drawings.
- B. The concrete pad for trash receptacles shall slope at a ½ percent slope or crown from the center to the edges to eliminate any wet spots. The pad shall have a brushed finish.
- C. Trash Receptacles shall be surface mounted to the concrete pad with anchor bolts as per manufacturer's recommendations and approved shop drawings.

3.4 SIGNS (COMMUNITY PATH)

- A. Before fabricating the sign support structures, the Design-Builder shall submit erection plans and shop drawings for approval. Span lengths, post heights, vertical and horizontal clearances, material specifications, anchor bolt layout, and all pertinent information shall be included in the shop drawings.
- B. Locate signs and accessories where indicated, using mounting methods of types described and in compliance with manufacturer's written instructions and approved shop drawings.
 - 1. Install signs level, plumb, and at heights indicated, with sign surfaces free from distortion and other defects in appearance.
 - 2. Strictly comply with approved shop drawings and manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
 - 3. Signs on the viaduct shall be mounted on chain link fence frame supports over the path as indicated on the drawings. Mounting frame shall be attached to the security fence.

3.5 SOLAR-POWERED EMERGENCY CALL BOXES (COMMUNITY PATH)

- A. Emergency Call Boxes At-Grade
 - 1. At-grade Emergency Call Boxes shall be installed at the locations shown on the drawings in accordance with manufacturer's instructions and approved shop drawings.
 - 2. Call Box Terminal Foundation shall be installed as per Signal Communications Corp. Drawing No. 1000-0436-4 Typical Foundation Installation.
 - 3. Solar Panel shall be mounted to the top of the mounting pole at the appropriate orientation to the sun to receive sufficient sun exposure for maximum charging of the call box. Submit shop drawings detailing solar panel attachment to pole for approval.
 - 4. Antennae shall be mounted on top of the mounting pole as per manufacturer's instructions and approved shop drawings.

5. Concrete foundation for call boxes shall be designed to meet MassDOT requirements, the foundation shall slope at a ½ percent slope or crown from the center to the edges to eliminate any wet spots. Depth of concrete footing shall be 4'-0" minimum.
6. Height and installation of call boxes shall meet all ADA requirements.

B. Emergency Call Boxes on Viaduct

1. Emergency Call Boxes on the viaduct shall be installed at the locations shown on the drawings in accordance with manufacturer's instructions and approved shop drawings. Boxes shall be side mounted to the mounting pole as per approved shop drawings.
2. Call Box Terminal Foundation shall be installed as per Signal Communications Corp. Drawing No. 1000-0436-4 Typical Foundation Installation except that the foundation shall be the 12 inch wide parapet wall. Coordinate installation of call boxes on viaduct with other trades as required.
3. Solar Panel shall be mounted to the top of the mounting pole at the appropriate orientation to the sun to receive sufficient sun exposure for maximum charging of the call box. Submit shop drawings detailing solar panel attachment to pole for approval.
4. Antennae shall be mounted on top of the mounting pole as per manufacturer's instructions and approved shop drawings.
5. Height and installation of call boxes shall meet all ADA requirements.

- C. Testing and Coordination with the City of Somerville: Test the individual call boxes in a coordinated program with the City of Somerville and the Owner. Make adjustments until the installation is satisfactory to all parties.

3.6 STEEL BOLLARDS (COMMUNITY PATH)

- A. Bollards shall be set vertically plumb and securely anchored in cement concrete footings as shown on the drawings and as per approved shop drawings. Align bollards to the lines and grades indicated on the Plans. Install bollards in a vertical position, maintaining a consistent height of 39 inches above grade. The Design-Builder will be required to coordinate the sequence of operation in planning footings and installation of surrounding pavement so bollards are not damaged or impacted from grading or paving operations.
- B. Fixed bollards shall be fixed and embedded into a concrete footing as per drawings and approved shop drawings.
- C. Removable bollards shall be inserted into a steel tube sleeve 3'-0" long embedded into concrete footing and shall be equipped with a hinged locking device as indicated on the drawings. Locking device shall be embedded into concrete and shall be hinged so that when the bollard is removed, the locking device will be flush with the pavement. Install removable bollards as per details and approved shop drawings.
- D. All welds shall be ground smooth.
- E. Painting

1. Bollards shall be phosphate washed, primed with zinc rich primer, and painted with exterior grade polyester powder coat prior to being delivered to the site.
 2. After installation of bollards, provide touch-up painting, if necessary, as approved by the Owner.
 3. Follow the provisions of Section 09900 – PAINTING.
- F. Protect bollards from paint spatter, concrete splashes and other construction damage by wrapping in plastic sheeting or heavy craft paper and taping in place. Do not remove until adjacent work is completed. Repair any damage to painted finish.

3.7 COBBLESTONE (COMMUNITY PATH)

- A. Preparation of Subgrade: The Design-Builder shall trim and roll the subgrade to smooth, uniform lines to the satisfaction of the Owner, prior to placing the pavement.
- B. Concrete Base: Shall be installed as shown in the details and shall be as described in Section 901 CEMENT CONCRETE MASONRY of the MassDOT Standard Specifications.
- C. Expansion Joints: Shall be thirty (30) feet O.C. typical.
- D. Mortar Bed: Spread mortar over concrete base to the thickness indicated on the drawings.
- E. Setting Cobbles: All cobbles shall be clean when placed. The cobbles shall be carefully laid according to the patterns shown on the drawings or as directed by the Owner. Joints between cobbles shall be a maximum of one half inch (1/2”) and a minimum of one-quarter inch (1/4”) in width. Cutting of cobbles to meet pattern requirements will be permitted, subject to the approval of the Owner. Cobbles shall be laid so that there are no depressions exceeding one-quarter inch (1/4”). Correct any depressions exceeding one-quarter inch (1/4”) by lifting cobbles to bring to proper grade. All stones disturbed in making replacements or correcting depressions shall be settled into place by carefully ramming or tamping to grade by the use of a hand tamper applied upon a two inch (2”) board. Each section of pavement must be acceptable to the Owner before the joints in that section are filled.
- F. Filling Joints: Joints shall be completely filled with a cement grout mixture of one part Portland cement and two parts sand. The grout shall be firmly packed in the joints between cobbles. Immediately after the joints are filled, the pavement shall be cleaned. The finished surface shall be free of all cement stain and excess grout and shall be acceptable to the Owner.

3.8 INLAID PREFORMED THERMOPLASTIC ASPHALT PAVEMENT MARKING SYSTEM

- A. Application of Inlaid Preformed Thermoplastic Asphalt Pavement Marking System
 1. Manufacturer Certified Applicator Requirement: The material shall be supplied and applied only by an applicator certified by the manufacturer. The applicator shall provide proof of current certification before commencing work. The Certified Applicator shall follow the manufacturer’s current published application guidelines.
 2. Substrate Condition: The material must only be applied to a stable, high quality asphalt pavement substrate over a stable base that is free of defects, as per the manufacturer’s published

substrate guide. The asphalt pavement surface shall be dry and free from all foreign matter, including but not limited to, dirt, dust, de-icing materials, and chemical residue.

3. Procedure: The asphalt pavement surface is heated with the primary reciprocating infrared heater to the appropriate temperature range to allow for surface imprinting. The stamping template in the specified pattern is imprinted into the heated asphalt pavement using the 700-900 lb. vibratory plate compactor. The preformed thermoplastic sheets, precut at the factory by the material manufacturer to match the template pattern, are laid into the pattern created by the stamping template, and heated until thoroughly molten with the primary reciprocating infrared heater. The mobile infrared heater or approved propane heat torch may be used in areas inaccessible to the primary reciprocating infrared heater. The material is then allowed to cool thoroughly before being opened to vehicle or pedestrian traffic. (Consult the manufacturer's published application procedures for complete information.)
4. The inlaid preformed thermoplastic asphalt pavement marking system shall not be applied to Portland Cement Concrete.

3.9 LOW- MOW SEED MIX

- A. Seeding Period: Optimum time for seeding is between August 20th and October 20th. To reduce weed competition and improve chances of establishment, it is recommended that, if possible given contract limitations, seeding be done at this time. Otherwise, seeding shall be between March 15th and May 15th. Seeding outside of this period shall be as approved by the Owner. Seeding outside of the specified time without prior approval shall not be compensated.
- B. Unless otherwise directed by the supplier, installation shall be as follows:
 1. Site Preparation: Area shall be seeded immediately following placement and preparation of loam so as to reduce the chance of weed seeds establishing. Seeding shall take place within 3 days of soil preparation, depending on weather conditions. Seeding 7 days or more after site preparation or if weeds are already established shall require the Design-Builder to submit a plan of action to ensure removal of weeds prior to seeding. Owner shall approve site conditions prior to seeding.
 2. Seeding: Unless otherwise specified by the supplier, seeding shall be at the rate of 5 lbs. per 1,000 square feet and shall be as follows:
 - Seed shall be brought to the site in unopened bags for approval by the Owner. Owner shall collect certification from bag prior to opening bag and prior to any seeding activity. Seeding without approval of the Owner shall be considered unacceptable for payment. Certification list shall match species and percentages of submittal.
 - Apply seed with broadcast spreader or drop seeder.
 - Cover the seed with 1/8 to 1/4 inch of soil.
 - Firm the seed into the soil by rolling with a roller, cultipacker, or similar implement.
 - Mulch with approximately one inch of weed free straw such as winter wheat or marsh hay.
 3. Watering: Watering is essential for establishment, increasing germination rates and seedling survival. Seeds shall be watered every other morning for 15 to 30 minutes during the first four to six weeks after planting, except during rainy days. Once established, seed should be watered

only during dry periods. Design-Builder shall notify Owner prior to or after watering so that the site may be inspected if necessary.

4. Overseeding: Bare patches shall be overseeded in the fall (best by end of September). Rake seed into top ½ inch of soil with steel rake where this does not disturb existing lawn. Seed at a rate of ½ pound per 100 square feet, Mulch lightly with hay.
 5. Compost: If seed fails to germinate or coverage is poor due to poor soil conditions, ½ inch of finish compost shall be spread over lawn prior to re-seeding.
 6. Mowing: It is recommended that Low Mow/No Mow turf be mowed to a height no lower than 3 inches from the ground.
- C. Inspection: Seeding shall be inspected 45 days after completion of seeding to assess establishment of the seeded species. Acceptance shall be based on adequate coverage of the seeded species (no bare spots greater than approximately 6 inches in diameter) and adequate weed control. Weed species shall not comprise more than 10% of the seeded area.

3.10 PARKING BUMPER CURBS

- A. Parking Bumper Curbs shall be installed as per manufacturer's recommendations and as detailed on the drawings and approved shop drawings.

3.11 LOW RETAINING WALLS (MAINTENANCE FACILITY SITE)

- A. As shown and detailed on the Plans, complying with the requirements of Section 02359, MODULAR PRECAST BLOCK RETAINING WALLS, and as directed by the Resident Engineer, install low height retaining walls on the site.

3.12 SHELTER (SKILTON AVENUE)

- A. Erection
1. Installation:
 - a. Install all foundations and anchor bolts according to manufacturer's installation instructions and these specifications.
 2. General Contractor:
 - a. Design-Builder shall coordinate the construction of the shelter with all other building trades impacted.
 3. Tolerances:
 - a. Tolerances on steel structural members are set according to AISC construction practices, abided in the factory, and cannot be increased. No field slotting or opening of holes will be allowed. It is therefore essential that Design-Builders conform to the tolerances specified on the installation drawings for anchor bolt or column layout details.
 4. OSHA Compliance:
 - a. OSHA Compliance to Steel Erection Standard 29CFR 1926 Subpart R-Steel Erection.
- B. Repair
1. Do not attempt any field changes without first contacting manufacturer.

C. Field or Site Quality Control

1. Field or Site Tests and Inspections as required by the Owner or by the local building inspector.

3.13 BARRIER-FREE FOUNTAIN (SKILTON AVENUE)

- A. Barrier-Free Fountain shall be installed in accordance with the contract drawings, as per manufacturer's recommendations and approved shop drawings.

3.14 DOG WASTE STATION (SKILTON AVENUE)

- A. Dog Waste Station shall be installed in accordance with the contract drawings, as per manufacturer's recommendations and approved shop drawings.

3.15 PET SHOWER (SKILTON AVENUE)

- A. Pet Shower shall be installed in accordance with the contract drawings, as per manufacturer's recommendations and approved shop drawings.

3.16 TREE GUARD (SKILTON AVENUE)

- A. Tree Guard shall be installed in accordance with the contract drawings, as per manufacturer's recommendations and approved shop drawings.

3.17 LIGHTED BOLLARD (SKILTON AVENUE)

- A. Lighted Bollard shall be installed in accordance with the contract drawings, as per manufacturer's recommendations and approved shop drawings; Design-Builder shall coordinate work with electrical contractor.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02509

PAVEMENT BASE COURSES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the construction of base courses for bituminous pavements on prepared subgrades to the lines, grades, compacted thickness, and cross sections indicated.
- B. Related Work:
 - 1. Section 02100 - SITE PREPARATION
 - 2. Section 02196 – GEOTEXTILE MATERIALS
 - 3. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 4. Section 02300 – EARTHWORK
 - 5. Section 02513 - BITUMINOUS CONCRETE PAVEMENT
 - 6. Section 02524 – CURBS, GUTTERS AND WALKS

1.2 REFERENCE STANDARDS

- A. American Society for Testing and Materials (ASTM)
- B. Commonwealth of Massachusetts, Massachusetts Department of Transportation (MassDOT) Standard Specifications for Highways and Bridges (Latest Edition).

1.3 SUBMITTALS

- A. Submit the following under provisions of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
 - 1. See 2.1.C below.

1.4 QUALITY ASSURANCE

- A. General: Design-Builder shall establish and maintain quality control for operations under this section to assure compliance with contract requirements and maintain records of his quality control for all materials, equipment, and construction operations.
- B. The services of qualified inspection and testing agencies shall be used for this work.
- C. Testing: Design-Builder shall arrange for services of a commercial laboratory for material and compaction testing. Design-Builder shall coordinate and cooperate with testing lab to insure timely completion of required tests.

- D. Laboratory Maximum Density: Tests shall be made in accordance with ASTM D 1557 for each type of material to be used on Project to determine optimum moisture content and laboratory maximum density values.
- E. Materials Analysis: Aggregate base material shall be tested per ASTM D 422.
- F. The MBTA reserves the right to perform inspections and testing at the plant and in the field at any time during the execution of work.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Base courses shall conform to the requirements of Section M2.01 of the MassDOT Standard Specifications for Highways and Bridges (Latest Edition). Each stone size shall meet its respective gradation as tabulated below:

**GRADATION REQUIREMENTS FOR COARSE AGGREGATE
(PERCENT BY WEIGHT)**

Nominal Size of Stone Sieve Size	Stone Sizes					
	2 in.	1-1 /2 in.	1-1 /4 in.	3 /4 in.	1 /2 in.	3 /8 in.
2-1/2"		100				
2"	90-100	100				
1-1/2"		95-100	100			
1-1/4"	25-50		85-100			
1"		35-70		100		
3/4"	0-15	0-25	10-40	90-100		
5/8"					100	
1/2"	0-5		0-8	10-50	85-100	100
3/8"				0-20	15-45	85-100
No. 4				0-5	0-15	20-50
No. 8					0-5	0-15
No.16						0-5

- B. Filter fabric: Provide filter fabric where indicated on Contract Documents.
- C. Prior to constructing the base course, Design-Builder shall submit the proposed plants, equipment, and material sources for approval.

PART 3 - EXECUTION

3.1 SUBGRADE

- A. The preparation of the subgrade shall be in accordance with specifications section 02300 - EARTHWORK, and the relevant provisions of Section 400 of the MassDOT Standard Specifications.

3.2 TRANSPORTATION OF MATERIALS

- A. Handle and transport mixed base materials in a manner that minimizes segregation and loss of moisture. Cover all loads in accordance with State laws unless hauling is off road and is approved. Unless approved, do not dump material into piles, haul over the completed base course, or stockpile the material on the job site.

3.3 INSTALLATION

- A. General Requirements: aggregate base shall be constructed to lines and grades indicated on Drawings. When constructed in more than one layer, first layer shall be cleaned of loose and foreign matter by sweeping with power sweepers or power brooms, except that hand Brooms may be used in areas where power cleaning is not practicable. Adequate drainage shall be provided during entire period of construction to prevent water from collecting or standing on the area to receive aggregate base. Line and grade stakes shall be provided as necessary for control. Grade stakes shall be in lines parallel to centerline of area under construction and suitably spaced for string lining.
- B. High Early Strength Cement Concrete shall be used in areas of roadway widening of six (6) feet or less in width. The cement concrete shall be set to a depth as shown on the plans or established by the MBTA. The top of the cement shall be set to allow for placement of pavement to match the adjacent roadway.
- C. Limit excavation for widening to an area that can be backfilled the same working day using graded aggregate base. Maintain the temporary graded aggregate base wedge with a 4:1 or flatter fill slope. Compact the material as directed. Leave the graded aggregate base wedge in place until placement of the hot mix asphalt base.
- D. Weather limitations: Base shall not be constructed when atmospheric temperature is less than 35°F. Base shall not be constructed on frozen subgrades or subgrade containing frost. If temperature falls below 35° F, completed areas shall be protected against any detrimental effects of freezing.
- E. Compaction: Compact graded aggregate base, bank run gravel base, and sand aggregate base to at least 97 percent of the maximum dry density. Compact graded stabilized aggregate base to at least 95 percent of the maximum dry density. Measure in place density per MSMT 350 or 352. Begin compaction operations, except on superelevated curves, at the sides of the course. Overlap the shoulder or berm at least 1 ft and progress toward the center parallel to the center line of the roadway. On superelevated curves, begin compaction at the low side and progress toward the high side. Continue compaction operations until all compaction marks are removed.
- F. Moisture and Dust Control Agents. When specified, add calcium or magnesium chloride at the plant or apply it to the surface of the material at the project site. Apply calcium chloride at the rate of 1

lb/yd². Apply magnesium chloride at the rate of 1 lb/yd² or as a solution at the rate of 1/2 gal/yd². Finishing: Surface of top layer shall be finished to grade and cross section shown. Finished surface shall be of uniform texture. Light blading during compaction may be necessary for finished surface to conform to lines, grades, and cross sections. If surface for any reason become rough, corrugated, uneven in texture, or traffic marked prior to completion, such unsatisfactory portion shall be scarified, reworked, recompacted, or replaced as directed.

3.4 FIELD TESTING AND PROTECTION

- A. In-Place Density: Field in-place density shall be determined in accordance with ASTM D 1556. Areas not meeting specified compaction requirements shall be reworked as recommended by testing lab and retested until specified compaction is obtained.
 - 1. Tests shall be performed as follows: Aggregate Base - Two (2) tests per lift
- B. Samples: Samples of all materials imported to site for use on Project shall be submitted to or taken by testing lab for testing as specified herein. Copies of all test reports shall be approved by Engineer prior to importing any materials to site.
- C. Defects: Settlement is considered to be among defects to be corrected. Design-Builder shall repair all defects and replace any permanent construction items disturbed by corrective measures at no additional cost to Owner.
- D. Smoothness: Surface of each layer shall show no deviations in excess of 3/8 inch when tested with 10-foot straightedge. Deviations exceeding this amount shall be corrected by removing material and replacing with new material, or by reworking existing material and compacting, as directed.
- E. Thickness: Compacted thickness of the aggregate base course shall be within 1/2 inch of the thickness indicated. Where measured thickness is more than 1/2 inch deficient, such areas shall be corrected by scarifying, adding new material of proper gradation, reblading, and recompacting as directed. Where thickness measures more than 1/2 inch thicker than indicated, course shall be considered as conforming to specified thickness requirements. Average job thickness shall be average of all thickness measurements taken for the job, but shall be within 1/4 inch of thickness indicated.
- F. Traffic: Completed portions of base course area may be opened to traffic provided there is no marring or distorting of the surface. Heavy equipment shall not be permitted except when necessary to construction, and then area shall be protected against marring or damage to completed work.
- G. Protection: Aggregate base course shall be maintained in satisfactory condition until accepted. Maintenance shall include immediate repairs to any defects and shall be repeated as often as necessary to keep area intact.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02513

BITUMINOUS CONCRETE PAVEMENT

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Construction of bituminous concrete pavement on prepared subgrade or aggregate subbase or base course, and on existing pavement, and for the base course for unit pavers; to the lines, grades, compacted thickness, and cross sections indicated.
 2. Construction of SUPERPAVE Hot Mix Asphalt (HMA) Pavement on prepared subgrade or aggregate subbase or base course to the lines, grades, compacted thickness, and cross sections indicated at locations shown on the plans. Work under SUPERPAVE Items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) SUPERPAVE REQUIREMENTS contained herein and the following:
 - a. The Equivalent Single Axle Loads (ESALs) for Shared Use Paths, Sidewalks, Driveways, and Small Parking Lots over a 20-year period, is <0.3 Million 18-kip (80-kn) ESALs.
 - b. The Equivalent Single Axle Loads (ESALs) for Large Parking Lots and Local Roads, over a 20-year period, are estimated to be between 0.30 and <3.0 Million 18-kip (80-kn) ESALs. (examples include: Horace Street, Tufts Street)
 - c. The Equivalent Single Axle Loads (ESALs) for the design travel lane of Local Roads over a 20-year period are estimated to be between 3.0 and <10 Million 18-kip (80-kn) ESALs. (examples include: Water Street, East Street, and West Boulevard)
 - d. The Equivalent Single Axle Loads (ESALs) for the design travel lane of Arterials and Collectors over a 20-year period are estimated to be between 10 and <30 Million 18-kip (80-kn) ESALs. (examples include: Washington Street and Medford Street)
 - e. Any pavement section anticipated to receive bus or truck traffic shall be a minimum of a traffic level 3 design (3.0 to <10 Million 18-kip (80-kn) ESALs.
 - f. If the traffic volume or functional classification is unknown or in disagreement, the ESALs shall be determined by the MBTA.

Functional Classifications, as described above, shall be obtained from the MassDOT road inventory map, as applicable: <http://services.massdot.state.ma.us/maptemplate/roadinventory/>

The PGAB Grade selected for this Contract is *PG 64-28*.

3. Constructing a Microsurfacing Surface Treatment Course to the lines, grades, compacted thickness, and cross sections indicated at locations shown on the plans.

4. Milling of existing bituminous concrete pavement surface to various depths and cross slope to produce a uniform surface for the application of the pavement overlay, as shown on the Approved Plans and as directed by the MBTA, and the legal disposal of the removed material off the site.
5. Micromilling of existing bituminous concrete pavement surface to various depths and cross slope as shown on the Approved Plans and as directed by the MBTA, and the legal disposal of the removed material off the site.
6. Construction of Bituminous Concrete Berm.

B. Related Work:

1. Section 02300 - EARTHWORK; excavation and compacted subgrade.
2. Section 02509 - PAVEMENT BASE COURSES
3. Section 02524 - CURBS, GUTTERS AND WALKS
4. Section 03300 - CAST-IN-PLACE CONCRETE

1.2 QUALITY ASSURANCE

- A. The MBTA reserves the right to perform inspections and testing at the plant and in the field at any time during the execution of work.
- B. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

1.3 QUALITY CONTROL

- A. The Design-Builder shall engage the services of a qualified independent testing agency approved by the Authority to perform quality-control testing in the field.
- B. Job Mix Formulae – SUPERPAVE HMA Pavement
 1. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.
- C. Job Mix Formulae – Bituminous Concrete Pavement (not SUPERPAVE)
 1. The composition limits specified in Table 02513-C at the end of this Section are master ranges of tolerances of materials in general. In order to obtain standard texture, density, and stability, furnish to the MBTA for approval a specific job mix formula for the particular uniform combination of materials and sources of supply to be used on each project. Establish the job mix formula in accordance with the requirements of the Massachusetts Department of Transportation (MassDOT) Standard Specifications Section M3.
 2. Should a change of sources of materials be made, furnish a new job mix formula for approval before using the new material.
 3. Two or more job mix formulae may be approved for a particular plant; however, only material conforming to one job mix formula will be permitted to be used on any given day. If the

Design-Builder elects to furnish bituminous concrete from more than one plant, the job mix formulae shall be adhered to by all plants.

4. When unsatisfactory results or other conditions make it necessary, the MBTA may establish new job mix formulae.

D. Job Mix Formulae – Microsurfacing

1. The job mix formula shall provide a minimum Marshall stability of 1,800 pounds and a flow of 6 to 16 units when tested according to the ASTM 1559 or AASHTO 245 procedure as modified. All component material used in the mix design shall be representative of the material proposed by the Design-Builder for use on the project.

E. Methods of Sampling and Testing – SUPERPAVE HMA Pavement

1. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

F. Methods of Sampling and Testing – Bituminous Concrete Pavement (not SUPERPAVE)

1. Performance Graded Asphalt Binder

- a. Viscosity: ASTM D4402.
- b. Dynamic Shear: AASHTO TP5.
- c. Flash Point: AASHTO T48.
- d. Rolling Thin Film Over Test: AASHTO T240.
- e. Mass Change %: AASHTO T240.
- f. PAV Aging: AASHTO PP1.
- g. Specific Gravity: ASTM D 3142.
- h. Creep Stiffness and M-Value: AASHTO TP1.

2. Cutback Asphalt

- a. Viscosity: ASTM D 2170.
- b. Flash Point: ASTM D 3143.
- c. Distillation: ASTM D 402.
- d. Water in Asphalt: AASHTO T55.
- e. Specific Gravity: AASHTO T228.

3. Emulsified Asphalt: ASTM D 977.

4. Mineral Aggregates and Filler

- a. Sieve Analysis, Aggregates: ASTM C 136.
- b. Sieve Analysis, Mineral Filler: ASTM D 242.
- c. Unit Weight of Aggregate: ASTM C 29.
- d. Material Passing No. 200 Sieve: ASTM C 117.
- e. Abrasion of Coarse Aggregate: ASTM C 131.
- f. Soundness of Aggregates: ASTM C 88.
- g. Specific Gravity, Coarse Aggregate: ASTM C 127.
- h. Specific Gravity, Fine Aggregate: ASTM C 128.
- i. Specific Gravity, Mineral Filler: AASHTO T100 to T133

5. Bituminous Concrete Mixtures
 - a. Density: AASHTO T166.
 - b. Compaction: ASTM D 2950.

- G. Methods of Sampling and Testing – Microsurfacing Surface Treatment
 1. Materials
 - a. The Design-Builder will permit the MBTA to take samples of the aggregate and asphalt emulsion to be used in the project at the MBTA’s discretion. Gradation and sand equivalent tests may be run on the aggregate and residual asphalt content test on the emulsion. Test results will be compared to specifications. Tests will be run by a qualified laboratory at the expense of the buyer. The buyer must notify the Design-Builder immediately if any test fails to meet the specifications.
 2. Micro-Surfacing Mixture
 - a. Samples of the mixture should be taken daily and may be taken directly from the mixing unit(s). Consistency and residual asphalt content tests may be made on the samples and compared to the specifications. Tests will be run by a qualified laboratory at the expense of the buyer. The buyer must notify the Design-Builder immediately if any test fails to meet specifications.
 3. Non-Compliance
 - a. If any two successive tests fail on the stockpile material, the job shall be stopped. It is the responsibility of the Design-Builder, at his own expense, to prove to the MBTA that the conditions have been corrected. If any two successive tests on the mix from the same machine fail, the use of the machine shall be suspended. It will be the responsibility of the Design-Builder, at his own expense, to prove to the MBTA that the problems have been corrected and that the machine is working properly.

- H. Composition and Compaction Acceptance Tests– SUPERPAVE HMA Pavement
 1. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

- I. Composition and Compaction Acceptance Tests – Bituminous Concrete Pavement (not SUPERPAVE)
 1. Where plant inspection is maintained, bituminous concrete will be acceptable for use if the specified tests from samples obtained at the production plant indicate conformance to the approved job mix formula.
 2. For determination of pavement density, perform in-place density testing by the Nuclear Density Method, ASTM D 2950. The number of tests shall be determined by the MBTA QA lab.
 3. The MBTA may also require bituminous cores to determine in-place density.
 4. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

1.4 SUBMITTALS

- A. Submit the following under provisions of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
 - 1. Product Data: For each material and manufactured product specified.
 - a. Submit manufacturer’s product data, installation instructions, use limitations and recommendations for each material used.
 - b. Provide certifications stating materials comply with requirements.
 - c. All work under SUPERPAVE HMA Pavement items shall also conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.
 - d. For Microsurfacing Surface Treatment the Design-Builder shall submit a signed mix design covering the specific material to be used on the project. This design shall be performed by a qualified laboratory. Once the materials are approved, no substitution will be permitted unless first tested and approved by the laboratory preparing the mix design

1.5 MAAB AND ADA COMPLIANCE

- A. Special attention is to be given to compliance with the American with Disabilities Act (ADA) and the requirements of the Massachusetts Architectural Access Board (MAAB).
 - 1. Slopes: All Walkways as defined by Section 22.1 of 521 CMR shall be graded to a maximum 4.5%. The cross pitch (perpendicular to travel) for all walkways and paths shall be constructed at 1.5% and the slope of all ramps shall be constructed at 7.5% with a construction tolerance of $\pm 0.5\%$. Ramps as defined in Section 24.1 of 521 CMR shall be constructed to a maximum slope of 8.33%.
 - 2. The Design-Builder is to assume that all sidewalk grades shall be verified/checked with a 2-foot long electronic ‘smart’ level.
 - 3. A 5-foot-0-inch minimum level (1.5% pitch maximum) area shall be provided at all entrances to buildings. Puddling of water at the entrances will not be allowed.
- B. The above requirements shall supersede the grades shown on the Approved Plans. If these requirements cannot be met with the grades shown on the plans, the designer shall be notified immediately for direction.

1.6 TEMPORARY PAVEMENT

- A. The Design-Builder shall place temporary bituminous concrete pavement in all trenches, construction access pits, and damaged pavement sections on a weekly basis for erosion and sediment control. Roadway patching shall be performed before any pavement milling. Additional roadway patching may be required to correct pavement defects made visible by the pavement milling.
- B. Temporary bituminous concrete pavement shall be used to provide temporary access and egress for vehicles and pedestrians to sidewalks and to those properties abutting the work area only as determined by the MBTA. The subsequent removal of this material, if directed by the MBTA, shall also be included in this item.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Performance Graded Asphalt Binder: AASHTO M320, grade as indicated, except that the requirements listed under Table 02513-A shall apply.
- B. Cutback Asphalts
 - 1. Medium-Curing: AASHTO M82, grade as indicated.
- C. Bituminous Emulsions
 - 1. Asphaltic Emulsions: AASHTO M140, grade as indicated. Use grade RS-1 for prime coat or tack coat.
 - 2. Cationic Emulsified Asphalt: AASHTO M208, grade as indicated.
 - 3. Clay-Type Asphalt Emulsion: A mineral colloid type of asphalt emulsion containing no chemical emulsifiers and meeting the following requirements:
 - a. Percent water, per AASHTO T59: 40 to 55
 - b. Percent residue by evaporation, per AASHTO T59: 45 to 60
 - c. Percent ash in residue, per ASTM D1010: 5 to 15
 - d. Curing time, per Massachusetts DPW standard test procedures: firm set in 48 hours maximum
 - e. Resistance to water, per Massachusetts DPW standard test procedures: no re-emulsification.
 - 4. Protective Seal Coat Emulsion: a homogeneous emulsion consisting of coat tar pitch dispersed in water by means of a mineral colloid, containing no asphaltic materials or chemical emulsifiers; capable of overcoming any separation or coagulation of its components by moderate stirring; meeting the following requirements:
 - a. Percent Water, per AASHTO T59: 50 maximum
 - b. Percent non-volatile matter, per ASTM D1010: 48 minimum
 - c. Percent ash in non-volatile matter, per ASTM D1010: 20 to 45
 - d. Percent solubility on non-volatile matter in carbon disulfide: 40 minimum
 - e. Resistance to water, per ASTM D466: no blistering, loss of adhesion, or re-emulsification
 - f. Resistance to petroleum solvents, per ASTM D466 with solvents substituted for water: no penetration nor loss of adhesion.
- D. Asphalt Anti-Stripping Additive
 - 1. General: An additive to asphalt to assist in the coating of wet aggregate and to increase the resistance of the bituminous coating to stripping in the presence of water; shall be chemically inert to asphalt (heat stable) and when blended with asphalt shall withstand storage at a temperature of 400 degrees F for extended periods without loss of effectiveness.
 - 2. Composition: An organic chemical compound free from inorganic mineral salts or inorganic mineral soaps, containing no ingredient harmful to the bituminous material or to the operator, and not appreciably altering the specified characteristics of the bituminous material; chemically inert to asphalt.

3. Heat Stability: The compound shall retain its effectiveness after heating in asphalt according to the prescribed method for 24 hours at 350 degrees F.
4. Resistance to Stripping. Treated Bitumen shall coat wet aggregate and shall retain at least 90 percent of the coating after 24 hours of static immersion. There shall be no loss of the retained coating after the immersion has been extended to one week.

E. Coarse Aggregate

1. General: Clean, crushed rock consisting of the angular fragments obtained by breaking and crushing shattered natural rock, free from a detrimental quantity of thin or elongated pieces, and free from dirt or other objectionable materials; having a percentage of wear of not more than 30; surface dry and having a moisture content of not more than 0.5 percent after drying. The use of crushed gravel stone will not be permitted.
2. Gradation: Blended from the stone sizes listed in Table 02513-B. Each stone size shall meet its respective gradation as tabulated in Table 02513-B. Sizes other than primary stone sizes may be used providing they are separately introduced on the cold feed belt and can be shown to be an improvement to the mix. Such usage shall require the prior written approval of the MBTA.

F. Fine Aggregate

1. General: Natural or stone sand or a blend thereof; or a blend of natural sand and stone screenings, or a blend of stone, sand and stone screenings;
 - a. Natural Sand: Clean, inert, hard durable grains of quartz or other hard durable rock, free of loam, clay, surface coatings or other deleterious substances.
 - b. Stone Sand: Process from the stone screenings, of either a primary or secondary crusher to produce a product that when used alone or blended in any combination with natural sand shall meet the specified gradation requirements. Wash plant or other equipment used for processing stone sand shall be as accepted by the MBTA.

G. Mineral Filler: Portland cement, limestone dust, hydrated lime, stone float, or stone dust, 100 percent passing a No. 50 sieve and not less than 65 percent passing a No. 200 sieve. Stone dust shall be produced from crushed ledge stone and shall be the product of a secondary crusher so processed as to deliver a product of uniform grading.

H. Reclaimed Asphalt Pavement (RAP): Reclaimed Asphalt Pavement (RAP) shall consist of the material obtained from the highways or streets by crushing, milling, or planing existing hot mix asphalt pavements. This material shall be transported to the hot mix asphalt production facility yard and processed through an appropriate crusher so that the resulting material will contain no particles larger than the maximum aggregate size of the hot mix asphalt mixture in which it will be used. The material shall be stockpiled on a free draining base and kept separate from virgin aggregates. The material contained in the RAP stockpiles shall have a reasonably uniform gradation from fine to coarse and shall be protected from accumulation of excessive moisture and shall not be contaminated by foreign materials. The use of RAP will be permitted provided that the end product is in conformance with the approved job-mix formula. The proportion of RAP to virgin aggregate for base course mixtures and intermediate course mixtures shall be limited to a maximum of 40% for drum mix plants and 20% for modified batch plants. The maximum amount of RAP for surface course mixtures shall be 15%. The PG binder grade for mixes combining RAP shall be PG 64-28 if recycled binder content is 25% or less. If recycled binder content exceeds 25%, the PG binder grade shall be 52-34.

I. Bituminous setting-bed materials for unit pavers

1. Primer for Base: ASTM D 2028, cutback asphalt, grade as recommended by unit paver manufacturer.
2. Fine Aggregate for Setting Bed: ASTM D 1073, No. 2 or No. 3.
3. Asphalt Cement: ASTM D 3381, Viscosity Grade AC-10 or Grade AC-20.
4. Neoprene-Modified Asphalt Adhesive: Paving manufacturer's standard adhesive consisting of oxidized asphalt combined with 2 percent neoprene and 10 percent long-fibered mineral fibers containing no asbestos.
5. Sand for Joints: Fine, sharp, washed, natural sand or crushed stone with 100 percent passing No. 16 sieve and no more than 10 percent passing No. 200 sieve.
 - a. Provide sand of color needed to produce required joint color.

J. Bituminous setting-bed mix for unit pavers

1. Mix bituminous setting-bed materials at an asphalt plant in approximate proportion, by weight, of 7 percent asphalt cement to 93 percent fine aggregate, unless otherwise indicated. Heat mixture to 300 degrees Fahrenheit.

K. Bituminous Berm

1. Work under this item shall conform to the relevant provisions of MassDOT Standard Specification Section 470.

2.2 CLASS I BITUMINOUS CONCRETE MIXES - BITUMINOUS CONCRETE PAVEMENT (NOT SUPERPAVE)

- A. Provide Class I bituminous concrete mixtures composed of mineral aggregate, mineral filler if required bituminous material, and anti-stripping additive if required, proportioned as specified herein to conform to the composition by weight tabulated in Table 02513-C and in the approved job mix formulae.
- B. Use sufficient mineral filler to correct any deficiencies in grading of fine aggregate.
- C. Anti-stripping additive, if required, shall be incorporated and thoroughly dispersed in the bituminous material in an amount equal to the percent by weight established by the MBTA's Materials Testing Laboratory. This percent will be based on the efficiency of the additive as determined by laboratory tests. No modification of the established additive concentration will be permitted because of the use of hydrophobic aggregate. The MBTA reserves the right to establish as minimum the percentage of additive required. Blend additive in the refinery with the asphalt in the presence of the Inspector.
- D. The percentages stated herein and in Table 02513-C are stated as proportional percentages of integral total aggregate for the mix.
- E. Furnish Intermediate Course, with anti-stripping additive, for use as protective (bottom) course of pavements on bridges, and elsewhere as indicated.
- F. Furnish Patching Mix with one percent hydrated lime.

2.3 SUPERPAVE HMA PAVEMENT MIXES

SUPERPAVE HMA Pavement mixes shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein. And the following:

- A. Construction of SUPERPAVE Hot Mix Asphalt (HMA) Pavement on prepared subgrade or aggregate subbase or base course to the lines, grades, compacted thickness, and cross sections indicated at locations shown on the Approved Plans. Work under SUPERPAVE Items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) SUPERPAVE REQUIREMENTS contained herein and the following:
1. The Equivalent Single Axle Loads (ESALs) for Shared Use Paths, Sidewalks, Driveways, and Small Parking Lots over a 20-year period, is <0.3 Million 18-kip (80-kn) ESALs.
 2. The Equivalent Single Axle Loads (ESALs) for Large Parking Lots and Local Roads, over a 20-year period, are estimated to be between 0.30 and <3.0 Million 18-kip (80-kn) ESALs. (examples include: Horace Street, Tufts Street)
 3. The Equivalent Single Axle Loads (ESALs) for the design travel lane of Local Roads over a 20-year period are estimated to be between 3.0 and <10 Million 18-kip (80-kn) ESALs. (examples include: Water Street, East Street, and West Boulevard)
 4. The Equivalent Single Axle Loads (ESALs) for the design travel lane of Arterials and Collectors over a 20-year period are estimated to be between 10 and <30 Million 18-kip (80-kn) ESALs. (examples include: Washington Street and Medford Street)
 5. Any pavement section anticipated to receive consistent bus or truck traffic shall be a minimum of a traffic level 3 design (3.0 to <10 Million 18-kip (80-kn) ESALs.
 6. If the traffic volume or functional classification is unknown or in disagreement, the ESALs shall be determined by the MBTA.

Functional Classifications, as described above, shall be obtained from the MassDOT road inventory map, as applicable: <http://services.massdot.state.ma.us/maptemplate/roadinventory/>

The PGAB Grade selected for this Contract is PG 64-28.

B. Warm-Mix Asphalt Pavement

1. All SUPERPAVE Hot Mix Asphalt Mixture shall be modified using a WMA additive capable of lowering plant production temperatures to below 260° F. Warm Mix Asphalt additives reduce compaction effort and permit lower production temperatures than conventional hot mix asphalt. The WMA additive shall be a product listed on the Northeast Asphalt User Producer Group (NEAUPG) website (<http://www.superpave.psu.edu/NEAUPG.html>), except that no WMA foaming technology will be permitted which requires the mechanical injection of steam or water into the liquid asphalt.
2. The WMA additive must be compatible with polyphosphoric acid modified binders, polymer modified binders, and the HMA producer's HMA anti-stripping agents. The WMA additive shall be introduced in accordance with the Manufacturer's dosing rates and approved blending methods. The WMA additive Manufacturer shall have an on-site representative at the beginning of paving operations. The Manufacturer's representative shall be available for additional consultation during the remaining Warm Mix production.
3. All work done under this Item shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) SUPERPAVE REQUIREMENTS contained herein and the relevant provisions of Sections 450 and 455 of the MassDOT specifications. The WMA

mixture design shall incorporate the requirements of NCHRP Report 691: Mix Design Practices for Warm Mix Asphalt “*Draft Appendix to AASHTO R35, Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)*”. In addition to the provisions of Sections 450 and 455, laboratory prepared samples that have been manufactured at specified temperatures with and without the WMA additive shall be submitted to MassDOT at least 45 days prior to placement for testing. These samples shall be subject to Hamburg Wheel testing for moisture damage and rutting for verification that the WMA is at least equal in performance to the HMA. Preparation of these samples shall be coordinated with the MassDOT.

C. Latex Modification of HMA

1. Latex-modify the Superpave Surface Courses for Roadways and Bridges only.
2. The latex polymer modifier type and amount shall be included as part of the job mix formula. The Superpave Hot Mix Asphalt mixtures shall be produced with asphalt binder modification as follows:
3. Latex Polymer Modified Asphalt Binder:
 - a. The polymer additive shall consist of unvulcanized Styrene Butadiene Rubber (SBR) in liquid latex form, with a minimum quantity of rubber solids of 3% by weight of the performance grade asphalt binder (PGAB) content of the mix. The PG 64-28 shall be modified to produce a PGAB grade of 70-28.
 - b. Quantity: 3% rubber solids by weight of the bitumen content of the mix. (Example: If the latex polymer is 70% solids, weight per gallon is 7.69 lbs. = 5.38 lbs. solids per gallon. If mix calls for 6% bitumen, 3% = 3.6 lbs. of latex solids per ton mix or 0.70 gallons of latex per ton of mix.)
 - c. The latex polymer modified asphalt binder shall be injected into the mix at the time of manufacture. In a drum plant, the liquid latex polymer shall be pumped into the asphalt binder through a spud welded to the asphalt binder line just prior to where it enters the drum. The constant rate at which the latex polymer is pumped shall be determined by the mix speed of the drum. In a batch plant, the polymer is pumped directly into the mix five (5) seconds after the asphalt binder starts to dump into the pug mill. Mix time per batch after polymer is pumped in is 45 to 60 seconds.
 - d. The plant shall be equipped with an in-line blender and a sample cock for Quality Control and Acceptance purposes.
 - e. A metering system shall be attached to a printer which prints a time and date stamp, latex flow rate and cumulative polymer usage during the HMA production, allowing the MBTA to reference the injection rate and latex used against the plant’s projection rate. The printout shall be set for a five minute interval. The latex polymer manufacturer will have a professional representative available at the HMA plant during the first day of mix production and placement, and as required thereafter by the MBTA.
 - f. The manufacturer of the SBR latex shall provide certified test results for Styrene Butadiene ratio, total rubber solids percentage by weight, pH, ash content, and viscosity to the MBTA prior to mix production.
 - g. Mix conforming to the requirements of these Special Provisions shall be placed when the ambient temperature is 50°F and rising when measured in the shade away from artificial heat.
 - h. Mixing temperature shall be 290°F to 325°F unless otherwise specified by the MBTA. Mix shall be placed at between 275°F and 310°F.

2.4 MICROSURFACING MIXES

A. Emulsified Asphalt

1. The emulsified asphalt shall be a quick-set latex modified cationic type CSS-1H emulsion and shall conform to the requirements specified in AASHTO M208 and ASTM 2397. It shall pass all applicable storage and settlement tests. The latex shall be milled into the emulsion. The cement mixing test shall be waived for this emulsion.
 - a. Special Residue Properties:

Distillation of residue will be at a temperature of 350 degrees F for 20 minutes. Softening point of the residue shall be 140 degrees F minimum. Viscosity, absolute at 140 degrees F, shall be 8,000 poise minimum.

B. Aggregate

1. The mineral aggregate used shall be of the type and grade specified for micro-surfacing. The aggregate shall be manufactured crushed stone such as granite, slag, limestone, chat, or other high quality aggregate or combination thereof.
 - a. Aggregate Physical Requirements
 1. Grading. The aggregate including natural fines when tested by AASHTO methods T11 or T27 or ASTM C117 or C136, should meet the referenced gradation requirements.
 2. Deleterious Substances. To limit the permissible amount of clay like fines in an aggregate, a sand equivalent value of 65 or higher is required when tested by ASTM 2419.
 3. Soundness. The aggregate shall have a weighted loss of not more than 15% when the sodium sulfate test is used or 20% when the magnesium sulfate test is used.
 4. Hardness. The aggregate wear, from resistance to abrasion, shall be a maximum of 35% when using AASHTO T96 or ASTM C131 test methods.

C. Water

1. The water shall be potable and shall be free of harmful soluble salts.

D. Modifier

1. Special quick-setting emulsifier agents shall be milled into the asphalt emulsion. The emulsified asphalt shall be so formulated that when the paving mixture is applied at thickness of one inch with the relative humidity at not more than 50% and the ambient air temperature of at least 75 degrees F. the material will cure sufficiently so that rolling traffic can be allowed in one hour with no damage to the surface, as verified by the MBTA.

E. Additives

1. A mineral additive shall be introduced to the mineral aggregate and may be any recognized brand of non-air entrained portland cement or hydrated lime that is free of lumps, or other approved mineral additive. It may be accepted upon visual inspection. The amount of mineral additive needed shall be determined by the laboratory mix design and will be considered as part of the material gradation requirement. A liquid field control additive is introduced and blended

with water to provide effective control of the required quick-set properties. This additive shall be made available by the chemical supplier or emulsion manufacturer and certifiable as being compatible with the mixture.

F. Mix Design

1. The qualified laboratory shall develop the job mix design and present certified test results for MBTA approval. The MBTA shall approve the design mix and all micro-surfacing materials and methods prior to use. The component materials shall be within the following limits:

- a. Residual Asphalt 5% to 9% by dry weight of aggregate
- b. Mineral Additive 0.5% to 3% by dry weight of aggregate
- c. Latex Modifier As required to provide specified properties
- d. Field Control Additive As required to provide specified properties
- e. Water As required to produce consistency
- f. Aggregate - Recommended Gradations:

Screen Size	Type II % Passing	Type III % Passing
3/8"	100	100
#4	90-100	70-90
#8	65-90	45-65
#16	40-65	30-50
#30	25-45	19-34
#50	15-30	12-25
#100	10-21	7-18
#200	5-13	4-12

PART 3 - EXECUTION

3.1 PLANT REQUIREMENTS

A. General: The plant used in the production of bituminous concrete shall comply with AASHTO M156, subject to the following additional requirements.

B. Plant Scales

- 1. Scales for measuring materials into the mixtures shall be springless dial type and shall be of standard make and design. Scale graduations and markings shall be plainly visible and dials shall be so located as to be easily readable from the operator's normal work station by direct sight or through repeating dials. Parallax effects shall be reduced to the practical minimum with clearance between indicator index and scale graduations not exceeding 0.06 inch. Dials shall be equipped with a full complement of adjustable index pointers for marking the required weight of each material to be weighed into the batch.
- 2. Digital scales will be either electric/mechanical (load cell and lever system) or fully electronic (all load cell). Digital indicators shall be of standard make and design. Scale graduations and capacity shall be plainly visible on the faceplate of the indicator, if panel mounted. If the unit is of desktop or wall-mount variety, a data sticker shall be located on the side of the unit. Indicators must be located as to be easily readable from the operator's normal workstation by sight.

3. Bitumen scales shall be accurate to 0.05 percent, have minimum graduations not greater than 0.025 percent, and shall be readable and sensitive to 0.0125 percent or less. Scales for any weigh box or hopper shall be accurate to 0.5 percent, have minimum graduations not greater than 0.5 percent and shall be readable and sensitive to 0.25 percent or less. The preceding percentages for both bitumen and aggregate scales are based on the maximum total batch weight of the mixtures.

C. Testing of Scales

1. All plant scales, including truck scales, shall be tested at the expense of the Design-Builder by a competent scale technician as follows:
 - a. Annually prior to use in MBTA work.
 - b. At intervals of not more than 90 calendar days.
 - c. At any time ordered by the MBTA.
2. A cradle or platform approved by the MBTA for each scale and at least ten standard fifty-pound test weights shall be provided for testing scales whenever directed by the MBTA. The use of a set of test weights for two or more plants will be permitted only when they can be made readily available with no more than an hour's notice.

D. Automated Batching

1. Automatic proportioning. Batch type mixing plants shall be equipped with approved automatic proportioning devices. Such devices shall include equipment for accurately proportioning batches containing the various components of the mixture by weight in the proper sequence and for controlling the sequence and timing of mixing operations. Interlocks shall be provided which will hold or delay the automatic batch cycling whenever the batched quantity of any component is not within the specified weight tolerance, when any aggregate bin becomes empty or when there is a malfunction in any portion of the control system. The weight setting and time controls shall be so equipped that they may be locked when directed by the MBTA.
2. Automatic Recordation. Recordation equipment shall be provided. Each recorder shall include an automatic printer system. The printer shall be so positioned that the scale dial and the printer can be readily observed at one location by the plant inspector. Use of repeating dials or an additional printer to achieve this condition will be permitted. The printer shall print, in digital form, on a delivery ticket the following data:
 - a. Date mixed.
 - b. Time of batching.
 - c. Tare weight of aggregate weigh box.
 - d. Tare weight of bitumen weigh bucket.
 - e. Accumulative weights as batched for each bin. (Total of last bin will be aggregate total).
 - f. Weight of bitumen.
 - g. Total weight of mix in truck (Pay weight). This printed ticket shall be used in lieu of truck scale weights.
3. Equipment Failure. If at any time the automatic proportioning of recording system becomes inoperative, the plant will be allowed to batch materials manually for a period not in excess of two working days. Manual batching for longer periods will require written permission of the MBTA.
4. Batching Controls

- a. The batching controls shall meet the following delivery tolerances with respect to the various components weighed in each batch:
 1. Tare Weight of Aggregate Weigh Box: + 0.5 percent of total batch weight.
 2. Tare Weight of Bitumen Weigh Bucket: + 0.1 percent of total batch weight.
 3. Individual Aggregate Components: + 1.0 percent of total batch weight.
 4. Combined Aggregate Components: + 1.5 percent of total batch weight.
 5. Mineral Filler: + 0.5 percent of total batch weight.
 6. Asphalt: + 0.1 percent of total batch weight.
- b. The total weight of the batch shall not vary more than plus or minus 2 percent from the theoretical design weight.
- c. If directed by the Owner, provisions shall be made for locking controls against tampering.

E. Plant Laboratory

1. A building shall be furnished at the site of the producing plant suitable for the housing and use of equipment necessary to carry on the various tests required and for recording and processing test results. This building shall be for the exclusive use of the Owner or his representatives for testing and recording purposes.
2. The building shall have a minimum floor area of 100 square feet; the least dimension to be 6 feet. Windows and doors shall be adequately screened; satisfactory lighting, heating and water shall be supplied. A table, chairs, desk and work bench shall be provided. Provision shall be made for the safe performance of extraction test determinations by providing an adequate exhaust fan and suitable means of disposing of used solvent and other waste.
3. If the Owner permits, the plant laboratory may be part of another building in which case it shall be entirely partitioned off from the remainder of such building.
4. Testing equipment shall be furnished as follows and installed in the building for use in testing the materials and mixtures supplied by the Plant for the work:
 - a. One Approved Rotary Extractor.
 - b. One Coarse Aggregate Sieve Shaker, power driven with a minimum clear sieve area of 324 square inches. The shaker shall be attached to a firm anchorage.
 - c. One each of the following square opening screens for coarse aggregate shaker: 2 inch, 1-1/2 inch, 1 inch, 3/4 inch, 1/2 inch, 1/8 inch, No. 4 and No. 8.
 - d. One Fine Aggregate Sieve Shaker, power driven and independent of the coarse aggregate shaker, for eight inch minimum diameter sieves.
 - e. One each of the following standard eight inch minimum diameter square opening sieves: 3/4 inch, 1/2 inch, 3/8 inch, No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200, with pan and cover.
 - f. One Sample Splitter with a minimum capacity of one cubic foot. It shall be the clam shell type and the chute width shall be adjustable from a minimum of 1/2 inch up to 2 inches.
 - g. One Solution Balance, 20 kilogram capacity, weighing directly to 1 gram, with two weighing beams and a taring beam; tare capacity to be 2 kilograms; weighing beams to read 1000 grams by 100 gram divisions and 100 grams by 1 gram division. Additional matching weights (one 1 kg., two 2 kg., one 5 kg., and one 10 kg.) shall be provided to fulfill the capacity of 20 kilograms. The platform to be 11 inches in diameter.
 - h. One Approved Scale with a minimum capacity of 2000 grams and with a sensitivity of 0.50 grams
 - i. Two Approved Dial Type Thermometers, range 50 degrees F. to 500 degrees F.
 - j. One Approved Hot Plate

5. Approval of a plant will be contingent upon approval of the aforementioned requirements for Plant Laboratory, including the building and appurtenances, furnishings, facilities including heat, light, power and water, the testing equipment, and any other incidentals.
- F. Sampling facilities. Adequate and convenient sampling facilities shall be provided to allow the Inspector to obtain representative samples from the full width and depth of the discharge area of each aggregate bin. The sampling tray shall be structurally supported during the sampling operation. Access to the sampling facilities shall be provided requiring no more difficulty than that to climb a ladder leading to a secure platform with railings.
- G. Inspection. The Engineer or his authorized representative shall have access at any time to all parts of the plant for:
 1. Inspections of the conditions and operations of the plant.
 2. Confirmation of the adequacy of the equipment in use.
 3. Verification of the character and proportions of the mixture.
 4. Determination of temperatures being maintained in the preparation of the mixtures.
 5. Inspection of incidental related procedures.
- H. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

3.2 PREPARATION OF MIXTURES

- A. Preparation of Asphalt Cement. Place bituminous materials in the mixer at a temperature between 275 and 375 degrees F., as directed.
- B. Preparation of Mineral Aggregate. Thoroughly dry and heat aggregates before placing them in the mixer. Control the temperature of the aggregates so that the temperature of the complete mixture shall be within the range specified in paragraph C. below.
- C. Preparation of Bituminous Concrete Mixtures (Not SUPERPAVE). Combine the heated and dried aggregates and mineral filler and convey them into the mixer in the proportionate amounts of each size required to meet the job mix formula. After these materials have been mixed for the specified dry-mixing time, add the asphalt cement and mix for the specified wet-mixing time. Measure asphalt cement by weight or by an approved metering device. The temperature of the mixture when discharged shall be between 275 and 325 degrees F.
- D. Preparation of SUPERPAVE HMA Pavement. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

3.3 TRANSPORTATION AND DELIVERY OF MIXTURES.

- A. Vehicles for transportation of mixtures from the plant to the jobsite shall be clean of all foreign materials, tight, and evenly and lightly coated with a suitable thin oil or approved soap solution. No excess of lubricant shall be allowed to accumulate in low spots in the body. When necessary, vehicles shall be insulated so that the mixture is delivered for placement at the proper temperature.

- B. Arrange dispatching of trucks from the plant so that all material which is delivered to the jobsite during any day shall be placed and shall have received final compaction before nightfall of the same day, unless satisfactory artificial light is provided.
- C. Do not transport mixtures such a distance that segregation of the ingredients takes place or that any crust is formed on the top, bottom, or sides of the mixture which will not crumble or flatten out when the mixture is dumped or which might otherwise be deleterious to the mixture in place on the work.
- D. During transportation of the mixture from the plant to the spreader at the jobsite, keep the mixture fully covered at all times with canvas or other suitable material of sufficient size and thickness to furnish complete protection.
- E. Deliver the mixture to the jobsite at a temperature governed by the air temperature in the shade and away from artificial heat, as follows with a tolerance of plus or minus 20 degrees F.:

1. Normal Layered Construction:

Air Temperature	Delivered Mix Temperature
35 degrees F.	300 degrees F.
40 degrees F.	290 degrees F.
65 degrees F.	280 degrees F.
90 degrees F. and Over	275 degrees F.

2. Deep Lift Paving (3 inches and over), Base and Binder Courses only:

Air Temperature	Delivered Mix Temperature
35 degrees F.	280 degrees F.
40 degrees F.	270 degrees F.
65 degrees F. and over	260 degrees F.

3.4 TRANSPORTATION AND DELIVERY OF SUPERPAVE MIXTURES

- A. Transportation of SUPERPAVE HMA Pavement shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

3.5 TRANSPORTATION AND DELIVERY OF MICROSURCAING MIXTURES

- A. Stockpiling: Precautions shall be taken to insure that stockpiles do not become contaminated. The mineral aggregate shall be screened prior to being weighed for job site delivery. This weight shall be done by means of a scale approved by the MBTA.

3.6 PRIME COAT (OR TACK COAT)

- A. Where an existing hardened surface is used as a base for new pavement, or elsewhere where the surface to receive bituminous pavement is, in the MBTA's judgment, unsatisfactory to receive the pavement, give the surface a prime coat of bituminous material of the kind and grade indicated or directed. Where unsatisfactory conditions, requiring application of prime coat, are due to the fault of the Design-Builder, provide the prime coat at no additional expense to the MBTA.
- B. Clean the existing surface of all foreign matter and loose material before applying prime coat. Apply the prime coat by mechanical means at the rate indicated or directed.

3.7 SPREADING AND FINISHING - BITUMINOUS CONCRETE PAVEMENT (NOT SUPERPAVE)

A. General

- 1. Place bituminous concrete in courses as indicated.
- 2. When an existing surface or new base, upon which the bottom course is to be laid, contains unsatisfactory irregularities, in the MBTA's judgment, eliminate such irregularities by placing and compaction of mixture, so as to furnish a surface with true contour and grade before placing any specified bottom course.
- 3. Paint thoroughly the contact surfaces of bridge curbing, manholes, catch basins, and other appurtenant structures in pavement, with a thin coating of bitumen immediately prior to placing any mixture against them.
- 4. Give special attention to proper testing of the surface of each course with a straightedge. Finished surfaces shall be even and uniform throughout.
- 5. Remove and replace with new mixture any mixture which becomes loose or broken, mixed with dirt, or defective in any way. Finish and compact the repaired area to conform to the surrounding area. Remove and replace areas of one square foot or more showing an excess of bitumen.
- 6. No mixture shall be placed unless the breakdown and intermediate rolling can be completed by the time the material has cooled at 175 degrees F., and provided that the density of the pavement attains at least 95 percent of the laboratory compacted density.

B. Spreading and Finishing Equipment

- 1. The equipment for spreading and finishing shall be mechanical, self-powered pavers, capable of spreading and finishing the mixture to line, grade, width, and crown by means of fully automated controls for both longitudinal and transverse slope.
- 2. The pavers shall be equipped with hoppers and distributing screws of the reversing type to place the mixture evenly in front of adjustable screeds. They shall be equipped with a quick and efficient steering device and shall have reverse as well as forward traveling speeds.
- 3. The pavers shall employ mechanical devices such as equalizing runners, straight edge runners, evener arms or other compensating devices to adjust the grade and confine the edges of the

mixture to true lines. They shall be capable of spreading the mixture without segregation in layers to the depths and widths required. They shall be equipped with blending or joint leveling devices for smoothing and adjusting all longitudinal joints between adjacent strips or courses of the same thickness.

4. The screed shall be adjustable for profile and shall have an indicating level attached.
5. An approved device will be required for heating the screed to the temperature required for the laying of the mixtures without pulling or marring.
6. The term "screed" includes any "strike-off" device operated by cutting, crowding, or other practicable action, which is effective on the mixtures at permissible workable temperatures without tearing, shoving, or gouging and which produces a finished surface of the evenness and texture required.
7. The pavers employed on projects requiring in excess of 15,000 tons shall operate by the use of a sensing grid for operation to a stringline and matching shoe for joints.
8. The paver shall be provided with a "ski" which may be employed for paving on the previously laid bituminous concrete base, or binder as directed or permitted by the Owner.
9. The paver employed on deep lift construction shall be capable of satisfactorily feeding the mix without intermittent stopping during the discharge of the mix from the trucks into the paving machine.
10. If during construction, it is found that the spreading and finishing equipment in use leaves tracks or indented areas, or produces other permanent blemishes in the pavement which are not satisfactorily corrected by the scheduled operations, the use of such equipment shall be discontinued and other satisfactory spreading and finishing equipment shall be provided.
11. Complete all compaction rolling before the bituminous concrete temperature drops below 185 degrees Fahrenheit.

C. Machine Spreading

1. Deposit mixtures in the approved mechanical spreader, spread immediately, and strike off in a uniform layer to the full width required and to such depth that each course, when compacted, shall have the required thickness and shall conform to the indicated grade and cross section contour.
2. Deposit mixture in the center of the hoppers, exercising care to avoid overloading and spilling. Operate the pavers, while the mixture is being spread, at a speed which will produce a uniform surface texture.
3. Immediately after each course is screeded and before roller compaction is started, check the surface, adjust any irregularities, remove accumulation from the screed by rake or lute, and remove and replace any unsatisfactory spots in the course. Correct irregularities in line and grade along outside edges by addition or removal of material before the edge is rolled. Indiscriminate casting of mix on the new screeded surface, where irregularities are not evident, will not be permitted.
4. All edges shall be true and uniform.

D. Hand Spreading

1. Spreading by hand methods will be permitted only for particular locations in the work which because of irregularity, inaccessibility or other unavoidable obstacles do not allow mechanical spreading and finishing.
2. When hand spreading is permitted, place the mixture by dumping on approved steel dump sheets outside the area upon which it is to be spread; or by other approved methods. Immediately thereafter, distribute the mixture into place by means of hot shovels, and spread it with hot rakes or lutes in a loose layer of uniform density and correct depth. Tines of the rakes shall be not less than 1/2 inch longer than the loose depth of mixture, and spaces between tines shall be not less than 1 inch.
3. Do not dump loads faster than they can be properly handled by the shovelers, and do not distribute the dumped load faster than it can be properly handled by the rakers. Rake carefully and skillfully to avoid segregation and so that, after the first passage of the roller over the raked mixture, no back patching will be necessary.

3.8 SPREADING AND FINISHING - SUPERPAVE HMA PAVEMENT MIXES

- A. SUPERPAVE HMA Pavement mixes shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

3.9 SPREADING AND FINISHING – MICROSURFACING

A. General

1. If directed by the MBTA the Design-Builder shall pretreat the cracks in the pavement surface with fiber reinforced crack filler by Fiber Reinforced Method prior to the application of microsurfacing.

B. Equipment

1. General

- a. All equipment, tools, and machines used in the performance of this work shall be maintained in satisfactory working condition at all times to ensure a high quality product.

2. Tack Coat

- a. The Design-Builder shall apply a tack coat consisting of one part emulsified asphalt and three parts water with a distributor at .10-.15 gallons per square yard. This emulsified asphalt should be the CSS1H emulsion grade. It is recommended that a tack coat always be applied to a concrete or brick surface.

3. Mixing Equipment

- a. The material shall be mixed by a self-propelled micro-surfacing mixing machine which shall be a continuous flow mixing unit able to accurately deliver and proportion the aggregate, emulsified asphalt, mineral and field control additives, and water to a revolving multi-blade twin shafted mixer and discharge the mixed product on a

continuous flow basis. The machine shall have sufficient storage capacity for aggregate, emulsified asphalt, mineral and field control additives, and water to maintain an adequate supply to the proportioning controls. The machine may be equipped with self-loading devices which provide for the loading of materials while continuing to lay micro-surfacing, thereby minimizing construction joints.

4. Proportioning Devices

- a. Individual volume or weight controls for proportioning each material to be added to the mix, i.e., aggregate, emulsified asphalt, mineral and field control additives, and water shall be provided and properly marked. These proportioning devices are usually revolution counters or similar devices and are used in material calibration and determining the materials output at any time.

5. Emulsion Pump

- a. The emulsion pump shall be a heated positive displacement type.

6. Spreading Equipment

- a. The surfacing mixture shall be spread uniformly by means of a mechanical type spreader box attached to the mixer, equipped with paddles to agitate and spread the materials throughout the box. A front seal shall be provided to insure no loss of the mixture at the road contact point. The rear seal shall act as final strike off and shall be adjustable. The mixture shall be spread to fill cracks and minor surface irregularities and leave a uniform skid resistant application of material on the surface. The spreader box and rear strike off shall be so designed and operated that a uniform consistency is achieved to produce a free flow of material to the rear strike off. The longitudinal joint where two passes join shall be neat appearing, uniform and lapped. All excess material shall be removed from the job site prior to opening the road. The spreader box shall have suitable means provided to side shift the box to compensate for variations in pavement width and longitudinal alignment. A Rut Box shall be available to prefill wheel ruts when necessary prior to overlay to eliminate puddles or runoff interruption. The box shall be readily adjustable from 4' - 6' width with hydraulically adjusted strike off screeds to attain maximum grade and profile.

7. Auxiliary Equipment

- a. Suitable surface cleaning equipment, traffic control equipment, hand tools and any support equipment shall be provided as necessary to perform the work.

C. Machine calibration

1. Each mixing unit to be used in performance of the work shall be calibrated in the presence of the MBTA prior to construction, or previous calibration documentation covering the exact materials to be used may be acceptable provided they were made during that calendar year. The documentation shall include the individual calibration of each material at various settings, which can be related to the machine metering devices.

D. Application

1. General

- a. The surface should be pre-wetted by fogging ahead of the spreader box when required by local conditions. The rate of application of the fog spray shall be adjusted during the day to suit temperatures, surface texture, humidity, and dryness of the pavement surface.
 - b. The micro-surfacing mixture shall be of the desired consistency upon leaving the mixer and no additional materials should be added. A sufficient amount of material shall be carried in all parts of the spreader at all times so that a complete coverage is obtained. Overloading of the spreader shall be avoided. No lumping, balling, or unmixed aggregate shall be permitted.
 - c. No streaks, such as those caused by oversized aggregate, will be left in the finished surface. If excessive oversize develops, the job will be stopped until the Design-Builder proves to the MBTA that the situation has been corrected.
2. Joints
- a. No excessive buildup, uncovered areas or unsightly appearances shall be permitted on longitudinal or transverse joints. The Design-Builder shall provide suitable width spreading equipment to produce a minimum number of longitudinal joints throughout the project. When possible, longitudinal joints shall be placed on lane lines. Half passes and odd widths passes will be used only in minimum amounts. If half passes are used, they shall not be the last pass of any paved areas.
3. Mix Stability
- a. The micro-surfacing mixture shall possess sufficient stability so that premature breaking of the material in the spreader box does not occur. The mixture shall be homogeneous during and following mixing and spreading. It shall be free of excess water or emulsion and free of segregation of the emulsion and aggregate fines from the coarser aggregate.
4. Hand Spreading
- a. Areas which cannot be reached with the mixing machine shall be surfaced using hand squeegees to provide complete and uniform coverage. The area to be handworked shall be lightly dampened prior to mix placement. Care shall be exercised to leave no unsightly appearance from handwork.
 - b. The same type finish as applied by the spreader box shall be required. Handwork shall be completed at the time of the machine applying process.
5. Lines
- a. Care shall be taken to insure straight lines along curbs and shoulders. No runoff on these areas will be permitted. Lines at intersections will be kept straight to provide a good appearance.
6. Rolling
- a. If required by the plans, specified areas shall be rolled by a self-propelled 10 ton pneumatic roller with a tire pressure of 50 PSI and equipped with a water spray system.

E. Weather limitations

1. The material shall be spread only when the road surface and atmospheric temperatures are at least 45 degrees F and rising and the weather is not rainy and there is no forecast of temperatures below 32 degrees F within 48 hours from the time of placement of the mixture.

3.10 COMPACTION - BITUMINOUS CONCRETE PAVEMENT (NOT SUPERPAVE)

A. Compaction Equipment

1. After the paving mixture has been properly spread, initial compaction shall be obtained by the use of power rollers of approved design and weight per inch width of roller. The rollers shall be steel-wheeled supplemented with pneumatic-tired rollers where required, or where permitted, vibratory rollers.
2. Steel wheel rollers for initial and intermediate rolling shall have a weight of not less than 240 pounds per inch width of tread; for top course, minimum weight shall be 285 pounds per inch width of tread.
3. Pneumatic-tired rollers, when conditions warrant, shall be provided with devices capable of varying tire pressures. When the mixture being spread by each paver requires more than the minimum number of steel wheel rollers, at least one of the additional rollers for each paver shall be a pneumatic-tired roller, except where the use of a vibratory roller is permitted. When using a pneumatic-tired roller, care shall be taken that initial rolling by the steel wheel roller be restricted to one pass where upon the pneumatic-tired roller shall immediately follow the initial steel wheel rolling.
4. Vibratory steel drum rollers shall not be used on top course mix or structures. The machine shall have a device registering the number of vibrations per minute and a tachometer shall be provided to the Owner in order to check the operation of the roller.
5. The V.P.M. on base and binder course material shall be a minimum of 1400 V.P.M. and a maximum of 1500 V.P.M., or in accordance with the recommendations of the manufacturer, when approved by the MBTA.
6. The vibratory roller shall be operated with the vibrating drum in the direction of the paver and the vibrating action of the roller shall be completely shut off during change of direction and care exercised to start this action only when the roller is in motion. In order to prevent creeping and aggregate crushing during rolling of layered pavement, care shall be taken not to exceed one pass in the direction of the paver with vibrator in action and one return in a static condition and for deep lift pavements these passes shall not exceed two operations in each direction, except that the number of vibratory passes in either direction may be varied in order to obtain the required density.
7. An oscillatory roller, 10 ton minimum, shall be used for compaction of hot mix asphalt on bridge decks and in locations where heavy vibration is prohibited or undesirable.
8. A smoothing roller of either the pneumatic-tired, oscillatory, or steel wheeled type shall be used immediately behind the last pass of the vibrating roller. The use of a vibratory roller may be suspended by the MBTA if, in his opinion, unsatisfactory results are being obtained and no

further mix shall be spread until a sufficient number of approved rollers are on the project to satisfy the compaction requirements.

9. A plate shall be attached to each roller which shall show the ballasted and unballasted weight per inch width of tread.
10. The number of rollers and passes required shall be governed by the compaction results; however, at least one steel roller shall be provided for each paver employed on the paving operation. This is independent of the requirements of the pneumatic-tired roller.

B. Compaction Procedures

1. Roll the mixture longitudinally, diagonally, and transversely as may be necessary to produce the required contour for surface. Start longitudinal rolling at the side and proceed toward the center of the pavement, except on superelevated curves start at the low side and progress to the high side, overlapping on successive trips by at least 12 inches.
2. Continue the rolling so that all roller marks, ridges, porous spots, and impressions are eliminated and the surface has the required contour and grade. Maintain the motion of the rollers at all times slow enough to avoid any displacement of the hot mixture. Correct any displacement or marring of the surface resulting from reversing the direction of the roller or from any other cause.
3. To prevent adhesion with the mixture, keep the wheels of steel rollers lightly moistened with water. Excess water or oil for this purpose will not be permitted.
4. To prevent "rolloff" of the pavement edges and longitudinal joints on deep lift paving, leave the outer eight inches of the deep lift mixture unrolled until the temperature of the mix ranges between 150 and 180 degrees F., whereupon compact it with a steel roller.
5. Along curbs, structures, and all places not accessible with a roller, compact the surface thoroughly with mechanical tamping devices, smooth and true to established line, grade, and contour.
6. The in place density of each pavement course tested shall be $95\% \pm 2.5\%$ of the maximum theoretical density as determined by AASHTO T 209. The Authority shall conduct confirmatory testing.

3.11 COMPACTION - SUPERPAVE HMA PAVEMENT MIXES

- A. SUPERPAVE HMA Pavement mixes shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

3.12 JOINTS

- A. Place mixture as nearly continuously as possible. Pass the roller over the unprotected end of newly placed mixture only when the placing of the course is to be discontinued for such length of time as will permit the mixture to attain initial stability. In all such cases, including the formation of joints as herein specified, provide for proper bond with the new surface for the full specified depths of the courses.

- B. Maximum length of longitudinal joint shall be such that the temperature of the mixture at the joint shall not be less than 150 degrees F. when the abutting mixture is placed. Joints which fall below 200 degrees F. shall receive an application of hot poured rubberized asphalt prior to the adjacent pass.
- C. Make longitudinal and transverse joints in a careful manner, well bonded and sealed, true to line and grade. Where directed, cut back longitudinal and transverse joints to expose the full depth of the course and, when laying of the course is resumed, paint the exposed edge of the joint with a thin coat of bitumen. Carefully rake the new mixture against the joint, then thoroughly tamp and roll.
- D. In making joints along any adjoining edge such as curb, gutter, or an adjoining pavement, and after the mixture is spread by the paver, place by hand just enough of the hot material to fill any space left open. Set up these joints with the back of a rake at the proper height and level to receive the proper compaction.
- E. Stagger transverse and longitudinal joints in successive courses so that there is a minimum of one foot overlap between longitudinal joints in adjacent courses.
- F. Overlap the rolling of successive widths of courses so as to leave smooth, uniform joints and cross sections.
- G. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements).

3.13 PAVEMENT ON BRIDGES

- A. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) and the Standard Bridge Deck Pavements memorandum dated November 12, 2009.
- B. Engineer, the Design-Builder shall provide temporary markings at no additional cost to the MBTA.

3.14 FIELD QUALITY CONTROL

- A. Test the plane of the finished surfaces of base, binder, and surface courses with a 16-foot straightedge, except use a 10-foot straightedge on vertical courses and on the top course of resurfaced streets which contain manhole covers, valve boxes, and the like.
- B. Carefully apply the straightedge immediately after the first compaction by rolling, and from then on as may be necessary until and after the final compaction of the material in place. Hold the straightedge in successive positions parallel to the road centerline and in contact with the road surface; check the entire area from one side of the pavement to the other.
- C. Correct irregularities which vary 3/8 inch from a true finished surface in base and binder courses, and 1/4 inch in top courses.
- D. Irregularities which may develop before the completion of rolling and while the material is still workable, may be remedied by loosening the surface mixture and removing or adding material as necessary. Should any unsatisfactory irregularities or defects remain after final compaction, correct the defective work by removing and replacing with new material to form a true and even surface.

- E. Micromilled Surface shall meet the requirements of the MassDOT Standard Specification section 415.62.
- F. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements) contained herein.

3.15 PAVEMENT MILLING

- A. The planed surface shall conform to the grades and cross slope required for the required minimum thickness overlay and to revise existing cross slope transitions.
- B. The Design-Builder shall obtain accurate elevations of the existing pavements and compare them with the proposed elevations shown on the drawings to determine the extent and depth of milling required to provide for the minimum 1 ¾ inch overlay and the extent and depth of leveling course required within the proposed pavement overlay areas.
- C. Equipment
 - 1. The machine shall be capable of being operated at speeds from 10 to 40 feet per minute and designed so that the operator can at all times observe the milling operation without leaving his control area. Pneumatic rubber-tire mounted equipment shall be used only for trimming and edging operations.
 - 2. The milling equipment shall have a cutting mandrel with carbide tipped cutting teeth and shall be designed specifically for planing bituminous concrete surfaces to close tolerances. The equipment shall accurately establish cross slope and profile grade controls. A vacuum equipped street sweeper, capable of removing all loose material from the roadway without causing dust to escape into the air, shall follow immediately behind the milling machine.
 - 3. The equipment furnished by the Design-Builder shall be maintained in good repair at all times.
- D. Protection of Utilities
 - 1. Throughout the milling operation, protection shall be provided around existing catch basin inlets, manholes, utility valve boxes, and any similar structures. Any damage to such structures as a result of the milling operation is the Design-Builder's responsibility and shall be repaired at the Design-Builder's expense. To prevent the infiltration of milled material into the storm sewer system the Design-Builder shall take special care to prevent the milled material from falling into the inlet openings or inlet grates. Any milled material that falls into inlet openings or inlet grates shall be removed at the Design-Builder's expense.
 - 2. Pavement areas abutting utility structures and other areas, which cannot be planed by the principal milling machine, shall be excavated with smaller mechanical milling equipment designed for this purpose or by manual methods.
- E. After the milling has been completed, all depressions, potholes and other irregularities shall be filled and any existing manholes or other structures shall be wedged using hot mix asphalt for miscellaneous work.
- F. The pavement shall be swept to remove cuttings at the end of each work period. No pavement cuttings shall remain on the project at the end of each work day, except as approved by the MBTA.

3.16 PAVEMENT MICROMILLING

A. Equipment

1. The milling equipment shall be self-propelled with sufficient power, traction, and stability to remove the existing HMA pavement to the specified depth and cross-slope. The milling machine shall be capable of operating at a minimum speed of 10 feet (3 meters) per minute, designed so that the operator can at all times observe the milling operation without leaving the control area of the machine, and equipped with the following:
 - a. A built in automatic grade control system that can control the longitudinal profile and the transverse cross-slope to produce the specified results.
 - b. Longitudinal controls capable of operating from any longitudinal grade reference, including string line, 30 foot (10 meter) ski minimum, 30 foot (10 meter) mobile string line minimum, or a matching shoe.
 - c. The transverse controls shall have an automatic system for controlling cross-slope at a given rate.
 - d. Cutting heads able to provide a minimum 6 foot (2 meter) cutting width and a 0 to 4 inch (0 to 100 mm) deep cut in one pass. The teeth on the evolving cutting drum must be continually maintained and shall be replaced as warranted to provide a uniform pavement texture.
 - e. An integral pickup and conveying device to immediately remove milled material from the roadway and discharge the millings into a truck, all in one operation.
 - f. All necessary safety devices such as reflectors, headlights, taillights, flashing lights and back up signals so as to operate safely in both day and night.
 - g. A means of effectively limiting the amount of dust escaping from the milling and removal operation in accordance with local, State, and Federal air pollution control laws and regulations.
2. The micromilling machine shall be equipped with a drum specifically designed to provide the surface specified below.
 - a. Control Strip
 1. The Design-Builder shall micromill a control strip. The control strip shall be 500 feet minimum in length with a uniformly textured surface and cross slope, as approved by the MBTA.
 2. The micromilled surface of the control strip shall provide a satisfactory riding surface with a uniform textured appearance. The micromilled surface shall be free from gouges, excessive longitudinal grooves and ridges, oil film, and other imperfections that are a result of defective equipment, non-uniform milling teeth, improper use of equipment, or otherwise poor workmanship. Any unsatisfactory surfaces produced in the control strip shall be corrected by additional micromilling at the Design-Builder's expense and to the satisfaction of the MBTA.
 3. The micromilled pavement surface shall have a transverse pattern of 0.2 – 0.3 inch center to center of each strike area. The Design-Builder shall perform surface texture measurements with a 10 foot (3 meter) straightedge in the transverse direction across the milled surface. The milled surface shall have a texture such that the variation from the edge of the straightedge to the top of ridges between any two ridge contact points shall not exceed 1/8 inch (3 mm). The difference in height from the top of any ridge to the bottom of the groove adjacent to that ridge shall not exceed 1/16" (1.6 mm). Any point in the surface not meeting these

requirements shall be corrected as directed by the MBTA at the Design-Builder's expense.

3. Sweeper Equipment Requirements

- a. The Design-Builder shall provide a sufficient number of mechanical sweepers to ensure that the milled surface is free of millings and debris at the end of each day's milling operations. Each sweeper shall be equipped with a water tank, spray assembly to control dust, a pick-up broom, a dual gutter broom, and a dirt hopper. The sweepers shall be capable of removing millings and loose debris from the textured pavement.

B. Operation

1. The milling operations shall be scheduled to minimize the duration and placement of traffic on the milled surface. The milling operations shall not proceed more than 3 miles ahead of the paving operations. Under no circumstances shall the milled surface be left exposed to traffic for a period exceeding seven days. The Engineer may allow the Design-Builder to adjust the above limitations on milling production when necessary.
2. The Design-Builder shall coordinate milling and paving operations to minimize the exposure of milled surfaces to traffic. The Design-Builder shall ensure that milled surfaces are overlaid in a timely manner to avoid damage to the pavement structure. Any damage to the pavement structure resulting from extended exposure of the milled surface to traffic shall be repaired as directed by the MBTA at the Design-Builder's expense.
3. The existing pavement shall be removed to the average depth shown on the plans, in a manner that will restore the pavement surface to a uniform cross-section and longitudinal profile. The longitudinal profile of the milled surface shall be established using a 30 foot (10 meter) mobile ski, mobile string line, or stationary string line. The cross-slope of the milled surface shall be established by a second sensing device or by an automatic cross-slope control mechanism. The Design-Builder will be responsible for providing all grades necessary to remove the material to the proper line, grade, cross section, superelevation, and transitions shown on the plans or as directed by the MBTA. The requirement for automatic grade or slope controls may be waived by the MBTA in locations warranted by the situation, including intersections and closely confined areas.
4. The Engineer may adjust the average milling depth specified on the plans by $\pm 3/4"$ ($\pm 20\text{mm}$) during each milling pass at no additional payment to minimize delamination of the underlying pavement course or to otherwise provide a more stable surface. If delamination or exposure of concrete occurs when milling a HMA pavement course from an underlying Portland Cement Concrete (PCC) pavement, the Design-Builder shall cease milling operations and consult the MBTA to determine whether to reduce the milling depth or make other adjustments to the operation.

C. Protection of Utilities

1. Throughout the milling operation, protection shall be provided around existing catch basin inlets, manholes, utility valve boxes, and any similar structures. Any damage to such structures as a result of the milling operation is the Design-Builder's responsibility and shall be repaired at the Design-Builder's expense. To prevent the infiltration of milled material into the storm sewer system the Design-Builder shall take special care to prevent the milled material from falling into the inlet openings or inlet grates. Any milled material that falls into inlet openings or inlet grates shall be removed at the Design-Builder's expense.

D. Vertical Faces

1. All permanent limits of the milled area shall be sawcut or otherwise neatly cut by mechanical means to provide a clean and sound vertical face. No vertical faces, transverse or longitudinal, shall be left exposed to traffic. If any vertical face is formed in an area exposed to traffic a temporary paved transition with a maximum 12:1 slope shall be established. If the milling machine is used to temporarily transition the milled pavement surface to the existing pavement surface, the temporary transition shall be constructed at a maximum 12:1 slope.

E. Opening to Traffic

1. Prior to opening a milled area to traffic, the milled surface shall be thoroughly swept with a mechanical sweeper to remove all remaining millings and dust. This operation shall be conducted in a manner so as to minimize the potential for creation of a traffic hazard and to comply with local, State, and Federal air pollution control laws and regulations. Any damage to vehicular traffic as a result of milled material becoming airborne is the responsibility of the Design-Builder and shall be repaired at the Design-Builder's expense. Temporary pavement markings shall be placed in accordance with the provisions of Section 02052 as shown on the plans or directed by the MBTA.

F. Inspection

1. The milled surface shall provide a satisfactory riding surface with a uniform textured appearance. The milled surface shall be free from gouges, excessive longitudinal grooves and ridges, oil film, and other imperfections that are a result of defective equipment, non-uniform milling teeth, improper use of equipment, or otherwise poor workmanship. Any unsatisfactory surfaces produced shall be corrected by remilling at the Design-Builder's expense and to the satisfaction of the MBTA.
2. The Design-Builder shall perform Quality Control inspection of all work items addressed as specified in the table below. Inspection activities during milling of HMA pavement may be performed by qualified Production personnel (e.g. Skilled Laborers, Foremen, Superintendents). However, the Design-Builder's QC personnel shall have overall responsibility for QC inspection. The Design-Builder shall not rely on the results of Department Acceptance inspection for Quality Control purposes. The Engineer shall be provided the opportunity to monitor and witness all QC inspection.
3. The milled surface of each travel lane shall be divided into longitudinal Sublots of 500 feet (150 meters). The Design-Builder shall perform a minimum of one random QC measurement within each Sublot with a 10 foot (3 meter) straightedge in the transverse direction across the milled surface. Additional selective QC measurements within each Sublot will be performed as deemed necessary by the QC personnel. All QC inspection results shall be recorded on NETTCP Inspection Report Forms. The Engineer will also randomly inspect a minimum of 25% of the Sublots. The Design-Builder shall perform surface texture measurements with a 10 foot (3 meter) straightedge in the transverse direction across the milled surface. The milled surface shall have a texture such that the variation from the edge of the straightedge to the top of ridges between any two ridge contact points shall not exceed 1/8 inch (3 mm). The difference in height from the top of any ridge to the bottom of the groove adjacent to that ridge shall not exceed 1/16" (1.6 mm). Any point in the surface not meeting these requirements shall be corrected as directed by the MBTA at the Design-Builder's expense.

4. In isolated areas where surface delamination between existing HMA layers or a surface delamination of HMA on Portland Cement Concrete causes a non-uniform texture to occur, the straightedge surface measurement requirements stated in the preceding paragraph may be waived, subject to the approval of the Owner.
5. Minimum QC Inspection of Milling Operations

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Equipment	As specified in QC Plan	Per QC Plan	Per QC Plan	Per QC Plan
Environmental Conditions	Protection of Inlets & Utilities	Per QC Plan	Existing Surface	Visual Check
	Removal of Millings & Dust	Per QC Plan	Milled Surface	Visual Check
Workmanship	Milling Depth	Per QC Plan	Milled Surface	Check Measurement
	Cross-Slope & Profile	Per QC Plan	Milled Surface	Check Measurement
	Milled Surface Texture	Per QC Plan	Milled Surface	Visual Check
	Milled Surface Roughness	Once per 600 feet (150 meters) per milled lane	Milled Surface per MassDOT Specification 410.67	10 foot (3 meter) standard straightedge
	Sawcut Limit Vertical Face	Per QC Plan	Sawcut Limits	Visual Check

3.17 RAISING AND ADJUSTING CASTINGS

- A. In areas of permanent top course paving, existing municipally-owned catch basin and manhole castings and valve boxes shall be raised to the proper grade required by the MBTA.
- B. Castings owned by private utilities shall be raised by their own forces. The Design-Builder shall be responsible for coordinating this work.

3.18 PAVEMENT MARKINGS

- A. The Design-Builder shall replace all pavement markings removed or covered-over in carrying out the work, and as required by the MBTA, no sooner than 48 hours after completion of the permanent pavement.

3.19 OPENING TO TRAFFIC

- A. No vehicular traffic or loads shall be permitted on the newly completed pavement until adequate stability has been attained, and the material has cooled sufficiently to prevent distortion or loss of fines, and the pavement has achieved a maximum temperature of 140 degrees F.
- B. If the climatic or other conditions warrant it, the period of time before opening to traffic may be extended at the discretion of the MBTA.
- C. All work under SUPERPAVE HMA Pavement items shall conform to the relevant provisions of Section 450 and 455 (00717 Superpave requirements).

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection with the work are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

TABLE 02513 – A

SPECIFICATION REQUIREMENTS FOR PERFORMANCE GRADED ASPHALT BINDERS

TESTS AT PG TEMPERATURE deg. C.	PG 64-22	PG 64-28	PG 52-34
Viscosity, Brookfield 135 degrees C Pa-sec.	3 Max.	3 Max	3 Max
Dynamic Shear, 10 Rad./sec. Kpa	1.00 Min.	1.00 Min.	1.00 Min.
RTFO, % Change	1.0 Max.	1.0 Max.	1.0 Max.
RTFO, Residue Dynamic Shear, KPa	2.20 Min.	2.20 Min.	2.20 Min.
PAV Residue Dynamic Shear, KPa	5,000 Max.	5,000 Max.	5,000 Max.
Creep Stiffness (s), MPa	300 Max.	300 Max.	300 Max.
M Value	0.300 Min.	0.300 Min.	0.300 Min.

TABLE 02513-B

**GRADATION REQUIREMENTS FOR COARSE AGGREGATE
(PERCENT BY WEIGHT)**

Nominal Size of Stone Sieve Size	Stone Sizes					
	2 in.	1-1 /2 in.	1-1 /4 in.	3 /4 in.	1 /2 in.	3 /8 in.
2-1/2"		100				
2"	90-100	100				
1-1/2"		95-100	100			
1-1/4"	25-50		85-100			
1"		35-70		100		
3/4"	0-15	0-25	10-40	90-100		
5/8"					100	
1/2"	0-5		0-8	10-50	85-100	100
3/8"				0-20	15-45	85-100
No. 4				0-5	0-15	20-50
No. 8					0-5	0-15
No.16						0-5

TABLE 02513-C

**SPECIFICATIONS FOR HOT MIX ASPHALT
PERCENT BY WEIGHT PASSING SIEVE DESIGNATION**

Sieve Designation and % Binder Content	HMA Base Course	HMA Base/ Intermed. Course Binder	HMA Intermed. Course Dense Binder	HMA Surface Course Dense Binder	HMA Surface Course Standard Top	HMA Surface Course Modified Top	HMA Dense Mix	HMA Surface Treatment	HMA OGFC
2 inches	100								
1 inch	57 – 87	100	100	100		100			
¾ inch		80 - 100	80 – 100	80 – 100		95 - 100			
5/8 inch					100				
½ inch	40 - 65	55 - 75	65 – 80	65 – 80	95 - 100	79 – 100	100		100
3/8 inch					80 - 100	68 – 88	80 - 100	100	90 –
No. 4	20 - 45	28 - 50	48 – 65	48 – 65	50 - 76	48 – 68	55 - 80	80 - 100	30 – 50
No. 8	15 - 33	20 - 38	37 – 49	37 – 49	37 - 49	33 – 46	48 - 59	64 - 85	5 – 15
No. 16					26 - 40	20 – 40	36 - 49	46 - 68	
No. 30	8 - 17	8 - 22	17 – 30	17 – 30	17 - 29	14 – 30	24 - 38	26 - 50	
No. 50	4 - 12	5 - 15	10 – 22	10 – 22	10 - 21	9 – 21	14 - 27	13 - 31	
No. 100					5 - 16	6 – 16	6 - 18	7 - 17	
No. 200	0 - 4	0 - 5	0 – 6	0 – 6	2 - 7	2 – 6	4 - 8	3 - 8	1 – 3
Binder	4 - 5	4.5 - 5.5	5 – 6	5.1 – 6	5.6 - 7.0	5.1 – 6	7 - 8	7 - 8	6 – 7

Percentages shown in table above for aggregate sizes are stated as proportional percentages of total aggregate for the mix. Unless authorized by the Owner, no Job-Mix Formula will be approved which specifies:

- a. Less than 6% binder for HMA Surface Course – Standard Top.

Less than 5.5% binder for HMA Surface Course – Dense Binder and HMA Surface Course – Modified Top for mixes containing RAP.

TABLE 02513-D

ACTION LIMITS FOR AGGREGATE GRADATIONS AND BINDER CONTENT

SIEVE DESIGNATION/BINDER CONTENT	ACTION LIMIT
Passing No.4 Sieve and Larger Sieve Sizes	JMF Target +/- 7%
Passing No. 8 Sieves	JMF Target +/- 4%
Passing No. 16 to No. 50 Sieves (Inclusive)	JMF Target +/- 4%
Passing No. 100 Sieve	JMF Target +/- 4%
Passing No. 200 Sieve	JMF Target +/- 2%
Binder	JMF Target +/-0.4%

Deviations from the final approved mix design for bitumen content and gradation of aggregates shall be within the action limits for individual measurements as specified in Table 02513-D. The limits still will apply if they fall outside the master grading band in Table 02513-C except as noted on the specific state approved Job Mix Formula or Laboratory Trial Mix Formula.

SECTION 450 AND 455 (00717 SUPERPAVE REQUIREMENTS)

SUPERPAVE REQUIREMENTS

SECTION 450
HOT MIX ASPHALT PAVEMENT

Section 450 - Hot Mix Asphalt Pavement entirely replaces the following Sections and Subsections of the Standard Specifications for Highways and Bridges:

- **Section 420 - Class I Bituminous Concrete Base Course Type I-1**
- **Section 460 - Class I Bituminous Concrete Pavement Type I-1**
- **Subsection M3.01.0 - Asphalt Cement**
- **Subsection M3.11.06 - Bituminous Materials**
- **Subsection M3.11.08 - Inspection**
- **Subsection M3.11.09 - Composition and Compaction Acceptance Tests**

The Design-Builder shall adhere to all of the requirements herein of Section 450, Hot Mix Asphalt Pavement. All QC Inspection Report Forms and Test Report Forms must be submitted to the Department by the Design-Builder at the completion of each Lot. Material produced and placed must conform to the Quality Limits specified in Subsection 450.77. Design-Builder QC data and Department Acceptance data for each Lot falling under HMA Lot Category A (Large Lot) or Category B (Small Lot) will be evaluated using Quality Level Analysis and must meet the minimum Percent Within Limits specified in Subsection 450.77.

NOTE: The Pay Adjustment provisions included in Subsection 450.92 will be applied to items under this contract.

**SECTION 450
HOT MIX ASPHALT PAVEMENT**

DESCRIPTION

450.20 General.

This work shall consist of producing and placing Hot Mix Asphalt (HMA) pavement. HMA mixtures shall be composed of the following: Mineral aggregate, mineral filler (if required), Performance Graded Asphalt Binder (PGAB), and as permitted, reclaimed materials (limited to Reclaimed Asphalt Pavement (RAP), Manufactured Asphalt Shingles (MAS), and Processed Glass Aggregate (PGA)). The HMA pavement shall be constructed as shown on the plans and as directed on the prepared or existing base in accordance with these specifications and in close conformity with the lines, grades, compacted thickness and typical cross section as shown on the plans. Unless specified otherwise, each HMA pavement course placed shall be comprised of one of the mixture types listed in Table 450.1.

Table 450.1 - HMA Pavement Courses & Mixture Types

Pavement Course	Mixture Type	Mixture Designation
Friction Course	<ul style="list-style-type: none"> • Open-Graded Friction Course - Polymer Modified 	OGFC-P
Surface Course	<ul style="list-style-type: none"> • SUPERPAVE Surface Course - 4.75 • SUPERPAVE Surface Course - 9.5 • SUPERPAVE Surface Course - 12.5 • SUPERPAVE Surface Course - 19.0 	SSC - 4.75 SSC - 9.5 SSC - 12.5 SSC - 19.0
Intermediate Course	<ul style="list-style-type: none"> • SUPERPAVE Intermediate Course - 12.5 • SUPERPAVE Intermediate Course - 19.0 	SIC - 12.5 SIC - 19.0
Base Course	<ul style="list-style-type: none"> • SUPERPAVE Base Course - 25.0 • SUPERPAVE Base Course - 37.5 	SBC - 25.0 SBC - 37.5
Leveling Course	<ul style="list-style-type: none"> • SUPERPAVE Leveling Course - 4.75 • SUPERPAVE Leveling Course - 9.5 • SUPERPAVE Leveling Course - 12.5 	SLC - 4.75 SLC - 9.5 SLC - 12.5
Bridge Surface Course	<ul style="list-style-type: none"> • SUPERPAVE Bridge Surface Course - 9.5 • SUPERPAVE Bridge Surface Course - 12.5 	SSC-B - 9.5 SSC-B - 12.5
Bridge Protective Course	<ul style="list-style-type: none"> • SUPERPAVE Bridge Protective Course - 9.5 • SUPERPAVE Bridge Protective Course - 12.5 	SPC-B - 9.5 SPC-B - 12.5

450.30 Quality Assurance.

A. Quality Assurance Responsibilities.

This is a Quality Assurance Specification wherein the Design-Builder is responsible for controlling the quality of materials and workmanship and the Department is responsible for accepting the completed work based on the measured quality. Quality Assurance is simply defined as “making sure the Quality of a product is what it should be”.

The core elements of Quality Assurance include: Design-Builder Quality Control (QC), Department Acceptance, Department Independent Assurance (IA), Dispute Resolution, Qualified Laboratories, and Qualified Personnel. Although Quality Assurance utilizes test results to control production and determine acceptance of the HMA, inspection remains as an important element in controlling the process and accepting the product.

The Design-Builder is responsible for providing an appropriate Quality Control system to ensure that all materials and workmanship meet the required quality levels for each specified Quality Characteristic. The Design-Builder will perform all required Quality Control inspection, sampling, and testing in accordance with these specifications and the Design-Builder’s Quality Control Plan.

The Department will monitor the adequacy of the Design-Builder’s QC activities and will perform Acceptance inspection, sampling, and testing. The Department’s Acceptance information will be utilized in the acceptance determination for each Lot of material produced and placed.

Independent Assurance is the responsibility of the Department’s Central Materials Laboratory. The function of IA testing is to periodically provide an unbiased and independent evaluation of the sampling and testing procedures used in the acceptance decision. Design-Builder QC and Department Acceptance testing procedures and equipment will be evaluated by IA personnel using one or more of the following: observation, calibration checks, split sample comparison, or proficiency samples (homogeneous samples distributed and tested by two or more laboratories). QC and Acceptance testing personnel are evaluated by observation and split samples or proficiency samples.

B. Hot Mix Asphalt Lots & Sublots.

The quality of each HMA pavement course of the same mixture type produced and placed will be inspected, tested, and evaluated on the basis of Lots and Sublots. A Lot is defined as “an isolated quantity of material from a single source which is assumed to be produced or placed by the same controlled process”.

The Lot size and corresponding unit of measure is a function of the individual Quality Characteristic evaluated. Lot sizes for Quality Characteristics subject to Department Acceptance are as shown in Table 450.2.

Changes in the target values, material sources, or JMF for an HMA mixture type will constitute a change in Lot, requiring the establishment of a new Lot. All Lots will be properly identified for accurate evaluation and reporting of HMA quality.

Table 450.2 - HMA Lot Sizes

Quality Characteristic	Lot Size & Unit of Measure
PG Asphalt Binder Grading	Total Tons of HMA from all JMFs using the same PGAB Grade (from same PGAB Supplier), produced by a single plant and placed within same construction season.
PG Asphalt Binder Content	Total quantity of an HMA mixture type with same JMF for same individual pavement course, produced by a single plant using the same source of materials and placed at a uniform plan thickness within the same construction season, not to exceed 18,000 tons. (See Table 450.3).
Volumetrics - Air Voids	
In-place Density	
Thickness	
Ride Quality (IRI)	Total length (miles) of individual wheel paths (in all travel lanes and ramps) of in-place HMA with same JMF for same individual pavement course, produced by a single plant and placed within same construction season, and which is located within the same posted speed limit range as defined in Table 450.19
Wheel Path Deviations	

C. HMA Quality Assurance Requirements.

These Specifications establish three categories under which Hot Mix Asphalt Lots will be produced, placed, evaluated and accepted. Table 450.3 below defines each of the Lot categories and outlines the required Quality Assurance activities of the Design-Builder and the Department. The division of the Lot categories is based on the total estimated contract quantity of each individual HMA mixture type per each project location. For contracts containing multiple Hot Mix Asphalt items, it is possible to have work performed under more than one HMA Lot category.

(1) Determination of Lot Size and Lot Category

When the total contract quantity of an HMA mixture type is < 2,100 tons (1,925 Mg), it shall be classified as a Minor Lot (Category C Lot).

When the total contract quantity of an HMA mixture type is ≥ 2,100 tons (1,925 Mg), but < 7,500 tons (6,875 Mg), it shall be classified as a Small Lot (Category B Lot).

When the total contract quantity of an HMA mixture type is ≥ 7,500 tons (6,875 Mg), but ≤ 15,000 tons (13,750 Mg), it shall be classified as a Large Lot (Category A Lot).

When the total contract quantity of an HMA mixture type is > 15,000 tons (13,750 Mg), each 15,000 tons (13,750 Mg) will represent a Category A Lot. If the quantity remaining after all 15,000 ton (13,750 Mg) Category A Lots is ≤ 3,000 tons (2,750 Mg), it shall be added to the final Lot providing a final Lot quantity not to exceed 18,000 tons (16,500 Mg). If the quantity remaining after all 15,000 ton (13,750 Mg) Category A Lots is > 3,000 tons (2,750 Mg), it shall constitute a separate Category A Lot.

(2) Determination of Sublot Size

Each HMA Lot will be divided into Sublots of uniform size. The size of each HMA Sublot shall be as listed in Table 450.10 and Table 450.17. If the HMA quantity at the end of a Lot is equal to or greater than one half of a full Sublot, then such quantity shall be identified and evaluated as a separate Sublot. If the HMA quantity at the end of a Lot is less than one half of a full Sublot, then such quantity shall be combined with the previous full Sublot quantity and shall be identified and evaluated as the final Sublot.

Table 450.3 - HMA Lot Categories & Quality Assurance Requirements

Quality Assurance Requirements	Category A (Large Lot)	Category B (Small Lot)	Category C (Minor Lot)
Total Quantity for individual Lot of HMA:	$\geq 7,500$ tons (6,875 Mg), but $\leq 15,000$ tons (13,750 Mg) (See Note 1)	$\geq 2,100$ tons (1,925 Mg), but $< 7,500$ tons (6,875 Mg)	< 2100 tons (1,925 Mg)
QC Plan Required:	YES	YES	(See Note 2)
Design-Builder QC Inspection Required:	YES (Subsection 450.64)	YES (Subsection 450.64)	YES (Subsection 450.64)
Design-Builder QC Testing Required:	YES (Subsection 450.65)	YES (Subsection 450.65)	YES (Subsection 450.65)
(a) Control Strip Required:	YES	NO	NO
Control Charts Required:	YES	NO	NO
Quality Level Analysis Required:	YES	YES	NO
MassDOT Acceptance Inspection & Testing Performed:	Minimum 25% of Sublots (Subsection 450.74)	Minimum 50% of Sublots), But Minimum 3 Sublots (Subsection 450.74)	100% of Sublots (Subsection 450.74)
QC Test Results included in MassDOT Acceptance Determination:	YES (If Validated)	YES (If Validated)	NO
Pay Adjustment Applied:	YES (Subsection 450.92)	YES (Subsection 450.92)	NO

Note 1: Category A Lots shall not exceed 18,000 tons (16,500 Mg) as specified in Subsection 450.30C(1)

Note 2: If all HMA Lots fall under Category C then a QC Plan is not required. However, if any Lots on the project fall under Category A or Category B, then any Category C Lots must be addressed in the QC Plan.

MATERIALS

450.40 General.

Materials shall meet the requirements in the following Subsections of Division III, Materials and as otherwise specified herein:

Asphalt Emulsion	M3.03.0
Hot Poured Joint Sealer	M3.05.0
Asphalt Anti-Stripping Additive	M3.10.0
Job-Mix Formula	M3.11.03
Mineral Aggregate	M3.11.04
Mineral Filler	M3.11.05
Plant Requirements	M3.11.07

450.42 Hot Mix Asphalt Mix Design.

The Design-Builder shall be responsible for development of all HMA Laboratory Trial Mix Formulas (LTMF). The aggregate gradation structure and target PG Asphalt Binder content of each LTMF for HMA base courses, HMA intermediate courses, and HMA surface courses shall conform to the Control Points in Section 455. The aggregate gradation structure and target PG Asphalt Binder content for Open-Graded Friction Course (OGFC-P) shall conform to the master ranges in M3.11.03 – Table B.

All LTMFs for HMA pavement courses shall be supported by volumetric mix designs. Volumetric mix designs are not required for OGFC-P.

All HMA LTMF's will be submitted to the Owner with adequate samples of individual ingredients for verification of each proposed mixture. Upon the Owner's laboratory verification of the LTMF for Category A Lots, a Control Strip will be necessary. Once each LTMF for Category B Lots or Category C Lots is laboratory verified and accepted by the Owner, the LTMF will become the approved job mix formula (JMF).

Two or more job-mix formulas per HMA mixture type may be approved for a particular plant, however, only HMA conforming to one job-mix formula is permitted to be produced and placed on any given day.

450.44 Reclaimed Asphalt Pavement (RAP).

Reclaimed Asphalt Pavement (RAP) shall consist of the material obtained from the highways or streets by crushing or milling existing HMA pavements. This material shall be transported to the HMA production facility yard and processed through an appropriate crusher so that the resulting material will contain no particles larger than the maximum aggregate size of the HMA mixture in which it will be used. The material shall be stockpiled on a free draining base, covered and kept separate from the virgin aggregates. The material contained in the RAP stockpiles shall have a reasonably uniform gradation from fine to coarse and shall be protected from accumulation of excessive moisture and shall not be contaminated by foreign materials.

The use of RAP will be permitted at the option of the Design-Builder provided that the end product is in conformance with the approved job-mix formula. The proportion of RAP to virgin aggregate for base course mixtures and intermediate course mixtures shall be limited to a maximum of 40% for drum mix plants and 20% for modified batch plants. The maximum amount of RAP for all surface course mixtures listed in Table 450.1 shall be 15%. No RAP will be allowed in OGFC-P mixtures.

450.46 Manufactured Asphalt Shingles (MAS)

Manufactured Asphalt Shingles (MAS), as defined in M3.11.04, may be used in HMA leveling courses, HMA base courses, and HMA intermediate courses at a maximum rate of 5% by weight only when RAP is not included in the job mix formula. When MAS is used in HMA mixtures containing RAP or other reclaimed materials, the MAS will be considered as part of the overall allowable mass of reclaimed materials in the mixture, as defined in M3.11.06. HMA mixtures containing MAS shall be designed, produced, and placed in accordance with the requirements contained in Section M3.

450.48 Performance Graded Asphalt Binder.

A. Standard Asphalt Binder Grade.

The Asphalt Binder shall be a Performance Graded Asphalt Binder (PGAB) which meets the specification requirements of AASHTO Standard M320. PGAB shall be provided by an Approved Supplier (AS) in accordance with the Approved Supplier Certification (ASC) system outlined in AASHTO R26, "Standard Practice for Certifying Suppliers of Performance Graded Asphalt Binders".

The standard PGAB grade for Massachusetts has been determined based upon the expected minimum and maximum pavement in-service temperature using the *LTPPBind software* with a High Reliability (96-98%). Unless indicated otherwise on the Plans or in the Special Provisions, the standard PGAB Grade of PG64-28 shall be used.

B. Asphalt Binder Modifiers for Reclaimed Materials.

For any HMA containing reclaimed materials, an asphalt binder modifier shall be added to the mixture to restore the asphalt binder properties of the reclaimed materials to a level that is consistent with the specified virgin PGAB. If greater than 25% RAP is used in an HMA mixture, the PGAB modifier grade used shall be in accordance with Table 450.4. The type and amount of asphalt binder modifier to be used shall be included as part of the LTMF. Only Performance Graded Asphalt Binders will be used as modifiers and shall meet the requirements of AASHTO M 320. However, the resulting final PGAB grade shall be in accordance with Table 450.4 (or the specified PGAB grade per the contract).

For HMA Category A Lots and Category B Lots incorporating greater than 25% RAP in the LTMF, the Design-Builder shall perform, as part of the mix design, full binder testing per AASHTO M 320 on samples of asphalt binder recovered from the RAP (by Abson recovery) blended in the appropriate proportion with samples of the virgin PGAB.

For HMA Category A Lots containing greater than 25% RAP, the Design-Builder shall also perform full binder testing (on asphalt binder recovered from the RAP blended with the virgin PGAB) for the Control Strip and for Quality Control during HMA production and placement as specified in Subsection 450.65.

Table 450.4 - PGAB Grades for HMA Mixtures Containing RAP

Amount of RAP in Mixture	PGAB Modifier Grade	Resulting PGAB Grade
\leq 25% RAP by Weight of Mixture	None	64-28
> 25% to 40% RAP by Weight of Mixture	52-34	64-28 \pm 2°C

CONSTRUCTION PROCEDURES

450.50 General.

Prior to the start of any work activity addressed in Subsections 450.53 thru 450.59 below, a Construction Quality Meeting shall be held to review the Design-Builder's Quality Control system. The Design-Builder shall present and discuss with the Owner in sufficient detail the specific Quality Control information and activities contained in each section of their QC Plan as outlined in Subsection 450.61 below. The meeting is intended to ensure that the Design-Builder has an adequate Quality Control system in place and that the Design-Builder's personnel are fully knowledgeable of the roles and activities for which they are responsible to achieve the specified level of quality. Design-Builder personnel required to attend the Construction Quality Meeting include; the Project QC Manager, all other QC personnel (production facility and field operations), all Superintendents, and the Foremen for field operations. The Design-Builder shall provide a copy of the approved QC Plan for each Design-Builder and Department attendee of the meeting.

450.51 Control of Grade and Cross-Section.

The Design-Builder will provide a longitudinal and transverse reference system, with a maximum spacing of 100 ft (30 meters), for the purpose of locating and documenting sampling and testing locations and related uses. It is the Design-Builder's responsibility to clearly mark this reference system in the field. Work related to this reference system is incidental and will be included as part of the Design-Builder's Quality Control system. The Department shall provide information tying in the Design-Builder's reference system to the State Mile Marker System.

The Design-Builder shall furnish, set and maintain all line and grade stakes necessary to guide the automated grade control equipment. Where required these control stakes shall be maintained by the Design-Builder and used throughout the operations, from the grading of the subbase material up to and including the final course of the pavement.

Under normal conditions, where more than one course of HMA is to be constructed, the use of the string line for grade control may be eliminated or discontinued after the construction of the initial course of HMA. For resurfacing projects, where only one course of HMA is to be constructed, the use of the string line for grade control may be eliminated. The use of approved automation may then be substituted for the string line where lines and grades are found to be satisfactory by the Owner.

450.52 Weather Limitations.

HMA shall only be placed on dry, unfrozen surfaces and only when the temperature requirements contained in Table 450.5 below are met.

The Design-Builder may continue HMA placement when overtaken by sudden rain, but only with material which is in transit from the HMA production facility at the time, and then only when the temperature of the HMA mixture is within the temperature limits specified and when the existing surface on the roadway is free of standing moisture.

The construction of HMA pavement shall terminate November 15 and shall not be resumed prior to April 1 except as determined and directed in writing by the Owner depending upon the necessity and emergency of attendant conditions, weather conditions, and location of the project. Only in extreme cases will the placement of surface courses be permitted between November 15 and April 1. Regardless of any temperature requirements, OGFC-P mixtures shall not be placed after October 31 or before May 1 without the written permission of the Owner.

Table 450.5 - Temperature Limitations for HMA Placement

HMA Pavement Course	Lift Thickness Inches (mm)	Minimum Air Temperature °F (°C)	Minimum Surface Temperature °F (°C)
Friction Course	1 (25)	50 (10)	55 (13)
Surface Course	< 1¾ (45)	45 (7)	50 (10)
Surface Course	≥ 1¾ (45)	40 (4)*	45 (7)
Intermediate Course	All	40 (4)*	45 (7)
Base Course	All	40 (4)*	45 (7)
Leveling Course	As Specified	45 (7)	50 (10)

*When the air temperature falls below 50° F (10° C), extra precautions shall be taken in drying the aggregates, controlling the temperatures of the materials, and in placing and compacting the mixtures.

The Design-Builder shall supply the Owner with an approved dial type thermometer with a temperature range of -50° to 500° F (10° to 260° C) and an infrared pistol thermometer for each paving machine in operation on the project. The infrared pistol thermometer shall be Fahrenheit or Celsius selectable and conform to the following requirements:

- Portable and battery operated
- LCD Display to nearest 1° F (1° C)
- Temperature operating range of 0° to 750° F (-18° to 400° C)
- Accuracy of ± 2%
- Repeatability of +/- 5° F (± 3° C)
- Emissivity preset at 0.95

The thermometers will remain the property of the Design-Builder upon completion of the project.

450.53 Preparation of Underlying Surface.

HMA mixtures shall be placed only upon properly prepared surfaces that are clean from foreign materials. The underlying surface shall be prepared in accordance with the requirements below, prior to the placement of HMA pavement courses.

A. Subbase or Reclaimed Base.

Prior to the placement of HMA base course mixtures, the Design-Builder shall inspect the prepared subbase or reclaimed base material to ensure that it is in conformance with the required grade, cross-section, and in-place density. Subbase or reclaimed base material that is not in accordance with the plans or specifications shall be re-worked or replaced to meet the applicable requirements of Sections 401, 402, or 403 before the start of HMA placement. The subbase or reclaimed base shall not be frozen or have standing water when placing HMA.

B. Milling Existing HMA Pavement.

When specified on the plans, existing HMA pavement courses shall be milled and removed from the project by the Design-Builder. Milling shall be performed in conformity with the limits, line, grade, and typical cross-section shown on the plans and in accordance with Section 130, Milling Existing HMA Pavement. All Quality Control activities for milling shall be addressed in the Design-Builder's HMA QC Plan.

C. Patching Existing Pavement Courses.

Areas of existing HMA pavement courses that are significantly distressed or unsound shall be removed and replaced with patches using new Hot Mix Asphalt. The location and limits of patching will be as identified in the plans or as directed by the Owner.

Each existing pavement course determined to be unsound shall be removed to the full depth of the pavement course within a rectangular area. For each patch location equal to or greater than 50 square feet (4.6 square meters) in area (and having a minimum dimension of 4 feet (1.2 meters)) where the existing pavement courses are removed down to subbase, the subbase shall be compacted by mechanical means to not less than 95% of the maximum dry density of the subbase material as determined by AASHTO T 99 method C at optimum moisture content. Each edge of the patch area shall be sawcut or otherwise neatly cut by mechanical means to provide a clean and sound vertical face. The vertical face of each edge shall be thoroughly coated with a hot poured rubberized asphalt sealant meeting the requirements of ASTM D3405 immediately prior to placing the HMA patching mixture.

Delaminated areas of existing pavement courses resulting from pavement milling shall be cut back neatly by mechanical means to the limits of any unsound material. After removing all unsound material, the underlying pavement surface within the patch limits shall receive a thorough tack coat at a rate of application of 1/10 gal/s.y. (0.40 liters/square meter) immediately prior to placing the HMA patching mixture.

HMA patching mixture shall be the same mixture type as the existing pavement course being patched or as specified on the plans or as directed by the Owner. The lift thickness of the patching mixture shall not exceed four times the nominal maximum aggregate size of the mixture. The patching mixture will be placed by hand or by mechanical means and shall match the thickness, grade, and cross-slope of the surrounding pavement. The HMA patching mixture shall be compacted using a steel wheel roller. For patch areas not large enough to permit use of a roller, compaction shall be accomplished using a mechanical tamper capable of achieving the required in-place density. The Design-Builder shall test the in-place density of each patched area using a calibrated density gauge and record the test data for each patched area on NETTCP Test Report Forms. The in-place density of the HMA patching mixture shall be not less than 92% of the maximum theoretical density of the mixture as determined by AASHTO T 209.

D. Leveling Courses.

HMA Leveling Courses shall only be used when specified in the Plans or Special Provisions. The HMA mixture used for a Leveling Course shall be as specified in the Plans or Special Provisions and shall conform to the relevant Materials requirements of Section 450.

E. Preparation of Curbs, Edging, and Utilities.

All curbs or edging shall be installed or reset to the line and grade established on the plans. The surface elevation of all catch basin frames and grates, manholes, utility valve boxes, or other utility structures located in the pavement shall uniformly match the grade and cross-slope of the final pavement riding surface. Adjustment of all curbs, edging, and utilities shall be completed prior to the placement of the HMA surface course. When OGFC-P is specified to be placed over the HMA surface course, all curbs, edging, and utilities shall be adjusted prior to

placement of the surface course mixture. Hand placement of HMA along curbs and edging or around utilities after placement and compaction of the surface course shall not be permitted.

F. Sweeping Underlying Surface.

The Design-Builder shall provide a mechanical sweeper equipped with a water tank, spray assembly to control dust, a pick-up broom, a dual gutter broom, and a dirt hopper. The sweeper shall be capable of removing millings and loose debris from the underlying surface.

All milled pavement surfaces shall be thoroughly swept in accordance with Section 130, prior to opening a milled area to traffic, to remove all remaining millings and dust. All other existing pavement surfaces shall be swept immediately prior to application of the tack coat. Any new HMA pavement course that has been open to traffic, or that was placed 30 days prior to placement of the subsequent pavement course, shall also be swept immediately prior to application of the tack coat.

G. Tack Coat.

A tack coat of asphalt emulsion, grade RS-1 shall be uniformly applied to existing or new pavement surfaces prior to placing pavement courses as specified below. The existing surface shall be swept clean of all foreign matter and loose material using a mechanical sweeper and shall be dry before the tack coat is applied.

(1) Tack Distributor System.

A pressure distributor shall be used to apply the tack coat. The tack distributor system shall be equipped with the following to control and monitor the application:

- (b) System for heating the asphalt emulsion uniformly to specified temperature.
- (c) Thermometer for measuring the asphalt emulsion temperature.
- (d) Adjustable full circulation spray bar.
- (e) Positive controls including tachometer, pressure gauge, and volume measuring device.

(2) Tack Application Requirements.

The tack coat material shall be applied by a pressure distributor. All nozzles on the distributor shall be open and functioning. All nozzles shall be turned at the same angle to the spray bar. Proper nozzle angle shall be as determined by the manufacturer of the distributor spray bar. The spray bar shall be adjusted so that it is at the proper height above the pavement surface to provide a double overlap spray for a uniform coverage of the pavement surface. A double lap application requires that the nozzle spray patterns overlap one another such that every portion of the pavement receives spray from exactly two nozzles.

When an HMA pavement course is placed on an existing tight smooth pavement surface, a tack coat shall be applied at the rate of 1/20 gal/s.y. (0.20 liters/square meter). All existing surfaces subjected to milling shall receive a tack coat at the rate of 1/15 gal/s.y. (0.28 liters/square meter). Tack coat shall be applied to cover approximately 90% of the pavement surface.

Any new HMA pavement course that has been open to traffic, or that was placed 30 days prior to placement of the subsequent pavement course, shall receive a tack coat at an application rate of 1/20 gal/s.y. (0.20 liters/square meter).

When the surface of a new HMA pavement course is in a condition which in the Owner's judgment is unsatisfactory for the direct placement of the subsequent pavement course, a tack coat shall be applied at the applicable rate specified above for the particular pavement surface condition.

In addition to the requirements above, all vertical surfaces of curbs, edging, utilities, and drainage structures shall receive a thorough tack coat application immediately prior to placing each HMA pavement course.

(3) Tack Inspection.

The asphalt emulsion temperature and application rate shall be periodically measured and properly recorded by the Design-Builder on NETTCP Inspection Report Forms. If the temperature or application rate is determined to not be in conformance with the specification requirements above, the Design-Builder shall make appropriate adjustments to the tack application operations.

450.54 Hot Mix Asphalt Transportation and Delivery.

A. Haul Unit Equipment.

The trucks used to transport HMA to the field placement site shall have tight, clean, smooth metal beds. When necessary to maintain the required HMA temperature, trucks shall be equipped with insulated beds. The truck beds shall be evenly and lightly coated with an approved release agent to prevent HMA mixture adherence. Release agents may consist of soapy water or commercial oil emulsions (also known as soluble oils) in the proportions recommended by the manufacturer. Truck beds shall be kept free of kerosene, gasoline, fuel oil, solvents, or other materials that could adversely affect the HMA mixture. Excess lubricant shall not be allowed to accumulate in low spots in the body. The Design-Builder shall employ sufficient procedures and QC inspection to ensure that all truck beds are free of contaminants, residual HMA, or excess release agent.

B. HMA Protection During Transport.

The HMA shall be transported from the plant to the field placement site in trucks previously cleaned of all foreign materials. During transportation of the HMA from the plant to the placement equipment at the site, each load shall be fully covered at all times, without exception, with canvas or other suitable material of sufficient size and thickness, which is tightly secured to furnish complete protection. The HMA shall not be transported such a distance that segregation of the mixture takes place or that a crust is formed on the surface, bottom or sides of the HMA.

C. Coordination and Inspection of HMA Delivery.

The dispatching of trucks from the plant shall be continuously coordinated to ensure that all HMA mixture planned to be delivered to the field placement site may be placed and compacted before the end of the scheduled work day. During paving operations, the Design-Builder shall provide for ongoing two-way radio or cellular phone communication between the field placement site and the HMA plant.

The target temperature and allowable range of the HMA when delivered at the field placement site will be established in the Design-Builder's Quality Control Plan. The Design-Builder shall measure the temperature of the HMA, either from the trucks prior to discharge or from the paver hopper, using a metal stemmed dial type thermometer at the minimum frequency indicated in the approved QC Plan. All QC temperature measurement results of the delivered HMA mixture shall be recorded on NETTCP Inspection Report Forms. The Design-Builder shall also visually inspect the delivered HMA for crusting or material (physical) segregation. The Design-Builder shall reject any loads of HMA with material which is crusted, segregated, or which is not within the delivery temperature range established in the Design-Builder's Quality Control Plan.

450.55 Hot Mix Asphalt Placement.

A. Material Transfer Vehicles

For projects on all controlled access highways with HMA Category A Lots, a Material Transfer Vehicle (MTV) will be required. The MTV shall be used to place each pavement

course, with the exception of leveling courses, on the mainline of the traveled way including all travel lanes, auxiliary lanes, and collector/distributor (C/D) lanes.

(1) MTV Equipment Requirements.

The MTV shall be self-propelled and capable of remixing and transferring the HMA mixture to the paver so that the HMA mat behind the paver has a uniform homogeneous temperature and appearance. The MTV shall be equipped with the following:

- (a) A truck unloading system, capable of 600 tons per hour (550 Mg per hour), which shall receive HMA from the trucks and independently deliver the mixture from the trucks to the paver.
- (b) A paver hopper insert with a minimum capacity of 14 tons (12.7 Mg) shall be installed in the hopper of conventional paving equipment. The paver hopper insert shall be marked to identify the point at which the insert is 50% full.
- (c) An internal storage bin with a minimum capacity of 25 tons (22.7 Mg) of mixture and a remixing system in the bottom of the storage bin to continuously blend the mixture as it discharges to a conveyor system; or a dual pugmill system located in the paver hopper insert with two full length longitudinally mounted counter-rotating screw augers to continuously blend and feed the mixture through the paver to the screed.

(2) MTV Operations.

The Design-Builder shall ensure that the MTV is loaded continuously to keep the paver moving. The volume of HMA in the paver hopper insert shall remain above the 25% capacity mark during all paving operations. In the event the MTV malfunctions during HMA placement operations, the Design-Builder shall continue placement of material until such time there is sufficient HMA placed to maintain traffic in a safe manner. The Design-Builder may continue placement of HMA until any additional mixture in transit has been placed. Paving Operations may resume only after the MTV has been repaired and is fully operational.

(3) Bridge Loading Restrictions.

The MTV shall be subject to all bridge load restrictions. The Design-Builder shall verify the sufficiency of the current bridge ratings with the Owner. In the event that the MTV exceeds the maximum allowable bridge load, the MTV shall be empty when crossing the bridge and shall be moved across without any other Design-Builder vehicles or equipment being on the bridge. The MTV shall be moved across the bridge in a travel lane and shall not be moved across the bridge on the shoulder. The MTV shall be moved at a speed no greater than five miles per hour (8 kph) without any acceleration or deceleration.

B. Pavers.

Each HMA pavement course shall be placed with one or more pavers at the specified grade, cross-slope, and lift thicknesses.

(1) Paver Equipment Requirements.

Each paver shall be a self-contained, power propelled unit and shall produce a finished surface of smooth and uniform texture without segregating, tearing, shoving or gouging the HMA. The pavers shall be equipped with the following:

- (a) A receiving hopper having sufficient capacity to ensure a uniform and continuous placement operation.
- (b) Automatic feed controls, which are properly adjusted to maintain a uniform depth of material ahead of the screed.
- (c) Automatic screed controls with sensors capable of sensing the transverse slope of the screed, and providing the automatic signals that operate the screed to maintain grade and transverse slope.

- (d) An adjustable vibratory screed with full-width screw augers and heated for the full width of the screed.
- (e) Capable of spreading and finishing HMA pavement courses in widths at least 12 inches (300mm) more than the width of one travel lane.
- (f) Capable of being operated at forward speeds to satisfactorily place the HMA.

(2) Paver Operations.

The Design-Builder shall ensure that the paver is loaded continuously to keep the placement operation moving. The volume of HMA in the paver receiving hopper shall remain above the paver tunnel during all paving operations. Proper practices shall be utilized to ensure that HMA is not dumped or spilled onto the prepared underlying surface in front of the paver by trucks unloading into the receiving hopper.

C. HMA Placement Inspection.

The HMA shall be free of identifiable material (physical) segregation or temperature related segregation. The HMA placed shall be a homogeneous mixture that is of uniform temperature. The Design-Builder shall inspect the HMA in the paver receiving hopper for material (physical) segregation. The Design-Builder will also inspect the uncompacted HMA mat behind the paver for longitudinal streaks, end-of-load segregation or other irregularities.

The Design-Builder shall also measure the temperature differential in the uncompacted mat behind the paver. Each HMA pavement course behind the paver shall be divided into longitudinal Sublots of 500 feet (150 meters). The mat temperature differential of the uncompacted HMA shall be measured at a minimum of one location in each Sublot along a straight transverse line behind the paver at a minimum frequency of once per Sublot. The transverse line for mat temperature measurement shall be established at a distance within 10 feet (3 meters) behind the paver screed. Temperature measurements shall be obtained by the Design-Builder using an infrared pistol thermometer at two (2) foot intervals along the transverse line across the width of the mat and recorded on NETTCP Inspection Report Forms. The difference between the highest and lowest temperature measurement shall not exceed 20°F (10°C).

If the maximum mat temperature differential is exceeded, or if material segregation or irregularities in the HMA mat behind the paver are noted, the Design-Builder shall review the production, transportation, and placement operations and take corrective action. The Design-Builder shall make every effort to prevent or correct any irregularities in the HMA, such as changing pavers or using different and additional equipment. The Design-Builder's Quality Control Plan shall fully outline procedures for inspecting the HMA mat during placement, identifying and troubleshooting material segregation or temperature related segregation, and implementing corrective action.

450.56 Hot Mix Asphalt Compaction.

A. Compaction Equipment Requirements.

The Design-Builder shall employ compaction equipment as outlined in the approved Quality Control Plan. Equipment used for compaction of HMA Base Courses, Intermediate Courses and Surface Courses may include steel wheeled rollers, vibratory rollers, oscillation rollers, or pneumatic-tired (rubber tired) rollers as determined appropriate by the Design-Builder for the particular mixture type being placed. The number and type of rollers used for breakdown, intermediate, and finish rolling shall be sufficient to achieve the target in-place density and specified course thickness.

B. Compaction Operations.

The rollers shall not crush the aggregate in the HMA mixture and shall be capable of reversing without shoving or tearing the mixture. The Design-Builder shall outline in the Quality Control Plan the proposed rolling sequence for each HMA pavement course to be placed. For HMA Category A Lots, the initial rolling pattern for each pavement course will be confirmed or adjusted during placement of the Control Strip in accordance with the requirements of Subsection 450.66B. As Lot placement progresses during the construction season, the rolling pattern shall be adjusted as necessary to achieve the specified HMA in-place density.

C. Compaction of Open-Graded Friction Course.

Vibratory rollers, oscillation rollers, or rubber tire rollers will not be permitted on Open Graded Friction Course (OGFC-P) mixtures. Initial rolling of OGFC-P should be accomplished with the breakdown roller within a short distance of the paver. Any subsequent rolling shall be accomplished without over-rolling the mixture. Breakdown and Intermediate Rolling of OGFC-P shall be completed before the material has cooled to 195°F (90°C).

D. Inspection & Testing of Compacted HMA.

The compacted HMA pavement course shall be free of material (physical) segregation and shall meet the requirements for in-place density, thickness, and ride quality specified in Subsection 450.65F. The Design-Builder shall inspect each Sublot of HMA throughout the compaction operation and shall further inspect the in-place HMA after Sublot completion and identify any areas of visible material (physical) segregation. The Design-Builder shall reject any in-place Sublot of HMA which is determined to be segregated through procedures established in the Quality Control Plan. The Design-Builder will also test each Sublot for in-place density, thickness, and ride quality as specified in Subsection 450.65F.

450.57 Hot Mix Asphalt Joints.

The Design-Builder shall plan the sequence of HMA placement to minimize transverse and longitudinal joints in each pavement course. Paving operations should employ long pulls or tandem pavers, whenever practicable, to reduce the number and length of joints.

A. Transverse Joints.

Where the start or end of a new HMA pavement course meets existing HMA pavement, the existing pavement shall be sawcut to form a transverse butt joint for the full depth of all new pavement courses. The sawcut shall follow a straight line and provide a clean and sound vertical face. Material at any intermediate transverse joint resulting from suspension of placement of a new HMA pavement course shall also be sawcut and removed to provide a clean vertical face before continuing placement of the pavement course.

When traffic is to be carried over any transverse joint before completion of an HMA pavement course, the Design-Builder shall provide a temporary tapered joint with a maximum 12:1 slope. The HMA mixture forming the taper shall be placed on heavy wrapping paper or other suitable material to serve as a bond breaker. The temporary tapered joint shall be sawcut to reveal the full depth of the pavement course and form a transverse butt joint with a clean vertical face. The temporary tapered joint material shall be completely removed before resuming placement of the HMA pavement course.

Prior to the start of HMA placement at each transverse joint, the vertical joint face shall be thoroughly coated with a hot poured rubberized asphalt sealant meeting the requirements of ASTM D3405, with a minimum of 15% ground reclaimed tire rubber. The asphalt sealant temperature and application rate for each pavement course shall be established in the

Design-Builder's Quality Control Plan. No reheating of the joint face shall be permitted. Equipment used to apply the hot poured rubberized asphalt sealant shall be capable of maintaining the sealant at the established temperature and application rate sufficient to uniformly coat the vertical joint face without runoff or accumulation of the asphalt sealant.

B. Longitudinal Joints.

All longitudinal joints in HMA surface courses shall be located on the roadway centerline or on a lane line or edge line of the traveled way. The longitudinal joints in each pavement course below the surface course shall be successively offset from the joint in the surface course by no more than 12 inches (300 mm) and no less than six inches (150 mm).

(1) Vertical Joints.

When an HMA pavement course is placed using single paver pulls, the Design-Builder shall employ suitable equipment to confine the longitudinal edge of the HMA mixture to establish an edge that is near vertical. For all HMA surface course mixtures placed, when the Design-Builder's placement operations do not provide a confined and near vertical edge, the longitudinal edge of the surface course shall be sawcut full depth and removed to provide a clean vertical face before placement of the adjacent course of HMA.

All longitudinal joint edges of HMA surface courses, regardless of whether the joint edge is required to be sawcut, shall be treated prior to placing the adjacent pull of HMA. The vertical joint shall be coated with a hot poured rubberized asphalt sealant meeting the requirements of ASTM D3405, with a minimum of 15% ground reclaimed tire rubber. The asphalt sealant shall be applied at a sufficient temperature and application rate sufficient to uniformly coat the vertical joint face without runoff or accumulation of the sealant. The asphalt sealant temperature and application rate shall be established in the Design-Builder's Quality Control Plan. No reheating of the joint shall be permitted.

When placing an HMA surface course with pavers in tandem, the use of the hot poured rubberized asphalt sealant will be omitted, provided the temperature of the mixture at the longitudinal joint does not fall below 200°F (95°C) prior to the placement of the adjacent mat.

When the longitudinal edge of any HMA pavement course is placed against an adjoining edge such as existing pavement, curb, gutter, drainage or utility structure, or any metal surface, a tack coat shall be uniformly applied to the entire vertical joint surface in accordance with Subsection 450.53 prior to placement of the HMA.

(2) Wedge Joints.

The Design-Builder may use a longitudinal wedge joint when placing HMA pavement courses at a thickness of 1.75 inches (45 mm) or greater.

When a wedge joint is proposed for use, the joint detail shall be included in the Design-Builder's QC Plan. The wedge joint shall include a notched vertical edge with a minimum depth of 0.5 inches (12.5 mm). The sloped surface of the wedge joint shall not exceed a 6:1 slope. The Design-Builder shall use a commercially manufactured wedge joint attachment to the paver, or other attachment approved by the Owner, to form the wedge joint.

Hot poured rubberized asphalt sealant shall not be applied to wedge joints. A tack coat shall be applied to the entire surface of the wedge joint in accordance with Subsection 450.53 prior to placement of the adjacent pull of HMA.

C. Inspection & Testing of HMA Joints.

The hot poured rubberized asphalt sealant temperature and application rate shall be measured and properly recorded by the Design-Builder on NETTCP Inspection Report Forms a minimum of once per transverse joint and once per 1,000 feet (300 meters) of longitudinal joint. If the temperature or application rate is determined to not be in conformance with the

requirements established in the Design-Builder's Quality Control Plan, the Design-Builder shall make appropriate adjustments to the asphalt sealant application operations.

The placement and compaction of HMA at each transverse joint or longitudinal joint shall provide a tight bond between the existing pavement and the new pavement course. The Design-Builder shall visually inspect each transverse joint and longitudinal joint throughout the placement and compaction operations and shall further inspect the joints after Sublot completion and identify any bumps, depressions, openings, or other visible defects. The Design-Builder shall reject any in-place Sublot of HMA which is determined to have defective joints through procedures established in the Quality Control Plan.

Finished joint surfaces shall be smooth and true to the required grade and cross-slope without deviations exceeding 0.25 inches (6 mm), both transversely and parallel to the joint, when measured with a 10 foot (3 meter) standard straightedge. The in-place density of the completed HMA pavement course, within 1 foot (300 mm) of either side of the finished joint, shall be not less than 90% of the maximum theoretical density of the mixture as determined by AASHTO T 209. The Design-Builder will measure the surface smoothness and test the in-place density of each transverse joint and longitudinal joint of each Sublot of HMA as specified in Subsection 450.65F. All joint inspection and testing data shall be recorded on NETTCP Inspection Report Forms and Test Report Forms.

450.58 HMA Pavement on Bridges.

A. Bridge Course Mixture Requirements.

HMA pavement courses for bridge decks shall consist of a bridge protective course, placed first, followed by a bridge surface course. Unless specified otherwise on the plans, the bridge protective course mixture shall consist of Dense Binder treated with an approved anti-stripping compound as specified under M3.10.0.

The bridge protective course and bridge surface course shall be placed only after all curbing and edging, when included in the work, are in place. The bridge protective course shall be placed within 24 hours after the membrane waterproofing has been placed, unless an exception is granted by the Owner. No vehicular traffic shall be permitted over any bare membrane waterproofing except as provided for under Subsection 965.62. Equipment used for placement and compaction of the bridge protective course and bridge surface course shall be sufficient to place the HMA mixture at the required grade, cross-slope, thickness, and in-place density without damaging the underlying membrane waterproofing.

B. Inspection & Testing of Bridge Course Mixtures.

The Design-Builder shall inspect and test each Sublot of bridge protective course HMA mixture and bridge surface course HMA mixture in accordance with the requirements for mixture temperature, mat temperature, segregation, and joint quality as specified in Subsections 450.54 through 450.57. QC sampling and testing of each Sublot shall be performed for all HMA loose mix Quality Characteristics specified in Subsection 450.65F. The in-place density of the bridge protective course and bridge surface course shall be randomly tested using a calibrated density gauge and the test data recorded on NETTCP Test Report Forms. The in-place density of the bridge protective course and bridge surface course shall be not less than 90% of the maximum theoretical density of the mixture as determined by AASHTO T 209 and tested per AASHTO TP-68 or ASTM D2950. Cores shall only be allowed for Dispute Resolution. When the HMA bridge surface course is placed in conjunction with mainline pavement, QC testing for ride quality shall be performed as specified in Subsection 450.65F(11).

450.59 Opening to Traffic.

No vehicular traffic or loads shall be permitted on the newly completed HMA pavement until adequate stability has been attained and the material has cooled sufficiently to a temperature of 140° F (60° C) or less as indicated by a surface type thermometer. The Design-Builder shall clearly outline, in the Quality Control Plan, the specific criteria related to opening new pavement to traffic.

HMA cores shall be obtained by the Design-Builder for all Sublots placed each day in accordance with the approved Quality Control Plan prior to opening to traffic. At the discretion of the Owner, based on climactic or other conditions, obtaining of cores may be delayed for a period up to, but not to exceed, 48 hours. In the event of force majeure resulting from direction by Traffic Police or the Owner, the Design-Builder shall document the event and may submit a claim in accordance with current Department procedures. In such event, the affected Sublots will be isolated from the relevant HMA Lot and the HMA quality will be evaluated as a separate Lot.

DESIGN-BUILDER QUALITY CONTROL

450.60 General.

The Design-Builder shall provide a Quality Control (QC) system, as outlined in their Quality Control Plan, adequate to ensure that all materials and workmanship meet the required quality levels for each specified Quality Characteristic. The Design-Builder shall provide qualified QC personnel and QC laboratory facilities and perform Quality Control inspection, sampling, testing, data analysis, corrective action (when necessary), and documentation as outlined further below.

450.61 Design-Builder Quality Control Plan.

For projects with HMA Category A Lots (Large Lot) or Category B Lots (Small Lot), the Design-Builder shall provide and maintain a detailed Quality Control Plan, hereinafter referred to as the "QC Plan". If all HMA Lots fall under Lot Category C (Minor Lot) then a QC Plan is not required. However, if any Lots on the project fall under Lot Category A or Category B, then any Category C Lots must be addressed in the QC Plan. The QC Plan should sufficiently document the QC processes of all Design-Builder parties (i.e. Prime Design-Builder, SubDesign-Builders, Producers) performing work required under Section 450. The QC Plan is not intended to be a generic document, but rather must be project specific.

A. QC Plan Submittal Requirements.

At the pre-construction conference, the Design-Builder shall be prepared to discuss the Quality Control Plan. Information to be discussed shall include the proposed QC Plan submittal date, QC organization, and sources of materials. The Design-Builder shall submit one (1) hard copy and one (1) electronic copy of the QC Plan to the Owner for approval not less than forty-five (45) days prior to the start of any work activities related to HMA pavement construction (including preparation of underlying surface) addressed in Subsections 450.53 thru 450.59. The Design-Builder shall not start work on the subject work items without an approved QC Plan.

B. QC Plan Format and Contents.

The QC Plan shall be structured to follow the format and section headings outlined below, and as outlined in further detail in the New England Transportation Technician Certification Program (NETTCP) "Model QC Plan" for HMA. In the event of discrepancies between the section headings below and the NETTCP Model QC Plan, the current version of the Model QC Plan shall take precedence. The pages of the QC Plan shall be sequentially numbered. The QC Plan shall address, in sufficient detail, the specific information requested under each section and subsection contained in the NETTCP Model QC Plan.

C. QC Plan Approval and Modifications.

Approval of the QC Plan will be based on the inclusion of the required information. Revisions to the QC Plan may be required prior to approval for any part of the QC Plan that is determined by the Department to be insufficient. Approval of the QC Plan does not imply any warranty by the Owner that the QC Plan will result in completed work that complies with the specifications. It remains the responsibility of the Design-Builder to demonstrate such compliance. The Design-Builder may modify the QC Plan as work progresses when circumstances necessitate changes in Quality Control personnel, laboratories, or procedures. In such case, the Design-Builder shall submit an amended QC Plan to the Department for approval a minimum of three calendar days prior to the proposed changes being implemented.

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450.62 Quality Control Personnel Requirements.

The Design-Builder's Quality Control organization shall, at a minimum, consist of the personnel outlined below that meet the described minimum qualifications. Every effort should be made to maintain consistency in the Quality Control organization, however substitution of qualified personnel shall be allowed. When circumstances necessitate substitution of QC personnel not originally listed in the approved QC Plan, the Design-Builder shall submit an amended QC Plan for approval in accordance with Subsection 450.61C.

A. Quality Control Manager.

The Design-Builder's Quality Control system and QC Plan shall be administered by a qualified project assigned Quality Control Manager (QC Manager). The QC Manager must be a full-time employee of the Design-Builder or a Quality Control consultant engaged by the Design-Builder. The QC Manager shall have full authority to institute any and all actions necessary for the successful implementation of the QC Plan. The QC Manager (or their assistant in the QC Manager's absence) shall be available to communicate with the Owner at all times.

Principal responsibilities of the QC Manager shall include preparation and submittal of the Design-Builder's QC Plan, managing the activities of all QC personnel, communicating on quality issues within the Design-Builder's organization, and ensuring that all requirements outlined in the approved QC Plan are met.

For all projects with HMA Category A Lots (Large Lot), the QC Manager shall be certified by the NETTCP as a Quality Assurance Technologist. For projects having only HMA Category B Lots or Category C Lots, the Design-Builder may submit alternate qualifications for the QC Manager acceptable to the Department.

B. Production Facility Quality Control Technician(s).

All Design-Builder Quality control sampling, testing, and inspection conducted at the HMA production facility shall be performed by qualified Production Facility Quality Control Technicians (Plant QCTs). The Design-Builder shall provide a sufficient number of Plant QCTs to adequately implement the minimum Quality Control requirements contained in Section 450 and as outlined in the approved QC Plan. A minimum of one (1) qualified Plant QCT shall be present at each production facility location. HMA will not be accepted by the Department unless the Plant QCT is physically present at the plant during production and correctly performs the required Quality Control inspection, testing and documentation.

All Plant QCTs shall be certified as a HMA Plant Technician by the NETTCP.

C. Laboratory Quality Control Technician(s).

Any QC testing that is performed at off site laboratories (i.e. other than at the production facility or field site) shall be performed by qualified Laboratory Quality Control Technicians (Laboratory QCTs). The Design-Builder shall provide a sufficient number of Laboratory QCTs to adequately implement the minimum Quality Control requirements contained in Section 450 and as outlined in the approved QC Plan.

All Laboratory QCTs shall be certified as a HMA Plant Technician by the NETTCP.

D. Field Quality Control Technician(s).

All Design-Builder Quality Control sampling, testing, and inspection conducted at the HMA field placement site shall be performed by qualified Field Quality Control Technicians (Field QCTs). The Design-Builder shall provide a sufficient number of Field QCTs to adequately implement the minimum Quality Control requirements contained in Section 450 and as outlined in the approved QC Plan. A minimum of one (1) qualified Field QCT will be present at each field placement site. HMA will not be accepted by the Department unless the Field QCTs is physically

present at the site during pre-placement and placement operations and correctly performs the required Quality Control inspection, testing and documentation.

All Field QCTs shall be certified as a HMA Paving Inspector as certified by the NETTCP.

450.63 Quality Control Laboratory Facility Requirements.

All Design-Builder Quality Control testing shall be performed in laboratories qualified through the NETTCP Laboratory Certification Program (LCP) or accredited through the AASHTO Accreditation Program (AAP). Laboratory facilities shall be kept clean and all equipment shall be maintained in proper working condition. The QC Manager shall have overall responsibility for ensuring that all laboratories utilized for Quality Control are in compliance with the requirements of the NETTCP LCP. This includes providing required AASHTO, ASTM, and NETTCP reference documents and ensuring that all required equipment and tools are properly functioning and calibrated.

The Engineer shall be permitted unrestricted access to inspect and review the Design-Builder's laboratory facility. The Engineer will advise the Design-Builder in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. Deficiencies shall be grounds for the Owner to order an immediate stop to incorporating materials into the work until deficiencies are corrected. The Engineer shall be provided with laboratory space and the availability of laboratory testing equipment to conduct Acceptance testing at the HMA plant.

450.64 Quality Control Inspection.

The Design-Builder shall perform Quality Control inspection of all work items addressed under Section 450. Inspection activities during HMA production and placement may be performed by qualified Production personnel (e.g. Skilled Laborers, Foremen, and Superintendents). However, the Design-Builder's QC personnel shall have overall responsibility for QC inspection. The Design-Builder shall not rely on the results of Department Acceptance inspection for Quality Control purposes. The Engineer shall be provided the opportunity to monitor and witness all QC inspection.

Quality Control inspection activities must address the following four primary components:

- Equipment
- Materials
- Environmental Conditions
- Workmanship

The minimum frequency of Quality Control inspection activity shall be in accordance with the requirements below and as outlined in the approved QC Plan. The results and findings of QC inspection shall be documented on NETTCP Inspection Report Forms (IRFs).

A. QC Inspection for Preparation of Underlying Surface.

The Design-Builder’s personnel will perform Quality Control inspection during preparation of the underlying surface in accordance with the requirements of Subsection 450.53. The minimum items to be inspected shall be as outlined in Table 450.6 and Table 450.7. The Design-Builder shall identify in the QC Plan the specific inspection activities necessary to ensure the quality of the work, including any additional inspection activities not specifically listed in Table 450.6 and Table 450.7.

Table 450.6 - Minimum QC Inspection of HMA Patching Operations

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Equipment	As specified in QC Plan	Per QC Plan	Per QC Plan	Per QC Plan
Materials	Aggregates & PG Binder (Correct Type)	Per QC Plan	HMA Production Facility	Visual Check + Manufacturer COC
	Rubberized Asphalt Sealant (Correct Type)	Per QC Plan	Per QC Plan	Check Manufacturer COC
	Temperature of HMA Mix	4 per Day ⁽¹⁾	From Haul Vehicle at Patching Site	Check Measurement
Environmental Conditions	Underlying Surface Soundness & Moisture	Per QC Plan	Underlying Surface	Visual Check
	Temperature of Air & Underlying Surface	1 per Day ⁽²⁾	At Patching Site	Check Measurement
Workmanship	Sawcut Limit Vertical Face	Per QC Plan	Sawcut Limits	Visual Check
	Rubberized Asphalt Sealant Application Rate	Per QC Plan	Sawcut Limits	Check Measurement
	HMA Lift Thickness	Per QC Plan	HMA Lift	Check Measurement
	Cross-Slope & Profile	Per QC Plan	Compacted HMA	Check Measurement

- (1) The initial temperature measurements will be taken from haul vehicles on the first or second load.
- (2) As a minimum, the temperature measurements of the air and underlying surface shall be obtained prior to starting the HMA patching placement.

Table 450.7 - Minimum QC Inspection of Tack Coat Operations

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Equipment	As specified in QC Plan	Per QC Plan	Per QC Plan	Per QC Plan
Materials	Asphalt Emulsion (Correct Type)	Per QC Plan	Per QC Plan	Check Manufacturer COC
	Asphalt Emulsion Temperature	(See Note 1)	From Tack Distributor System	Check Measurement
Environmental Conditions	Underlying Surface Cleanliness & Moisture	Per QC Plan	Underlying Surface	Visual Check
	Temperature of Air & Underlying Surface	1 per Day ⁽²⁾	At Paving Site	Check Measurement
Workmanship	Asphalt Emulsion Application Rate	(See Note 1)	From Tack Distributor System	Check Measurement

- (1) The Asphalt Emulsion Temperature and Application Rate shall be checked as follows:
- After application of the first 1,000 lane-feet (300 lane-meters) per HMA pavement course.
 - After application of the next 1,500 lane-feet (450 lane-meters) per HMA pavement course.
 - After application of the next 2,500 lane-feet (750 lane-meters) per HMA pavement course.
 - Thereafter, a minimum of once per 5,000 lane-feet (1500 lane-meters) each day.
- (2) As a minimum, the temperature measurements of the air and underlying surface shall be obtained prior to starting the tack coat placement.

B. QC Inspection for Production & Placement of HMA Lots.

The Design-Builder’s QC personnel will perform Quality Control inspection at both the HMA production facility and at the site of HMA field placement to ensure that the production and placement processes are providing work conforming to the contract requirements. The minimum items to be inspected for each HMA Lot shall be in accordance with the requirements of Subsection 450.54 thru Subsection 450.59 and as outlined in Table 450.8a and Table 450.8b. The Design-Builder shall identify in the QC Plan the specific inspection activities necessary to ensure the quality of the work, including any additional inspection activities not specifically listed in Table 450.8a and Table 450.8b.

(1) Wheel Path Deviations.

A wheel path is defined as 3 feet (1 meter) from and parallel to each longitudinal edge of a travel lane. Each wheel path for all HMA pavement course Lots shall be inspected for Wheel Path Deviations (high points or low points). Inspection shall be performed using a 10-foot (3 meter) standard straightedge in the longitudinal direction on each wheel path. The Sublot size and minimum frequency of QC inspection for Wheel Path Deviations shall be as specified in Table 450.8b, and in the approved Design-Builder Quality Control Plan. Each random inspection location shall be established by determining a randomly selected distance along the wheel path in accordance with ASTM D3665. Additional selective QC inspection for Wheel Path Deviations within each Sublot of compacted HMA pavement courses shall be as determined necessary by the Field QCT and as specified in the Design-Builder’s approved QC Plan.

The variation from the edge of the 10-foot (3 meter) straightedge to the top of the wheel path surface between any two contact points in the wheel path shall not exceed 0.25 inches (6 mm). The Design-Builder shall correct any location in a pavement course wheel path not meeting

this requirement. The corrective method(s) proposed by the Design-Builder shall be subject to the approval of the Department and shall be performed at the Design-Builder's expense. The Design-Builder shall re-inspect any Sublots where corrections are made and provide the Department with a copy of the inspection data for the corrected Sublots.

Table 450.8a - Minimum QC Inspection at HMA Production Facility

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Equipment	As specified in QC Plan	Per QC Plan	Per QC Plan	Per QC Plan
Materials	PG Binder (Correct Type)	Per QC Plan	HMA Production Facility	Visual Check + Manufacturer COC
	Aggregates (Correct Type)	Per QC Plan	HMA Production Facility	Visual Check
	RAP	Per QC Plan	HMA Production Facility	Visual Check
	MAS	Per QC Plan	HMA Production Facility	Visual Check + Manufacturer COC
	Release Agent	Per QC Plan	Haul Vehicle Bed at Plant	Check QPL + Visual Check + Manufacturer COC
	Temperature of HMA Mix at Plant	4 per Day ⁽¹⁾	From Haul Vehicle at Plant	Check Measurement
Environmental Conditions	Stockpile Moisture	Per QC Plan	HMA Production Facility	Visual Check
	Air Temperature & Precipitation Forecast	1 per Day ⁽²⁾	HMA Production Facility	Check Measurement
Workmanship	Uncoated Mixture	Per QC Plan	HMA Production Facility	Visual Check
	Excess Blue Smoke or Moisture	Per QC Plan	HMA Production Facility	Visual Check
	Burnt Mix	Per QC Plan	HMA Production Facility	Visual Check
	Physical Segregation	Per QC Plan	HMA Production Facility	Visual Check

(1) The initial temperature measurements shall be taken from the first or second load.

(2) As a minimum, the air temperature measurements and precipitation forecast shall be obtained prior to starting the HMA Plant operation.

Table 450.8b - Minimum QC Inspection at HMA Placement Location

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Equipment	As specified in QC Plan	Per QC Plan	Per QC Plan	Per QC Plan
Materials	Rubberized Asphalt Sealant (Correct Type)	Per QC Plan	Per QC Plan	Check Manufacturer COC
	Temperature of Delivered HMA Mix	4 per Day ⁽¹⁾	From Haul Vehicle or Paver Hopper	Check Measurement
Environmental Conditions	Underlying Surface Soundness & Moisture	Per QC Plan	Underlying Surface	Visual Check
	Temperature of Air & Underlying Surface	1 per Day ⁽²⁾	At Paving Site	Check Measurement
Workmanship	Joint Location & Alignment	Per QC Plan	Per QC Plan	Visual Check
	Sawcut Joint Vertical Face	Per QC Plan	Joint Vertical Face	Visual Check
	Rubberized Asphalt Sealant Application Rate	Once per 1,000 ft (300 meters) per joint	Joint Vertical Face	Check Measurement
	Temperature Differential in HMA Mat	Once per 500 feet (150 meters) per pavement course	HMA Mat Behind Paver	Per Subsection 450.55C
	Physical Segregation	Per QC Plan	HMA Mat Behind Paver & Compacted HMA	Visual Check
	HMA Lift Thickness	Per QC Plan	HMA Lift	Check Measurement
	Cross-Slope	Per QC Plan	Compacted HMA	Check Measurement
	Joint Tightness	Per QC Plan	Compacted HMA	Visual Check
	Joint Surface Deviations	Once per 500 feet (150 meters) per joint	At Finished Joint	10 foot (3 meter) standard straightedge
	Wheel Path Deviations	Once per 2,000 ft (600 meters) per Wheel Path	Wheel Path	10 foot (3 meter) standard straightedge

(1) The initial temperature measurements will be taken from the first or second load.

(2) As a minimum, the temperature measurements of the air and underlying surface shall be obtained prior to starting the HMA placement.

450.65 Quality Control Sampling and Testing Requirements.

The Design-Builder's QC personnel will perform Quality Control sampling and testing at both the HMA production facility and at the site of HMA field placement to ensure that the production and placement processes are providing work conforming to the contract requirements. The Engineer will not sample or test for Quality Control or assist in controlling the Design-Builder's operations. All QC sampling and testing shall be in accordance with the AASHTO, ASTM, NETTCP, or Department procedures specified in Table 450.9 and Table 450.10. The Design-Builder shall furnish approved containers for all material samples. The Engineer shall be provided the opportunity to monitor and witness all QC sampling and testing.

A. Random Sampling.

The Design-Builder's Quality Control system shall utilize stratified random sampling of each Lot produced and placed to assure that all material within the Lot has an equal probability of being selected for testing.. The Design-Builder's qualified QC personnel shall obtain random QC samples at the minimum frequencies specified in Table 450.9 and Table 450.10. In all cases, application of the specified QC sampling frequencies shall result in a minimum one random sample per Sublot.

Random sample locations shall be determined using the random number tables and procedures contained in ASTM D 3665 or an electronic random number generator, as presented by the NETTCP. The determination of all random sample locations shall be documented on NETTCP Standard Test Report Form D3665. The Design-Builder will provide the Owner with the random QC sampling locations selected and documented for each Sublot prior to production and placement of the relevant Sublots.

B. Selective Sampling.

The Design-Builder's Quality Control system will also utilize selective sampling (i.e. non-random samples) as needed to provide supplemental information to assist in maintaining all production and placement processes in control. The Design-Builder's qualified QC personnel shall obtain selective QC samples from any Sublot as determined necessary and in accordance with the guidelines established in the approved QC Plan.

C. QC Sample Identification System.

The Design-Builder shall establish a reliable system for the identification of all QC samples obtained. All PG Asphalt Binder samples, HMA loose mixture samples, and core samples shall be correctly labeled with the following minimum information:

- (a) Contract No.
- (b) Date of Sample.
- (c) Mixture Type.
- (d) Lot & Sublot No.
- (e) Sample No.
- (f) Sample Type (i.e. Random or Selective).
- (g) Sample Location (e.g. Station & Offset).

All QC sampling data for Ride Quality and Wheel Path Deviations will be identified by the Design-Builder as directed by the Owner. The Design-Builder's system and procedures for identification of QC samples shall be outlined in the approved QC Plan.

D. Retention of Split Samples.

The Design-Builder’s qualified QC personnel shall obtain all material samples (PGAB samples, HMA loose mix samples, and cores) for QC testing. The Design-Builder will retain split samples from each PGAB sample and HMA loose mix sample and provide a split sample to the Owner if requested. The Design-Builder shall retain the original core samples after testing to serve as “split samples” and protect them from damage. All split samples shall be properly labeled and stored for a period of (30) days, or until tested. These split samples (PGAB samples, HMA loose mix samples, and cores) will be utilized if necessary, in the Dispute Resolution process. If mutually agreed upon by the Design-Builder and the Department, the retained split samples may be discarded prior to the required thirty (30) days.

E. Quality Control Testing of Prepared Underlying Surface.

The Design-Builder’s QC personnel will perform Quality Control testing during preparation of the underlying surface. All QC testing shall be in accordance with the AASHTO, ASTM, NETTCP, or Department procedures specified in Table 450.9. The Engineer shall be provided the opportunity to monitor and witness all QC testing.

Table 450.9 - Minimum QC Sampling & Testing of Prepared Underlying Surface

Quality Characteristic	Test Method(s)	Sublot Size	Minimum Test Frequency	Point of Sampling	Sampling Method
HMA Patching Mixture: PG Asphalt Binder Content	AASHTO T164 or AASHTO T308	150 tons (140 Mg)	1 per Sublot	From Haul Vehicle at Plant	Random AASHTO T168
HMA Patching Mixture: Combined Agg. Gradation	AASHTO T30	150 tons (140 Mg)	1 per Sublot	From Haul Vehicle at Plant	Random AASHTO T168
HMA Patching Mixture: Maximum Theo. Specific Gravity	AASHTO T209	150 tons (140 Mg)	1 per Sublot	From Haul Vehicle at Plant	Random AASHTO T168
HMA Patching Mixture: In-place Density	ASTM D2950 or AASHTO TP68	100 sq. feet. (10 sq. meter) per each Patch Area	1 per Sublot	From Compacted HMA Patch	Random ASTM D2950, AASHTO TP68

F. Quality Control Testing of HMA Lots.

The Design-Builder’s QC personnel will perform Quality Control testing at both the HMA production facility and at the site of HMA field placement to ensure that the production and placement processes are providing work conforming to the contract requirements. The Engineer shall be provided the opportunity to monitor and witness all QC testing of HMA. All QC testing of HMA Lots shall be in accordance with the AASHTO, ASTM, NETTCP, or Department test methods specified in Table 450.10 and the procedures outlined below.

Table 450.10 - Minimum Quality Control Sampling & Testing of HMA Lots

Quality Characteristic	Test Method(s)	Sublot Size	Minimum Test Frequency	Point of Sampling	Sampling Method
PG Asphalt Binder Grading	AASHTO M320	Per Supplier QC Plan or 24,000 tons (22,000 Mg) of HMA per Subsection 450.65F(1)	See Subsection 450.65F(1)	See Subsection 450.65F(1)	Random AASHTO T40
Aggregate Gradation	AASHTO T27	Per QC Plan	Per QC Plan	At HMA Plant Per QC Plan	Random AASHTO T2
PG Asphalt Binder Content	AASHTO T164 or AASHTO T308	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Haul Vehicle at Plant	Random AASHTO T168
Combined Aggregate Gradation	AASHTO T30	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Haul Vehicle at Plant	Random AASHTO T168
Maximum Theo. Specific Gravity	AASHTO T209	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Haul Vehicle at Plant	Random AASHTO T168
Bulk Specific Gravity	AASHTO T166 (SSD Method)	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Haul Vehicle at Plant	Random AASHTO T168
Volumetrics: Air Voids, VMA, VFA	AASHTO T245	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Haul Vehicle at Plant	Random AASHTO T168
In-place HMA Mat Density (Density Gauge)	ASTM D2950 or AASHTO TP68	150 tons (140 Mg)	1 per Sublot ⁽¹⁾	From Compacted HMA Course	Selective & Random ASTM D2950, AASHTO TP68
In-place HMA Mat Density (Cores)	AASHTO T230 AASHTO T166 AASHTO T269	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Compacted HMA Course	Random AASHTO T269
Thickness	AASHTO T269	600 tons (550 Mg)	1 per Sublot ⁽¹⁾	From Compacted HMA	Random AASHTO T269
Transverse Joint Density	ASTM D2950 or AASHTO TP68	Each Joint	1 per Sublot ⁽¹⁾	At Finished Joint	Random ASTM D2950, AASHTO TP68
Longitudinal Joint Density	ASTM D2950 or AASHTO TP68	500 feet (150 meters) per Joint	1 per Sublot ⁽¹⁾	At Finished Joint	Random ASTM D2950, AASHTO TP68
Ride Quality (IRI)	AASHTO PP52 Per Subsection 450.65F(11)	0.1 miles (160 meters) per each Wheel Path	3 Runs per Sublot	Each Pavement Course Per Subsection 450.65F(11)	Random Per Subsection 450.65F(11)
Wheel Path Deviations	10 foot (3 meter) standard straightedge	500 feet (150 meters) per each Wheel Path	1 per Sublot ⁽¹⁾	Each Pavement Course Per Subsection 450.65F(12)	Random Per QC Plan

(1) In the event that the total daily HMA production is less than one Sublot, a minimum of one random QC sample shall be obtained for the day's production.

(1) PG Asphalt Binder Grading.

QC testing of PG Asphalt Binder shall be performed by the PGAB Supplier in accordance with AASHTO R26 and the Supplier's approved PGAB Quality Control Plan. The Design-Builder shall submit to the Owner a Supplier's Certificate of Compliance (COC) along with copies of the certified AASHTO M320 test results for each Supplier Lot of PGAB from which the HMA Producer's PGAB was obtained.

If the Design-Builder modifies the PGAB at the HMA production facility through blending or introduction of an asphalt binder modifier, the Design-Builder (i.e. HMA Producer) shall assume responsibility as the PGAB Supplier per AASHTO R26. In such case, the Design-Builder shall obtain and test a minimum of one random sample of the modified PGAB for each 24,000 ton (22,000 Mg) HMA Sublot, as defined in Table 450.10, to determine conformance with AASHTO M320. A minimum of two 1-quart (1 Liter) containers of PGAB shall be obtained for each PGAB sample in accordance with AASHTO T40. All QC samples shall be split prior to testing and the un-tested portion of the sample shall be retained for a minimum of 30 days.

For HMA Category A Lots incorporating greater than 25% RAP or greater in the job-mix formula, the Design-Builder shall perform full asphalt binder grade testing on a minimum of one random sample from the Control Strip and from each Sublot as specified in Table 450.10 during HMA Lot production. The QC testing shall be performed on samples of asphalt binder recovered from the RAP (by Abson recovery) blended in the appropriate proportion with samples of the virgin PGAB to determine conformance with AASHTO M320. The PG Asphalt Binder Grade testing results shall be within $\pm 2^{\circ}\text{C}$ of the specified PGAB grade for the HMA pavement course mixture.

(2) Aggregate Gradation.

The virgin aggregates utilized in each HMA Lot shall be tested for Gradation in accordance with AASHTO T27. The Sublot size and minimum frequency of QC testing for Aggregate Gradation shall be as specified in the Design-Builder's approved QC Plan. Aggregate samples shall be obtained at the HMA plant from aggregate bins or stockpiles in accordance with AASHTO T2.

(3) PG Asphalt Binder Content.

Each HMA Lot produced and placed shall be tested for PG Asphalt Binder Content in accordance with either AASHTO T164 or T308. When AASHTO T164 is used, the test results shall be reported prior to ash correction. The Sublot size and minimum frequency of QC testing for PG Asphalt Binder Content shall be as specified in Table 450.10. Each material sample for PG Asphalt Binder Content shall be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

(4) Combined Aggregate Gradation.

Each HMA Lot produced and placed shall be tested for Combined Aggregate Gradation in accordance with AASHTO T30. The Sublot size and minimum frequency of QC testing for Combined Aggregate Gradation shall be as specified in Table 450.10. Each material sample for Combined Aggregate Gradation shall be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

The QC test results of Combined Aggregate Gradation must be plotted on Control Charts with Action Limits. Recommended Action Limits are provided in Table 450.11, however, the Action Limits to be used for each HMA Lot shall be as specified in the Design-Builder's approved QC Plan. If the QC test results for an individual Sublot fall outside of the established Action Limits, the Design-Builder shall evaluate the HMA production process and determine any adjustments necessary to bring the Combined Aggregate Gradation back within the Action Limits. If the subsequent Sublot test result falls outside of the Action Limits, the Design-Builder shall suspend Lot production until it can be demonstrated that the HMA mixture can be produced within the Action Limits. The Design-Builder's QC personnel shall document all action(s) taken to bring the HMA production process into control.

Table 450.11 - Recommended Action limits for Combined Aggregate Gradation

Sieve Size	Action Limit
Passing No. 4 Sieve (4.75mm) and larger sieve sizes	JMF Target +/-6 percent
Passing No. 8 sieves (2.36mm)	JMF Target +/-5 percent
Passing No. 16 (1.18mm) to No. 50 (300µm) sieves (inclusive)	JMF Target +/-3 percent
Passing No. 100(150µm) sieve	JMF Target +/-2 percent
Passing No. 200(75µm) sieve	JMF Target +/-1 percent

(5) Maximum Theoretical Specific Gravity.

Each HMA Lot produced and placed shall be tested for Maximum Theoretical Specific Gravity in accordance with AASHTO T209. The Sublot size and minimum frequency of QC testing for Maximum Theoretical Specific Gravity shall be as specified in Table 450.10. Each material sample for Maximum Theoretical Specific Gravity shall be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

(6) Bulk Specific Gravity.

Each HMA Lot produced and placed shall be tested for Bulk Specific Gravity in accordance with AASHTO T166 (SSD Method). The Sublot size and minimum frequency of QC testing for Bulk Specific Gravity shall be as specified in Table 450.10. Each material sample for Bulk Specific Gravity shall be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

(7) Volumetrics (Air Voids, VMA, VFA).

Each HMA Lot produced and placed shall be tested for Volumetrics (Air Voids, VMA, VFA) in accordance with AASHTO T245. The requirement for Volumetric testing of laboratory compacted specimens applies to HMA mixtures for all pavement courses, with the exception of Open Graded Friction Courses and Base Courses. The Sublot size and minimum frequency of QC testing for Volumetrics shall be as specified in Table 450.10. Each material sample for Volumetrics shall be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

(8) In-place HMA Mat Density.

Each HMA Lot produced and placed shall be tested for In-place Density using a density gauge or cores as specified below. The requirement for In-Place Density testing applies to all pavement courses, with the exception of Open Graded Friction Courses and Leveling Courses. The Sublot size and minimum frequency of random QC testing for In-place Density by either density gauge or core shall be as specified in Table 450.10.

(a) Testing In-Place Density by Density Gauge. Initial QC testing of In-Place Density during compaction of HMA pavement courses shall be performed selectively (or randomly when determined appropriate by QC personnel) using a density gauge in accordance with ASTM D2950 or AASHTO TP 68. QC testing of In-Place Density for all HMA bridge protective courses and bridge surface courses shall be performed randomly using a density gauge. Each random sampling and testing location for HMA bridge courses shall be established by determining a randomly selected tonnage and corresponding approximate longitudinal distance within the Sublot, along with a randomly selected offset distance in accordance with ASTM D3665. Additional selective QC sampling and testing within each Sublot of compacted HMA bridge protective courses or bridge surface courses shall be as determined necessary by the Design-Builder's QC personnel and as specified in the Design-Builder's approved QC Plan.

(b) Testing In-Place Density by Cores. Final QC testing of In-Place Density of all applicable HMA pavement courses shall be performed using 6-inch (150 mm) diameter cores in accordance with AASHTO T230, T166, and T269. Cores shall not be obtained from bridge protective surface courses. In-Place Density shall be de-

terminated from each core by comparing the Bulk Specific Gravity of the core to the average Maximum Theoretical Specific Gravity for all HMA mixture Sublots produced for the pavement course on the same day's production. Each core location shall be established by determining a randomly selected tonnage and corresponding approximate longitudinal distance within the Sublot, along with a randomly selected offset distance in accordance with ASTM D3665. If the randomly determined sampling location coincides with one of the following conditions, the sampling location shall be relocated immediately beyond the boundary distance as indicated below for the specific condition:

1. Within 1 foot (300mm) from an edge of pavement course to be left unconfined upon project completion
2. Within 1 foot (300mm) of any longitudinal joint or transverse joint.
3. Within 3 feet (1 meter) of any drainage structure.

Core samples shall be obtained in accordance with AASHTO T230 prior to opening the pavement course to traffic. At the discretion of the Owner, based on climactic or other conditions, obtaining of cores may be delayed for a period up to, but not to exceed, 48 hours. All cores shall be protected against damage and tested within 24 hours after they have been obtained. The Design-Builder shall fill all core holes, whether from QC sampling or Department Acceptance sampling, with fresh HMA mixture from the same Lot. The filled core holes shall be thoroughly compacted as outlined in the Design-Builder's approved QC Plan.

(9) Thickness.

Each HMA pavement course specified to be placed at a compacted thickness of 1 inch (25mm) or greater shall be tested for Thickness using cores, with the exception of the following courses:

1. Open Graded Friction Course.
2. Bridge Surface Course.
3. Bridge Protective Course.
4. Leveling Course.
5. In the absence of a Leveling Course, the first pavement course placed over existing pavement.

The aforementioned pavement courses are exempt only from determination of Thickness using cores and the corresponding statistical evaluation of Lot quality. The Design-Builder is still responsible for ensuring the minimum required thickness of these pavement courses using an appropriate sampling and testing protocol as outlined in the Design-Builder's approved QC Plan.

All sampling and testing for Thickness of the applicable pavement courses using cores shall be in accordance with AASHTO T269. The Sublot size and minimum frequency of random QC testing for Thickness shall be as specified in Table 450.10.

(10) Joint Density.

Each transverse joint and longitudinal joint formed during placement of a pavement course shall be tested for Joint Density using a density gauge in accordance with ASTM D2950. The requirement for Joint Density testing applies to all pavement courses, with the exception of Open Graded Friction Courses and Leveling Courses. The Sublot size and minimum frequency of random QC testing for Joint Density shall be as specified in Table 450.10.

Each random sampling and testing location shall be established by determining a randomly selected distance along the joint, along with a randomly selected offset distance within 1 foot (300 mm) of either side of the finished joint, in accordance with ASTM D3665. Additional selective QC sampling and testing of Joint Density within each Sublot of compacted HMA pavement courses or bridge protective surface courses shall be as determined necessary by the Field QCT and as specified in the Design-Builder's approved QC Plan.

(11) Ride Quality.

The finished surface of the pavement shall be uniform in appearance, free from irregularities in contour and texture and shall present a smooth riding surface. Ride Quality testing shall be performed for Quality Control on a periodic basis during construction of the HMA pavement courses specified below. QC testing shall be performed for HMA Category A Lots, at a minimum, within 24 hours after each 8 lane-miles (13 lane-kilometers) of an individual pavement course have been placed. QC testing of HMA Category B Lots shall be performed, at a minimum, every other paving day. In addition, the Design-Builder shall perform QC testing of the entire final pavement course placed upon completion.

(a) Pavement Courses Subject to Ride Quality Testing. For projects having a posted speed equal to or greater than 40 mph with HMA Lots falling under Lot Category A (Large Lots) or Category B (Small Lots), QC testing shall be performed with an inertial profiler to determine the Ride Quality of the following pavement courses:

- Friction Course (OGFC-P)
- Surface Course
- Intermediate Course (lift immediately beneath Surface Course only)
- Leveling Course (when placed immediately beneath Surface Course)
- Bridge Surface Course (when asphaltic bridge joints are used and when placed on the same contract with the mainline Surface Course)

At a minimum, the finished surface of these pavement courses will be tested for all mainline travel lanes, auxiliary lanes, ramps, and side road travel lanes. The Design-Builder may also elect to perform Ride Quality testing of the pavement courses beneath the courses indicated above in order to provide adequate Quality Control.

(b) Pavement Courses Excluded from Ride Quality Testing

The following pavement courses and surfaces are specifically excluded from Ride Quality testing:

1. All exposed concrete bridge decks and any Bridge Surface Course without asphaltic bridge joints (including 15 feet (5 meters) before the approach joint and 15 feet (5 meters) after the departure joint).
2. Mainline pavement courses less than one half mile (800 meters) in total length (excluding bridge lengths).
3. Side road pavement courses less than one Sublot (0.1 mile (160 meters)) in total length.
4. Single resurfacing pavement courses placed in one lift at a total plan (compacted) thickness less than 1.50 inches (40 millimeters).
5. Pavement courses on horizontal curves having a centerline radius of curvature of 500 feet (150 meters) or less, including the length of pavement within the super-elevation transition of such curves.
6. Pavement courses for shoulders.
7. Pavement segments with manholes or catch basins in the travel lane (the Ride Quality testing data for such pavement segments shall be excluded, including 15 feet (5 meters) before and after these manholes or catch basins).

(c) Inertial Profiler Equipment Requirements. All inertial profilers used for Design-Builder QC testing shall conform to the equipment specifications contained in AASHTO PP50 and ASTM E950. The inertial profiler shall be equipped with a system of transducers (height sensor, accelerometer, distance sensor) to measure the longitudinal pavement profile. An automated triggering system shall be provided that detects a reference mark to start, stop, and event mark the data collection process. The profiler equipment shall include an onboard computer system capable of storing all profile measurement data, calculating the real time International Roughness Index (IRI) per ASTM E1926 (independent of speed), and displaying profile plots.

(d) Certification and Correlation of Inertial Profilers. All inertial profilers used for Design-Builder QC testing must be certified for precision and accuracy in accordance with the requirements of AASHTO PP51. In addition, all Design-Builder QC profilers must be correlated against the Department's reference profiling device in accordance with the Department's correlation procedures. The certification and correlation of all profilers shall be conducted at the Profiler Correlation Center in New Bedford, MA established by the University of Massachusetts at Dartmouth. The certification and initial correlation of the Design-Builder's inertial profiler shall be completed prior to the start of Ride Quality testing on the project. After the initial correlation is successfully completed, the same inertial profiler can be used on any Department project without re-correlation for the remainder of the construction season. Equipment that does not pass the Department's correlation procedure shall not be used. The Design-Builder's use of inertial profiler equipment that has not been successfully correlated is sufficient grounds for withholding payment for QC testing of Ride Quality. The Design-Builder's inertial profiler equipment may be required to undergo re-correlation at any time during the construction season if significant variations are found within the Design-Builder's QC test data or between the QC test data and the Department's Acceptance test data.

(e) Ride Quality Testing Procedures. Ride Quality testing shall be performed in accordance with the procedures outlined in AASHTO PP52, as clarified or amended herein.

The Ride Quality will be measured for each wheel path [a wheel path is defined as 3 feet (1 meter) from and parallel to each longitudinal edge of the lane to be measured]. Each wheel path will be divided into 0.1 mile (160 meters) Sublots starting at the project limits in the direction of traffic. Partial Sublots may result at either end of the project or as a result of interruptions of the continuous pavement surface (i.e. bridge approaches, railroad crossing, cessation of daily paving operations, etc.).

Just prior to testing, the Design-Builder shall sweep the pavement and remove all foreign objects or materials on the pavement course surface. Testing will begin 15 feet (5 meters) after the transverse approach joint and end 15 feet (5 meters) before the transverse departure joint. A minimum of three and up to a maximum of five test runs will be performed on each wheel path. The final test result for each Sublot will be the average of the three best test runs.

(f) Data Format and Reporting Requirements. All Ride Quality QC testing data shall be collected and saved in electronic format in an ASCII data file. A copy of the raw data file shall be provided to the Owner on site immediately following testing of completed Sublots. A longitudinal profile shall be determined for all Sublots tested and an average IRI value shall be determined and reported for each Sublot (i.e. each 0.1 mile (160 meters) segment of each wheel path). The Design-Builder shall summarize the results for all Sublots, by corresponding Ride Quality Lot, in an electronic spreadsheet file (MS Excel) consistent with the format of the Department’s QA Spreadsheets. The summary spreadsheet of QC testing data shall be submitted to the Department, electronically and in hardcopy, within two days after the testing is completed.

(g) Ride Quality Monitoring & Corrective Action. The Design-Builder shall evaluate and monitor the test data for each pavement course requiring Ride Quality testing for conformance with the applicable Quality Limits specified in Table 450.19. If the running Quality Level for all Sublots placed and tested falls below the Suspension Quality Level (70 PWL), the Design-Builder shall suspend further placement of the corresponding pavement course and evaluate the Sublots placed for appropriate corrective action. If the running Mean IRI of all Sublots placed and tested for the pavement course immediately below the final course is greater than the Action Limits specified in Table 450.12, corrective action will be required prior to placement of the final pavement course.

When Ride Quality correction is required, the Design-Builder shall use one or more of the following corrective methods:

1. Removal and replacement of the entire pavement course.
2. Partial depth removal of the pavement course by milling and placement of new pavement course(s) of the same mixture type.
3. Overlaying (not patching) with the specified pavement course.
4. Diamond grinding or use of other surface profiling devices.

The corrective method(s) chosen by the Design-Builder shall be subject to the approval of the Department and shall be performed at the Design-Builder's expense. The Design-Builder shall retest any Sublots where corrections are made and provide the Department with a copy of the raw data file, the profile plot, and the IRI summary spreadsheet data for the corrected Sublots.

Table 450.12 - Action Limits for Pavement Course Below Final Pavement Course

Posted Speed Limit⁽¹⁾	Target IRI	Maximum Mean IRI of All Sublots Tested
Greater than or equal to 55 mph (90 km/hr)	60 in/mile (0.95 m/km)	≤ 85 in/mile (1.34 m/km)
40 mph (65 km/hr) to 55 mph (90 km/hr)	80 in/mile (1.26 m/km)	≤ 105 in/mile (1.66 m/km)
Less than 40 mph (65km/hr)	Not subject to Ride Quality testing	N/A

- (1) Note that projects with posted speed limits that fall into more than one of the Posted Speed Limit ranges above will be divided into multiple Lots and evaluated separately.

450.66 HMA Mix Design Verification and Control Strip Requirements.

For all pavement courses with HMA Lots falling under Lot Category A (Large Lots), the HMA mix design Verification and Control Strip procedures outlined below shall apply.

A. Laboratory Verification of HMA Mix Design.

The Design-Builder shall develop and submit a Laboratory Trial Mix Formula (LTMF) for each HMA mixture type, which is to be proposed as a Job Mix Formula, a minimum of forty-five (45) days prior to the start of HMA production. The Design-Builder shall not proceed to HMA production for the Control Strip as outlined below until the LTMF is verified by the Department.

B. HMA Control Strip.

The Design-Builder shall produce and place a Control Strip Lot for all HMA pavement courses, with the exception of Leveling Courses, on the first day of HMA production. The Control Strip will be used to verify that the HMA can be produced per the LTMF, to establish compaction patterns, and to verify that the equipment and processes for lay-down and compaction are capable of providing the HMA pavement course in conformance with these specifications. The Control Strip Lot shall consist of a minimum of 600 tons (550 Mg) of HMA, but not more than 1,800 tons (1,650 Mg). Each Control Strip will be divided into three (3) equal Sublots. The Design-Builder and the Department will both perform inspection, sampling, and testing on the Control Strip and evaluate the corresponding data as outlined below.

(1) Control Strip Inspection.

The Design-Builder's QC personnel shall perform inspection of each Control Strip Sublot at both the HMA production facility and at the site of HMA field placement. The specific items to be inspected for the Control Strip shall include the four primary inspection components (Equipment, Materials, Environmental Conditions, Workmanship) in accordance with the requirements of Table 450.8a, Table 450.8b and as specified in the Design-Builder's approved QC Plan. The Department will also inspect each Control Strip Sublot for the inspection components of Materials and Workmanship.

(2) Control Strip Sampling and Testing.

The Design-Builder and the Department shall independently sample and test the Control Strip Lot for the Quality Characteristics identified in Table 450.13. The Design-Builder and the Department shall each sample and test each Sublot produced and placed. Each Design-Builder QC sample and each Agency Acceptance sample shall be randomly obtained from each Sublot in accordance with ASTM D3665 and the prescribed sampling protocols for each Quality Characteristic as outlined in Subsection 450.65F. Split samples shall be retained for each Sublot by both the Design-Builder and the Department in accordance with Subsection 450.65D.

(3) Evaluation of Control Strip Inspection Data.

The Design-Builder and the Department shall each evaluate their respective Control Strip inspection data against the requirements for Materials and Workmanship specified in Subsection 450.53 thru Subsection 450.58.

(4) Evaluation of Control Strip Sampling and Testing Data.

The Design-Builder and the Department shall each evaluate their respective individual Sublot test results against the Control Strip Quality Limits in Table 450.13. The Design-Builder and the Department shall also evaluate the Control Strip Lot Quality Level (PWL) using the Specification Limits in Table 450.13 for those Quality Characteristics subject to Quality Level Analysis. The Design-Builder's QC test data shall be combined with the Agency's Acceptance test data to determine the Lot Quality Level, provided that the QC data is Validated against the Acceptance data in accordance with Subsection 450.77. The Control Strip Lot Quality Level must be 70 PWL or greater.

Table 450.13 - Control Strip Quality Limits

Quality Characteristic	Target	Specification Limits		Engineering Limits		Acceptance Limit
		LSL	USL	LEL	UEL	
PG Asphalt Binder Grading	Per Binder Grade specified	N/A	N/A	Per AASHTO M320	Per AASHTO M320	N/A
PG Asphalt Binder Content	Per LTMF	Target - 0.3 %	Target + 0.3 %	Target - 0.4 %	Target + 0.4 %	≥ 70 PWL
Volumetrics: Air Voids	4 %	2.7 %	5.3 %	2 %	6 %	≥ 70 PWL
Combined Gradation: Passing #4 (4.75mm) and Larger Sieves	Per LTMF	N/A	N/A	Target - 7%	Target + 7%	N/A
Combined Gradation: Passing #8 (2.36mm) Sieve	Per LTMF	N/A	N/A	Target - 5%	Target + 5%	N/A
Combined Gradation: Passing #16 (1.18mm) to #50 (300um) Sieve	Per LTMF	N/A	N/A	Target - 4%	Target + 4%	N/A
Combined Gradation: Passing #100 (150um) Sieve	Per LTMF	N/A	N/A	Target - 3%	Target + 3%	N/A
Combined Gradation: Passing #200 (75um) Sieve	Per LTMF	N/A	N/A	Target - 1.5%	Target + 1.5%	N/A
In-Place HMA Mat Density (Cores)	95 % of G _{mm}	92.5 % of G _{mm}	97.5 % of G _{mm}	92 % of G _{mm}	98 % of G _{mm}	≥ 70 PWL
Thickness*: (All Courses 1 inch (25mm) or greater)	Per Plans	- 20 % of Target Thickness	+ 20 % of Target Thickness	- 30 % of Target Thickness	+ 30 % of Target Thickness	≥ 70 PWL
Ride Quality*: Greater than or equal to 55 mph (90 km/hr)	50 in/mile (0.79 m/km)	N/A	70 in/mile (1.10 m/km)	N/A	80 in/mile (1.26 m/km)	≥ 70 PWL
Ride Quality*: 40mph (65 km/hr) to 55 mph (90 km/hr)	70 in/mile (1.10 m/km)	N/A	100 in/mile (1.58 m/km)	N/A	110 in/mile (1.74 m/km)	>70 PWL

*To be evaluated for applicable pavement courses subject to testing per Subsection 450.65F. The Quality Limits for Ride in Table 450.13 shall only apply to Control Strips for the final pavement course (HMA Surface Course or Friction Course). For pavement courses below the final pavement course that are subject to Ride Quality testing, the Mean IRI for the Control Strip Sublots shall be less than or equal to the Maximum Mean IRI values in Table 450.12.

(5) Verification of Control Strip Lot and LTMF.

In order for a Control Strip Lot and corresponding LTMF to be Verified, the following criteria must be met:

- a) All Attributes inspected for each Sublot must meet the specification requirements in Table 450.16.
- b) All individual Sublot test results for the Quality Characteristics tested on the Control Strip must be within the Ownering Limits in Table 450.13.
- c) If the evaluation of all inspection data and testing data for the Control Strip indicates that the individual Sublots are in conformance with the requirements outlined in Subsection 450.66 B paragraphs (3) and (4) above and the Lot Quality for each applicable Quality Characteristic in Table 450.13 is ≥ 70 PWL, the Control Strip Lot and LTMF shall be declared "Verified". In such event, the LTMF shall become the Job Mix Formula (JMF) for the Lot and the Design-Builder may proceed with production and placement of the first HMA Lot.
- d) If the Control Strip is not Verified, the Design-Builder shall reassess the LTMF, the production process, and the placement process to determine the apparent cause(s) of nonconformance. The Design-Builder must submit proposed adjustment(s) to the LTMF and/or the production process and/or placement process. If adjustments to the LTMF are "major" (as defined in Table 1 of AASHTO R 42), the Design-Builder will be required to submit a new LTMF for laboratory verification by the Owner per the requirements of Section 450.66A. If proposed adjustment(s) are accepted by the Owner, the Design-Builder may proceed with a subsequent Control Strip.
- e) If a 2nd or any subsequent Control Strip does not pass all of the inspection and testing requirements, the Design-Builder must submit proposed adjustment(s) to the LTMF and/or the production process and/or placement process,
- f) If the computed PWL for any Quality Characteristic, with the exception of thickness, is < 60 PWL, the Control Strip Lot will be determined rejected and shall be removed. If the mean thickness of the Lot is determined to be greater than the target, it may remain in place, but payment will be based upon the HMA tonnage calculated at the target thickness.
- g) For any Control Strip that is not Verified, the Design-Builder shall prepare a Corrective Action Plan for the nonconforming Control Strip Lot. The corrective method(s) proposed by the Design-Builder shall be subject to the approval of the Department and shall be performed at the Design-Builder's expense.

(6) Acceptance and Payment of Control Strips

(a) 1st and 2nd Control Strip

For each Control Strip Lot that has been Verified, payment shall be determined for each individual Quality Characteristic in accordance with the pay adjustment provisions of Subsection 450.92. If the Lot Quality Level for an individual Quality Characteristic is 90 PWL, payment for the Quality Characteristic shall be 100% of the Design-Builder's bid price for the pay item quantity placed on the Control Strip. If the Lot Quality Level for an individual Quality Characteristic is > 90 PWL, payment for the Quality Characteristic shall be an incentive amount determined in accordance with Subsection 450.92. If the Lot Quality Level for an individual Quality Characteristic is ≥ 60 PWL, but < 90 PWL, payment for the Quality Characteristic shall be a disincentive amount determined in accordance with Subsection 450.92. If the computed Quality Level for an individual Quality Characteristic is < 60 PWL, the Control Strip Lot will be determined rejected and removed in accordance with Subsection 450.66B(5) and shall receive no payment.

(b) 3rd Control Strip

If a 3rd Control Strip Lot is placed and is Verified, payment shall be limited to a maximum of 85% of the Design-Builder's bid price for the entire pay item quantity placed on the Control Strip, regardless of the actual calculated Quality Level for the Lot. If a 3rd Control Strip Lot is placed and is not Verified, payment shall be limited to a maximum of 80% of the Design-Builder's bid price for the entire pay item quantity placed on the Control Strip, regardless of the actual calculated Quality Level for the Lot. If the computed Quality Level for an individual Quality Characteristic is < 60 PWL, the Control Strip Lot will be determined rejected and removed in accordance with Subsection 450.66B(5) and shall receive no payment.

(c) 4th or Subsequent Control Strip

If a 4th or subsequent Control Strip Lot is placed and is Verified, payment shall be limited to a maximum of 75% of the Design-Builder's bid price for the entire pay item quantity placed on the Control Strip, regardless of the actual calculated Quality Level for the Lot. If a 4th or subsequent Control Strip Lot is placed and is not Verified, payment shall be limited to a maximum of 70% of the Design-Builder's bid price for the entire pay item quantity placed on the Control Strip, regardless of the actual calculated Quality Level for the Lot. If the computed Quality Level for an individual Quality Characteristic is < 60 PWL, the Control Strip Lot will be determined rejected and removed in accordance with Subsection 450.66B(5) and shall receive no payment.

450.67 Quality Control Documentation and Data Evaluation.

A. QC Inspection Documentation & Evaluation.

The Design-Builder shall document all QC inspection activity for each HMA Lot Category (Category A, B, or C) produced and placed. All inspection results shall be recorded within 24 hours of inspection on current NETTCP standard Inspection Report Forms (IRFs). The QC Manager shall evaluate inspection results in a timely manner to confirm that production and placement processes are in control. The Design-Builder shall submit hard copies of all IRFs to the Owner at the completion of each Lot.

B. QC Sampling and Testing Documentation & Data Analysis.

The Design-Builder shall document all QC sampling and testing data for each HMA Lot Category (Category A, B, or C) produced and placed. All sampling and testing data shall be recorded within 24 hours of sampling and testing on current NETTCP standard Test Report Forms (TRFs). The QC Manager shall evaluate sampling and testing results in a timely manner, as further outlined below, to confirm that production and placement processes are in control. All QC testing data shall be entered into the Department's MS-Excel QA Data Spreadsheets via the internet (mhdqa.com) within two (2) days after completion of testing. The Design-Builder shall submit hard copies of all TRFs to the Owner at the completion of each Lot.

(1) Control Charts.

For each HMA Category A Lot produced and placed, the Design-Builder shall use Control Charts as part of the QC system to assist in identifying assignable causes affecting the HMA production and placement processes. Control Charts shall be prepared for the Quality Characteristics subject to QC sampling and testing listed in Table 450.10. As a minimum, the Design-Builder shall plot all QC test results of each Lot on Control Charts for individual Sublot measurements or test values (Run Charts). It is also recommended practice for the Design-Builder to use Control Charts that plot Subgroups of data (e.g. X-Bar Charts, R Charts). The Design-Builder shall submit examples of the Control Charts to be used in the QC Plan. As a minimum, the Control Charts shall identify the Contract number, the Payment Item number, the Lot number, the Quality Characteristic, the Control Chart Target, the Upper and Lower Control Chart Limits, and Sublot or Subgroup numbers.

All Control Charts should be updated within 24 hours after the corresponding testing is completed and documented. Quality Control personnel should use the Control Chart data to monitor and adjust the production and placement processes or suspend operations as determined necessary. Control Charts for Quality Characteristics related to HMA production should be maintained at the HMA production facility. Control Charts for Quality Characteristics related to HMA field placement should be maintained at the project field site. Current Control Charts shall be posted in an accessible location. The Engineer shall be provided access to all Control Charts as part of the Department's monitoring of Design-Builder QC activity.

(2) Evaluation of Individual Sublot QC Test Results.

The Design-Builder shall evaluate the individual QC test results for each HMA Lot Category (Category A, B, or C) produced and placed. Each random QC test result shall be evaluated against the applicable Quality Limits within 24 hours of testing. For HMA Category A Lots and Category B Lots, each Sublot test value shall be within the Owning Limits specified in Table 450.19. For HMA Category C Lots, each Sublot test value shall be within the Specifications Limits indicated in Table 450.19.

If the evaluation of the QC testing data indicates that an individual Sublot is not in conformance with the applicable Quality Limits for the particular HMA Lot Category, the Design-Builder shall isolate the Sublot and perform selective sampling followed by additional random sampling of the Sublot to quantify the actual quality of the Sublot.

(3) Evaluation of Lot Quality Level.

For HMA Category A Lots and Category B Lots, the Design-Builder shall use all random QC test results to continuously evaluate the running quality level and determine the percent within limits (PWL) for each Lot during production and placement. The PWL shall be determined through Quality Level Analysis (QLA) for each of the applicable Quality Characteristics listed in Table 450.19 using the corresponding Specification Limits therein. The Design-Builder shall perform a running QLA using random QC data only at a minimum after each 5 Sublots have been tested and shall plot the cumulative PWL after each 5 Sublot interval. The Engineer shall be provided access to all records documenting the running QLA for each Lot as part of the Department's monitoring of Design-Builder QC activity.

If the running QLA shows the PWL falling below the Acceptable Quality Level (AQL) of 90 PWL, the Design-Builder shall initiate appropriate adjustments to the production or placement process or initiate corrective action in accordance with procedures outlined in the approved QC Plan. If the PWL falls below the Suspension Quality Level (SQL) of 70 PWL, the Design-Builder shall suspend production and placement of the Lot. The Design-Builder shall prepare a plan of corrective action for any nonconforming Lot, as further outlined below. If significant adjustment to the JMF or the production or placement process is required, a new Lot will be established. After resuming production and placement, the PWL for the Lot must be back at or above the AQL of 90 PWL.

450.68 Corrective Action.

As part of the Design-Builder's Quality Control system, the Design-Builder shall implement corrective action for any part of a Lot that is determined by inspection or testing to not be in conformance with the quality requirements specified in Section 450. If the results of QC inspection identify nonconforming material or workmanship within one or more Sublots, or if the evaluation of the QC testing data indicates that any Sublot is not in conformance with the applicable Quality Limits for the particular HMA Lot Category, the Design-Builder shall isolate the Sublot(s) and perform additional inspection or testing to further assess the quality of the Sublot. Selective inspection or testing should be used to determine the limits of nonconformance, followed by random inspection or testing to quantify the actual quality of the nonconforming area.

Based on the results of additional inspection or testing, the Design-Builder shall prepare a plan of corrective action for the nonconforming Sublot(s). The Corrective action plan shall be submitted to and approved by the Owner prior to initiating corrective action. All corrective action shall be performed at the Design-Builder's expense.

450.69 Quality Control Records System.

A. Quality Control Daily Diary.

The QC Manager should maintain a Quality Control Daily Diary (QC Daily Diary) to document all major activities or actions related to the Design-Builder's QC system. The QC Daily Diary serves as a summary record of key actions taken by QC personnel each day. Recommended Information which should be recorded in the QC Daily Diary includes:

- The day's weather or environmental conditions.
- A summary of production or placement activities completed.
- Any non-conforming material or workmanship identified.
- Any corrective actions recommended or taken by QC personnel.
- Discussions held with other Design-Builder personnel or Department personnel.
- Visitors to the production facility or field placement operation.

B. Quality Control Record Books.

The Design-Builder shall maintain one or more ringed binders referred to as "Quality Control Record Books" (QC Record Books) to store all required QC documents. Separate QC Record Books shall be kept at each HMA production facility and at the project field site. Either a separate QC Record Book shall be established for each HMA pavement course or the data for each pavement course may be included in a single QC Record Book provided the data is separated according to pavement course. QC data for each pavement course shall be organized into separate sections by Quality Characteristic and by Lot number.

QC documents to be stored in the QC Record Book(s) include:

- A signed copy of the current approved QC Plan.
- The original signed copies of all completed Inspection Report Forms.
- The original signed copies of all completed Random Sampling location forms.
- The original signed copies of all completed Test Report Forms.
- A current copy or printout of all Control Charts.
- A current copy or printout of all running QLA performed.
- Current summaries of all individual QC test results to date (by Lot & Sublot).
- Summary sheets of material quantities produced or placed (by Lot & Sublot).

Each required record shall be inserted into the corresponding QC Record Book within 24 hours after the document has been completed. All QC Record Books shall be maintained in a suitable location. The Engineer shall be provided access to all QC Record Books as part of the Department's monitoring of Design-Builder QC activity.

C. Quality Control Records Retention.

All Design-Builder QC records identified above shall be retained for a minimum of seven (7) years. The records shall be protected from damage or alteration. When requested by any State or Federal Agency for audit or similar purposes, the Design-Builder shall provide complete access to all QC records.

DEPARTMENT ACCEPTANCE

450.70 General.

The Department is responsible for performing all Acceptance activities and making the final acceptance determination for each HMA Lot produced and placed. The Department's Acceptance system will include monitoring the Design-Builder's QC activity, performing Acceptance inspection, sampling & testing, and determining the Quality and corresponding payment for each Lot. These activities will be performed for each HMA Lot Category (Lot Category A, B, and C) as outlined further below.

450.71 Acceptance System Approach.

A. Acceptance of Category A Lots.

The Engineer's acceptance determination for each HMA Category A Lot will be based on an evaluation of the Department's Acceptance inspection information and Acceptance testing data. The Engineer will perform Acceptance sampling and testing on a minimum of 25% of the Sublots produced and placed. Design-Builder QC test data will be included in the Department's acceptance determination for each Category A Lot provided the following requirements are met:

- Split Sample Correlation testing requirements are satisfied.
- The Design-Builder provides adequate Quality Control per the approved QC Plan.
- All QC test results included are from random samples.
- The QC test results are Validated against the Department's Acceptance test results.

B. Acceptance of Category B Lots.

The Engineer's acceptance determination for each HMA Category B Lot will also be based on an evaluation of the Department's Acceptance inspection information and Acceptance testing data. The Engineer will perform Acceptance sampling and testing on a minimum of 50% of the Sublots produced and placed, but not less than three (3) Sublots. Design-Builder QC test data will be included in the Department's acceptance determination for each Category B Lot provided the requirements outlined in paragraph A above are satisfied.

C. Acceptance of Category C Lots.

For all HMA Category C Lots, the Owner's acceptance determination will be based only on the Department's Acceptance inspection information and Acceptance testing data. The Engineer will perform Acceptance sampling and testing on 100% of the Sublots produced and placed. Design-Builder QC test data will not be included in the Department's acceptance determination for Category C Lots.

450.72 Department Monitoring of Design-Builder Quality Control.

For projects with HMA Category A Lots or Category B Lots, the Department will monitor the Design-Builder's Quality Control system to confirm that QC activities are being performed for each Lot in reasonable compliance with the approved QC Plan. Department monitoring of the Design-Builder's QC system is not intended to evaluate the Quality of the Work. The Engineer will not perform the QC responsibilities of the Design-Builder or provide constant direction to the Design-Builder on how to perform Quality Control. The Engineer's monitoring of QC activity will include the following:

- Periodic visual observation of QC inspection, sampling, and testing.
- Reviewing QC documentation and records.
- Providing feedback based on monitoring findings.

The Engineer will document all findings (positive or negative) from any monitoring of the Design-Builder's QC system on standard Monitoring Report Forms (MRFs). Copies of all MRFs will be provided to the Design-Builder on a timely basis. When deficiencies in the Design-Builder's QC system are identified and documented by the Owner, the Design-Builder shall take immediate action to address the deficiencies. If the Design-Builder fails to take appropriate action, the Design-Builder shall suspend production and placement of the corresponding Lot(s). The Department will withhold payment for the Design-Builder Quality Control Payment Item (Item No. 450.70) until the Design-Builder implements satisfactory corrective measures.

450.73 Acceptance Inspection.

The Engineer will perform Acceptance inspection of all work items addressed under Section 450 to ensure that all materials and completed work are in conformance with the contract requirements. Acceptance inspection is intended to visually assess the quality of each HMA Lot produced and placed and will address only the inspection components of Materials and Workmanship in support of the Department's final acceptance determination.

All Acceptance inspection activity by the Department will be performed independent of the Design-Builder's QC inspection at both the HMA production facility and at the site of HMA field placement. The Engineer will document the results and findings of Acceptance inspection on NETTCP Inspection Report Forms (IRFs). The Engineer will furnish a copy of all Department Acceptance inspection results to the Design-Builder within five (5) days following the inspection.

A. Acceptance Inspection of Prepared Underlying Surface.

The Department will perform Acceptance inspection of the prepared underlying surface prior to placement of HMA. The items to be inspected and minimum frequency of inspection will be in accordance with the requirements outlined in Table 450.14 and Table 450.15.

Table 450.14 - Department Acceptance Inspection of HMA Patching

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Materials	Mixture Type + PG Binder Grade (Correct Type)	1 per Day	HMA Production Facility	Visual Check + Manufacturer COC
	Rubberized Asphalt Sealant (Correct Type)	1 per Day	At Paving Site	Check Manufacturer COC
Workmanship	Sawcut Limit Vertical Face	25% of Patched Areas	Sawcut Limits	Visual Check
	Rubberized Asphalt Sealant Application Rate	25% of Patched Areas	Sawcut Limits	Visual Check + Check Measurement
	Cross-Slope & Profile	25% of Patched Areas	Compacted HMA	Check Measurement

Table 450.15 - Department Acceptance Inspection of Tack Coat

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Materials	Asphalt Emulsion (Correct Type)	1 per Day	At Paving Site	Check Manufacturer COC
Workmanship	Asphalt Emulsion Application Rate	Once per 5,000 lane-ft (1,500 lane-m)	Tacked Surface + Tack Distributor System	Visual Check + Check Measurement

B. Acceptance Inspection of HMA Lots.

The Department will perform Acceptance inspection at both the HMA production facility and at the site of HMA field placement. For purposes of Acceptance inspection, the total quantity of each HMA pavement course produced and placed during the same construction season will constitute a Lot. Each in-place HMA Lot will be divided into 500 lane-feet (150 lane-meters) Sublots. The items to be inspected and minimum frequency of inspection will be in accordance with the requirements outlined in Table 450.16.

(1) Wheel Path Deviations.

Each HMA Lot produced and placed will be inspected by the Owner for Wheel Path Deviations (high points or low points) using a 10 foot (3 meter) standard straightedge in accordance with the procedures outlined in Subsection 450.64B. Acceptance inspection for Wheel Path Deviations applies to all pavement courses (including bridge protective courses and bridge surface courses). The finished surface of each required pavement course will be inspected for all mainline travel lanes, auxiliary lanes, ramps, and side road travel lanes. The Sublot size and minimum frequency of Acceptance inspection for Wheel Path Deviations will be as specified in Table 450.16.

Table 450.16 - Department Acceptance Inspection of HMA Lots

Inspection Component	Items Inspected	Minimum Inspection Frequency	Point of Inspection	Inspection Method
Materials	HMA Mixture Type, Aggregates & PG Binder (Correct Type)	1 per Day	HMA Production Facility	Visual Check + Manufacturer COC
	Rubberized Asphalt Sealant (Correct Type)	1 per Day	At Paving Site	Check Manufacturer COC
Workmanship	Joint Location & Alignment	50% of Sublots, Once per Joint	At Finished Joint	Visual Check
	Sawcut Joint Vertical Face	50% of Sublots, Once per Joint	Joint Vertical Face	Visual Check
	Rubberized Asphalt Sealant Application Rate	50% of Sublots, Once per Joint	Joint Vertical Face	Visual Check + Check Measurement
	Physical Segregation	50% of Sublots, Once per Lane	Compacted HMA	Visual Check
	Cross-Slope	50% of Sublots, Once per Lane	Compacted HMA	Check Measurement
	Joint Tightness	50% of Sublots, Once per Joint	Compacted HMA	Visual Check
	Joint Surface Deviations	50% of Sublots, Once per Joint	At Finished Joint	10 foot (3 meter) standard straightedge
	Wheel Path Deviations	50% of Sublots, per Wheel Path	Wheel Path	10 foot (3 meter) standard straightedge

450.74 Acceptance Sampling & Testing.

A. Random Sampling.

The Department will utilize stratified random sampling to determine the overall quality of each HMA Lot produced and placed. Random Acceptance sample locations will be determined by the Owner in accordance with ASTM D 3665 or by electronic random number generator, as presented by the NETTCP. All random Acceptance sample locations will be documented on NETTCP Standard Test Report Form D3665.

The Design-Builder shall furnish the Owner with approved containers for all Acceptance samples. The Engineer will obtain all random Acceptance samples independent of the Design-Builder's QC samples at the frequencies outlined below.

(1) Sampling HMA Category A Lots.

The Engineer will obtain Acceptance samples from a minimum of 25% of all Sublots in each HMA Category A Lot for all Quality Characteristics specified in Table 450.17, other than PG Asphalt Binder Grading and Ride Quality. Acceptance samples For PG Asphalt Binder Grading and Ride Quality will be obtained from each Sublot as defined in Table 450.17.

(2) Sampling HMA Category B Lots.

The Engineer will obtain Acceptance samples from a minimum of 50% of all Sublots, but not less than three (3) Sublots, in each HMA Category B Lot for all Quality Characteristics specified in Table 450.17, other than PG Asphalt Binder Grading and Ride Quality. Acceptance samples For PG Asphalt Binder Grading and Ride Quality will be obtained from each Sublot as defined in Table 450.17.

(3) Sampling HMA Category C Lots.

The Engineer will obtain Acceptance samples from 100% of all Sublots in each HMA Category C Lot for all Quality Characteristics specified in Table 450.17, other than Ride Quality. Acceptance sampling and testing for Ride Quality will not be performed on Category C Lots.

B. Selective Sampling.

The Department will utilize selective sampling (i.e. non-random samples) as needed to provide supplemental information to assist in quantifying the quality of apparent nonconforming material. When the results of acceptance inspection or random sampling and testing identify material which is not in conformance with the applicable Quality Limits for the particular HMA Lot Category, the Owner will isolate the corresponding Sublot(s) and perform selective sampling to further assess the quality of the Sublot. Selective inspection or testing will be used to determine the limits of nonconformance, followed by random inspection or testing to quantify the actual quality of the nonconforming area. The test results of selective Acceptance samples will not be combined with random Acceptance sample data in the determination of Lot acceptance using Quality Level Analysis as outlined in Subsection 450.78.

C. Design-Builder Assistance in Obtaining Acceptance Samples.

The Engineer will obtain all material samples for Acceptance testing by the Department. When requested by the Department, the Design-Builder shall assist the Owner in obtaining Acceptance samples in accordance with the following requirements:

- The Acceptance sample location and time will be randomly selected by the Owner and provided to the Design-Builder immediately prior to sampling.
- The Design-Builder's qualified QC personnel will only provide the physical labor to assist the Owner in obtaining the Acceptance sample.
- The Engineer will be present to direct and monitor the taking of the sample.
- The Engineer will take immediate possession of the Acceptance sample.

Design-Builder assistance may be requested in obtaining Acceptance samples for PG Asphalt Binder Grading and for In-Place Density and Thickness (HMA cores). The Design-Builder shall provide adequate traffic control for the Department to obtain cores, regardless of whether the Design-Builder assists the Owner in obtaining the Acceptance core samples.

D. Acceptance Sample Identification System.

The Department will use a standard system for the identification of all Acceptance samples. All PG Asphalt Binder samples, HMA loose mixture samples, and core samples will be labeled by the Owner with the minimum information indicated under Subsection 450.65C. Acceptance sampling data for Ride Quality and Wheel Path Deviations will be identified by the Owner in accordance with the Department’s Standard Operating Procedures (SOPs).

E. Retention of Split Samples.

Qualified Department personnel will obtain all material samples (PGAB samples, HMA loose mix samples, and cores) for Acceptance testing. The Department will retain split samples from each PGAB sample and HMA loose mix sample and provide a split sample to the Design-Builder if requested. The Department will retain the original core samples after testing to serve as “split samples” and protect them from damage. All split samples will be stored for a period of (30) days, or until tested. These split samples will be utilized if necessary, in the Dispute Resolution process. If mutually agreed upon by the Department and the Design-Builder, the retained split samples may be discarded prior to the required thirty (30) days.

F. Acceptance Testing of HMA Lots.

The Department will perform Acceptance testing using the random samples obtained in accordance with Subsection 450.74A from the HMA production facility and at the site of HMA field placement. The specific Quality Characteristics subject to Department Acceptance testing are identified in Table 450.17. All Acceptance testing of HMA Lots will be performed by the Owner in accordance with the AASHTO, ASTM, NETTCP, or Department test methods specified in Table 450.17 and the procedures outlined below. The Engineer will furnish a copy of all Department Acceptance test results/data to the Design-Builder within five (5) days following completion of testing.

(1) PG Asphalt Binder Grading.

The Department will review the Supplier’s Certificate of Compliance (COC) and corresponding certified AASHTO M320 test results submitted by the Design-Builder for each Supplier Lot of PGAB from which the HMA Producer’s PGAB was obtained. The Engineer will also obtain and test a minimum of one random Acceptance sample of PGAB for each 12,000 ton (11,000 Mg) HMA Sublot, as defined in Table 450.17, to determine conformance with AASHTO M320. A minimum of two 1-quart (1-Liter) containers of PGAB will be obtained for each Acceptance sample from the HMA Producer’s tanks in accordance with AASHTO T40. All PGAB Acceptance samples will be split prior to testing and the un-tested portion of the sample will be retained for a minimum of 30 days.

(2) PG Asphalt Binder Content.

The Engineer will test each HMA Lot produced and placed for PG Asphalt Binder Content in accordance with either AASHTO T164 or T308. When AASHTO T164 is used, the test results will be reported prior to ash correction. The Sublot size and minimum frequency of Acceptance testing for PG Asphalt Binder Content will be as specified in Table 450.17. Each material sample for PG Asphalt Binder Content will be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

Table 450.17 - Department Acceptance Sampling and Testing of HMA Lots

Quality Characteristic	Test Method(s)	Sublot Size	Minimum Test Frequency	Point of Sampling	Sampling Method
PG Asphalt Binder Grading	AASHTO M320	12,000 tons (11,000 Mg) of HMA using same PG Grade	1 per Sublot	From Tank Valve at HMA Plant	Random AASHTO T40
PG Asphalt Binder Content	AASHTO T164 or AASHTO T308	600 tons (550 Mg)	1 per Sublot sampled per Subsection 450.74A ⁽¹⁾	From Haul Vehicle at HMA Plant	Random AASHTO T168
Volumetrics: Air Voids	AASHTO T245	600 tons (550 Mg)	1 per Sublot sampled per Subsection 450.74A ⁽¹⁾	From Haul Vehicle at HMA Plant	Random AASHTO T168
In-place HMA Mat Density (Cores)	AASHTO T269 AASHTO T230 AASHTO T209 AASHTO T166	600 tons (550 Mg)	1 per Sublot sampled per Subsection 450.74A ⁽¹⁾	From Compacted HMA Course	Random AASHTO T269
In-place HMA Mat Density (Bridge Courses)	ASTM D2950 or AASHTO TP68	150 tons (140 Mg)	1 per Sublot sampled per Subsection 450.74A	From Compacted HMA Course	Random ASTM D2950 or AASHTO TP68
Thickness	AASHTO T269	600 tons (550 Mg)	1 per Sublot sampled per Subsection 450.74A ⁽¹⁾	From Compacted HMA Course	Random AASHTO T269
Ride Quality (IRI)	AASHTO PP52 per Subsection 450.65F(11)	0.1 miles (160 meters) per each Wheel Path	1 Per Sublot	Each Pavement Course per Subsection 450.65F(11)	Random per Subsection 450.65F(11)

(1) In the event that the total daily HMA production is less than one Sublot but greater than 150 tons (140 Mg), a minimum of one random Acceptance sample shall be obtained for the day's production.

(3) Volumetrics (Air Voids).

The Engineer will test each HMA Lot produced and placed for Volumetrics (Air Voids) in accordance with AASHTO T245. The requirement for Volumetric testing of laboratory compacted specimens applies to HMA mixtures for all pavement courses, with the exception of Open Graded Friction Courses and Base Courses. The Sublot size and minimum frequency of Acceptance testing for Volumetrics will be as specified in Table 450.17. Each material sample for Volumetrics will be obtained at the HMA plant from a randomly selected quadrant from the haul vehicle in accordance with ASTM D3665 and AASHTO T168.

(4) In-Place HMA Mat Density.

The Engineer will test each HMA Lot produced and placed for In-place HMA Mat Density. The requirement for In-Place Density testing applies to all pavement courses, with the exception of Open Graded Friction Courses and Leveling Courses, as outlined below.

(a) Testing In-Place Density by Cores. Acceptance testing of HMA pavement courses (other than bridge courses) for In-place Density will be performed using cores in accordance with the procedures outlined in Subsection 450.65F(8)(b). The Sublot size and minimum frequency of Acceptance testing for In-place Density of HMA pavement courses by core will be as specified in Table 450.17.

(b) Testing In-Place Density by Density Gauge. Acceptance testing of all HMA Bridge Protective Courses and Bridge Surface Courses for In-place Density will be performed using a density gauge in accordance with the procedures outlined in Subsection 450.65F(8)(a). The Sublot size and minimum frequency of Acceptance testing for In-place Density of HMA bridge courses by density gauge will be as specified in Table 450.17.

(5) Thickness.

Each HMA pavement course specified to be placed at a compacted thickness of 1 inch (25mm) or greater, with the exception of the HMA pavement courses identified in Subsection 450.65F(9), will be tested by the Owner for Thickness using cores. Acceptance sampling and testing for Thickness of the applicable pavement courses shall be in accordance with AASHTO T269. The Sublot size and minimum frequency of Acceptance testing for Thickness will be as specified in Table 450.17.

(6) Ride Quality.

Department Acceptance testing for Ride Quality will be required for all projects having a posted speed equal to or greater than 40 mph (65 km/hr) with HMA Lots falling under Lot Category A or Category B. The Engineer will perform Ride Quality testing on the final HMA pavement course placed (either Surface Course or OGFC-P, when specified) for all mainline travel lanes, auxiliary lanes, ramps, and side road travel lanes using an inertial profiler in accordance with the procedures outlined in Subsection 450.65F(11). Pavement courses and surfaces that are specifically excluded from Acceptance testing for Ride Quality are as specified in Subsection 450.65F(11)(b). The Sublot size and minimum frequency of Acceptance testing for Ride Quality will be as specified in Table 450.17.

The inertial profiler equipment used to perform Acceptance testing will be certified and correlated by the Department in accordance with the requirements and procedures outlined in Subsection 450.65F(11). The Department Acceptance data and Design-Builder QC data will be correlated and normalized using statistical procedures. The normalization of data will be based on the measurement difference/bias from the Department Reference Profiling Device determined during the device correlation conducted at the Profiling Center by UMass Dartmouth. The Department will provide software and procedures to perform the data normalization. The normalized Acceptance Ride Quality data and QC Ride Quality data will be used to determine the quality level (PWL) and corresponding pay for each Lot.

450.75 Split Sample Correlation.

Split Sample Correlation is an important part of the Department acceptance system for HMA Category A Lots and Category B Lots. Split Sample Correlation shall be performed when Validated Design-Builder QC test data is to be included in the acceptance determination. The purpose of Split Sample Correlation testing is to identify and eliminate any discrepancies in testing procedures or equipment that could result in significant differences between the Design-Builder’s QC testing results and the Owner’s Acceptance testing results.

Either prior to or on the first day of production and placement of any HMA Category A Lot or Category B Lot, the Design-Builder and the Department will conduct Split Sample Correlation. The Engineer or the Design-Builder may also request that Split Sample Correlation be performed at any time during HMA Lot production and placement. Department IA personnel may also test a split of the Correlation samples.

Split Sample Correlation will be performed on split material samples for those Quality Characteristics identified in Table 450.18. Correlation samples for HMA mixture testing shall be either laboratory prepared specimens or plant produced HMA specimens. Samples for HMA Category A Lots may be obtained from the Control Strip Lot. Correlation testing of the Design-Builder’s QC ride quality testing equipment and the Department’s Acceptance ride quality testing equipment will be performed in accordance with Subsection 450.65F(11)(c).

Table 450.18 Split Sample Correlation Allowable Differences

Quality Characteristic	Allowable Difference Between Design-Builder and Department Split Samples
Maximum Theoretical Specific Gravity (Gmm)	+/- 0.020
Bulk Specific Gravity (Gmb)	+/- 0.030
PG Asphalt Binder Content	+/- 0.4%
Volumetrics - Air Voids	+/- 1.4%
In-Place HMA Mat Density	+/- 1.4%
Thickness	+/- 10 %
Ride Quality (IRI)	Per Subsection 450.65F(11)(c)

If the Design-Builder’s Split Sample Correlation results differ from the Department’s results by more than the allowable differences specified in Table 450.18, then the Design-Builder and the Department shall determine and resolve the reasons for the differences prior to the start or continuation of HMA Lot production and placement.

450.76 Lot Acceptance Determination Based on Inspection Results.

The Department's Acceptance Inspection results will be used in the final acceptance determination for all HMA Lots (Lot Category A, B, and C). Prior to final acceptance of each HMA Lot produced and placed, the Department will periodically evaluate all Acceptance inspection information for the prepared underlying surface and the Lot. The materials and product workmanship for the completed Work will be evaluated for conformance with the plans and the requirements specified in Subsections 450.53 thru 450.58.

When the Acceptance information identifies deficiencies in either material quality or product workmanship for any underlying surface location or HMA Sublot(s), the location or Sublot(s) will be isolated and further evaluated by the Owner through additional Acceptance inspection (or sampling and testing, if relevant or possible). Depending upon the findings of the additional Acceptance inspection activity, the Owner will determine the disposition of the nonconforming Work in accordance with Division I, Subsection 5.03, Conformity with Plans and Specifications.

After each HMA Lot (and corresponding prepared underlying surface) is complete, including any corrective action, the Owner will evaluate all Acceptance inspection information for the Work. The Department will accept the subject Work if the Owner's evaluation of all inspection information for the completed Lot (and underlying surface) indicates that the corresponding materials and product workmanship meet the specified requirements (provided the evaluation of all Acceptance testing data for the subject Work per Subsection 450.77 also finds the Work to be acceptable).

450.77 Lot Acceptance Determination Based on Testing Data.

A. Evaluation of Lot Category A Testing Data.

Prior to final acceptance of each HMA Category A Lot produced and placed, the Owner will periodically evaluate all available Department Acceptance testing data for the Lot.

The Design-Builder's random QC testing data for each Lot will be included with the Department's random Acceptance testing data in the acceptance determination, provided that the QC data has been Validated in accordance with paragraph (1) below. The Department's Acceptance data and all Validated Design-Builder QC data will be evaluated using the Quality Limits specified in Table 450.19 and as further outlined below.

(1) Validation of Design-Builder QC Test Results.

Validation is defined as the mathematical comparison of two independently obtained sets of data to determine whether it can be assumed they came from the same Population. The Validation of each HMA Lot will be performed through a statistical comparison of the Owner's random Acceptance testing data and the Design-Builder's random QC testing data for the Lot.

The statistical comparison of testing data will be made using the test result Variances (*F-test*) and the test result Means (*t-test*) at a significance level of 0.01 and in accordance with the procedures contained in Appendix F the *AASHTO Implementation Manual For Quality Assurance* (February 1996). The Validation worksheet in the Department's MS-Excel QA Data Spreadsheets will be used to perform the Validation of each Lot.

If the Validation results indicate that the Design-Builder's QC test results and the Department's Acceptance test results can be assumed to be from the same Population, then the Design-Builder's QC test results will be included with the Department's Acceptance test results in the final acceptance determination for each Lot.

If the Validation results indicate that the Design-Builder's QC test results and the Department's Acceptance test results cannot be assumed to be from the same Population, then the Department will endeavor to determine the reason for the difference between the two data sets. If a reason for the difference cannot be determined, then only the Department's Acceptance test results will be used in the final acceptance determination for each Lot.

(2) Conformance with Engineering Limits.

The Engineer will evaluate all Department Acceptance testing data and Validated Design-Builder QC testing data for each Category A Lot to determine conformance with the Owning Limits in Table 450.19. Each Sublot test value for the Acceptance Quality Characteristics identified in Table 450.19 shall be within the Owning Limits.

If a Sublot test result is outside of the Owning Limits, the Owner will further assess the Sublot quality to determine whether the material in the Sublot can remain in place. The Engineer will isolate the Sublot and perform selective sampling followed by additional random sampling (if possible) within the Sublot to quantify the actual quality of the Sublot. The Engineer will determine the disposition of the Sublot in accordance with Division I, Subsection 5.03, Conformity with Plans and Specifications. If the Owner's assessment determines that the material quality is sufficient to permit the Sublot to remain in place without corrective action, all random testing data for the Sublot (including the original out of Engineering Limit test result) will be included in the Quality Level Analysis for the Lot in accordance with paragraph (3) below.

When a nonconforming Sublot is corrected or replaced, the Owner will perform Acceptance testing of the Sublot and evaluate the test results for conformance with the Owning Limits. The Acceptance test data for the corrected Sublot will replace the original Acceptance test result and will be included in the Quality Level Analysis for the Lot in accordance with paragraph (3) below. Once the above requirements have been met, the Department will accept all completed Sublots, provided that the overall Lot quality is above the Acceptance Limit as further outlined below.

(3) Analysis of Lot Quality Level.

For each HMA Category A Lot, the Owner will determine the Lot Quality Level, for the applicable Quality Characteristics in Table 450.19, using the Quality Level Analysis (QLA) procedures outlined in Subsection 450.78. The QLA procedure will evaluate all Department Acceptance testing data and Validated Design-Builder QC testing data using the Specification Limits in Table 450.19. The Department's MS-Excel QA Data Spreadsheets will be used to perform the QLA for each Lot.

All random test results that are within the Owning Limits will be included in the Quality Level Analysis. Individual Sublot test results that are beyond the Owning Limits, but for which the corresponding Sublot is permitted to remain in place per paragraph (2) above, will also be included in the Quality Level Analysis.

The QLA procedure will determine the Percent Within Limits (PWL) for each Lot. The Acceptance Limit (Rejectable Quality Level) for each completed Lot is 60 PWL. Each Lot must achieve a final Quality Level of at least 60 PWL in order to be accepted by the Department.

If the final computed Lot Quality Level is at 90 PWL, the Design-Builder will receive full payment at the unit bid price for the Lot. If the Lot Quality Level is greater than 90 PWL, the Design-Builder will receive an incentive pay adjustment for the Lot in accordance with Subsection 450.92. If the Lot Quality Level is less than 90 PWL but greater than or equal to 60 PWL, the Design-Builder will receive a disincentive pay adjustment for the Lot. If the final computed Lot Quality Level is below 60 PWL, the Lot will not be accepted. Payment for the Lot will be withheld and the Design-Builder shall submit a corrective action plan within 14 days following determination of the Lot PWL. The Engineer will review the corrective action plan and render a decision within 14 days of receipt of the corrective action plan. If the Owner determines that the Lot or some of the Sublots cannot remain in place, the Design-Builder shall remove and replace

the affected Lot or Sublots. If the Owner allows the Lot to remain in place, payment will be limited to a maximum of 75% of the bid price for the item.

(4) Final Lot Acceptance Determination.

After each HMA Category A Lot is complete, including any corrective action, the Owner will perform a final evaluation of all Department Acceptance data and Validated Design-Builder QC data for the Lot. The Department will accept the subject Lot if the Owner's evaluation of all testing data for the Lot is in conformance with the applicable Quality Limits as outlined in paragraph (2) and paragraph (3) above.

Table 450.19 - Quality Limits for Acceptance of HMA Lots

Quality Characteristic	Target	Specification Limits		Engineering Limits		Acceptance Limit
		LSL	USL	LEL	UEL	
PG Asphalt Binder Grading	Per Binder Grade specified	N/A	N/A	Per AASHTO M320	Per AASHTO M320	N/A
PG Asphalt Binder Content	Per JMF	Target - 0.3 %	Target + 0.3 %	Target - 0.4 %	Target + 0.4 %	60 PWL
Volumetrics: Air Voids	4 %	2.7 %	5.3 %	2 %	6 %	60 PWL
In-Place HMA Mat Density (Cores)	95 % of G _{mm}	92.5 % of G _{mm}	97.5 % of G _{mm}	92 % of G _{mm}	98 % of G _{mm}	60 PWL
In-Place HMA Mat Density (Bridge Courses)	95 % of G _{mm}	N/A	N/A	90 % of G _{mm}	N/A	N/A
Thickness: (All Courses 1 inch (25mm) or greater)	Per Plans	-20 % of Target Thickness	+20 % of Target Thickness	-30 % of Target Thickness	+30 % of Target Thickness	60 PWL
Ride Quality: Greater than or equal to 55 mph (90 km/hr)	50 in/mile (0.79 m/km)	N/A	70 in/mile (1.10 m/km)	N/A	80 in/mile (1.26 m/km)	60 PWL
Ride Quality: 40mph (65 km/hr) to 55 mph (90 km/hr)	70 in/mile (1.10 m/km)	N/A	100 in/mile (1.58 m/km)	N/A	110 in/mile (1.74 m/km)	60 PWL
Ride Quality: Less than 40 mph (65 km/hr)	Not subject to ride testing					

B. Evaluation of Lot Category B Testing Data.

Prior to final acceptance of each HMA Category B Lot produced and placed, the Owner will periodically evaluate all available Department Acceptance testing data for the Lot.

The Design-Builder's random QC testing data for each Lot will be included with the Department's random Acceptance testing data in the acceptance determination, provided that the QC data has been Validated. The Department's Acceptance data and all Validated Design-Builder QC data will be evaluated for conformance with Engineering Limits and for Lot Quality Level in accordance with the requirements of Subsection 450.77A above using the applicable Quality Limits specified in Table 450.19.

After each HMA Category B Lot is complete, including any corrective action, the Owner will perform a final evaluation of all Department Acceptance data and Validated Design-Builder QC data for the Lot. The Department will accept the subject Lot if the Owner's evaluation of all testing data for the Lot is in conformance with the applicable Quality Limits.

C. Evaluation of Lot Category C Testing Data.

For each HMA Category C Lot produced and placed, the Owner will evaluate all Department Acceptance testing data for the Lot entered into the Department's MS-Excel QA Data Spreadsheets after all HMA Sublots are complete in-place. The Design-Builder's random QC testing data for each Lot will not be included with the Department's random Acceptance testing data in the acceptance determination. The individual Sublot test results for each HMA Category C Lot will be evaluated against the Specification Limits contained in Table 450.19 (Note: the Owning Limits are not applied since the inherent variability for Minor Lot quantities is expected to be within the Specification Limits). Work under HMA Lot Category C will not be subject to an evaluation of Lot Quality Level using QLA procedures.

If a Sublot test result is outside of the Specification Limits, the Owner will further assess the Sublot quality in accordance with the requirements of Subsection 450.77A(2). The Engineer will determine the disposition of the Sublot in accordance with Division I, Subsection 5.03, Conformity with Plans and Specifications.

After each HMA Category C Lot is complete, including any corrective action, the Owner will perform a final evaluation of all Department Acceptance data. The Department will accept the subject Lot if the Owner's evaluation of the testing data for each Sublot is in conformance with the Specification Limits.

450.78 Quality Level Analysis Procedures.

For each Quality Characteristic subject to analysis of Lot Quality Level, the Quality Level Analysis (QLA) - Standard Deviation Method will be used to determine the percentage of the Lot that is within the Specification Limits. The number of significant figures retained in each step of the QLA calculations and the rounding of all reported values will be as established in the Department's MS Excel QA Data Spreadsheets. The estimated percentage of Work that is within the Specification Limits for a given Lot will be determined as follows:

A. Step 1 – Determine Lot Mean.

The Mean (\bar{X}) will be determined for each Lot using all random Department Acceptance sample test values and all random Design-Builder QC sample test values (provided they have been Validated). The Mean is calculated using the following equation:

Where: Σ = summation of
 x = individual test value of each material sample
 n = total number of material samples tested

B. Step 2 – Determine Lot Standard Deviation.

The Standard Deviation (s) will be determined for each Lot using all random Department Acceptance sample test values and all random Design-Builder QC sample test values (provided they have been Validated). The Standard Deviation is calculated using the following equation:

Where: $\Sigma(x^2)$ = summation of the squares of individual test values
 $(\Sigma x)^2$ = summation of the individual test values squared

C. Step 3 – Determine Upper Quality Index for Lot.

The Upper Quality Index (Q_U) will be determined for each Lot using the Lot Mean and Lot Standard Deviation calculated in Step 1 and Step 2 above. The Upper Quality Index is calculated using the following equation:

Where: USL = Upper Specification Limit from Table 450.19
 \bar{X} = The Lot Mean
 s = The Lot Standard Deviation

D. Step 4 – Determine Lower Quality Index for Lot.

The Lower Quality Index (Q_L) will be determined for each Lot using the Lot Mean and Lot Standard Deviation calculated in Step 1 and Step 2 above. The Upper Quality Index is calculated using the following equation:

Where: LSL = Lower Specification Limit from Table 450.19

X = The Lot Mean

s = The Lot Standard Deviation

E. Step 5 – Determine Percentage of Lot Below Upper Specification Limit.

The estimated percentage of the Lot falling below the Upper Specification Limit (P_U) will be determined using Table 450.20. The P_U value is determined from the table by entering the column for the number of material samples (n) representing the Lot and locating the row that corresponds to the Q_U value determined in Step 3 above. If no USL is specified in Table 450.20, the P_U value is equal to 100.

F. Step 6 – Determine Percentage of Lot Above Lower Specification Limit.

The estimated percentage of the Lot falling above the Lower Specification Limit (P_L) will be determined using Table 450.20. The P_L value is determined from the table by entering the column for the number of material samples (n) representing the Lot and locating the row that corresponds to the Q_L value determined in Step 4 above. If no LSL is specified in Table 450.20, the P_L value is equal to 100.

G. Step 7 – Determine Estimated Percent Within Limits for Lot.

The Lot Quality Level will be determined by estimating the Percent Within Limits (PWL). The PWL is determined using the P_U value from Step 5 and the P_L value from Step 6 above. The Percent Within Limits is calculated using the following equation:

$$PWL = (P_U + P_L) - 100$$

Table 450.20 - Values for Estimating Percent of Lot Within Specification Limits

P _U Or P _L (%)*	Upper Quality Index (Q _U) or Lower Quality Index (Q _L)														
								n = 10	n = 12	n = 15	n = 19	n = 26	n = 38	n = 70	n = 201
	n = 3	n = 4	n = 5	N = 6	n = 7	n = 8	n = 9	to n = 11	to n = 14	to n = 18	to n = 25	to n = 37	to n = 69	to n = 200	to n = ∞
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99		1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97		1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95		1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93		1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.07	1.14	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.96	0.93	0.91	0.90	0.90	0.89	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.67
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.65	0.65	0.64	0.64
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.58	0.58
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.52
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.32	0.27	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.20
57	0.25	0.21	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.22	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
55	0.18	0.15	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: If the calculated value of Q_U or Q_L does not correspond exactly to a value in the table, use the next lower value.

If Q_U or Q_L are negative values, P_U or P_L is equal to 100 minus the table value for P_U or P_L.

* P_U or P_L = Percent Within limits for positive values of Q_U or Q_L.

DISPUTE RESOLUTION

450.80 Disputable items

The Design-Builder or the Department may dispute any of the test values that are utilized in the acceptance determination for a given Lot. The specific Quality Characteristics which may be disputed are as listed in Table 450.21 below. All disputes shall be initiated within the 30 day split sample retention time limit as specified in Subsection 450.82 below.

450.81 Basis for Dispute

Differences from one individual Design-Builder QC test value to another (or from one individual Department Acceptance test value to another) within a Lot are expected due to inherent variability. Differences are also expected between the QC test values and the Acceptance values for a given Lot as a result of inherent variability. An individual QC test value cannot be directly compared to an individual Acceptance test value since the samples are randomly obtained independent of one another. However, if one or more of the Design-Builder's random QC test values for a Lot significantly differs from the Department's Acceptance test values for the same Lot, either party may dispute the validity of an individual test value.

450.82 Dispute Resolution Samples

Samples used for Dispute Resolution testing shall be the split samples required to be retained for thirty (30) days by the Design-Builder and the Department in accordance with Subsection 450.65D and Subsection 450.74E. Original cores are to be retained and shall be protected from damage. If In-place density or thickness is disputed, then the original core, unless damaged, will be used in the Dispute Resolution process. If the original disputed core is damaged, then a new core shall be obtained from within a 2-foot (600mm) radius of the location of the original core by the party whose data is being disputed in the presence of the other party. If ride quality smoothness test data is disputed, then the disputed Sublot(s) shall be re-sampled/retested by the party whose data is being disputed in the presence of the other party.

450.83 Dispute Resolution Steps

The Design-Builder may dispute the Department's Acceptance results and the Department may dispute the Design-Builder's Quality Control results by requesting that the dispute resolution split sample be tested. Such a request, either from the Design-Builder or the Department, must be made in writing within five days after the original sample was obtained. The following shall be provided in the written request:

- Sample reference number, including Lot and Sublot
- The specific Quality Characteristic and test result(s) being disputed
- The complete NETTCP test report form containing the disputed results

A. Step 1 – Split Sample Correlation.

Immediately prior to conducting testing for Dispute Resolution, the Design-Builder's QC testing personnel, the Department's Acceptance testing personnel (from the District), and a Department Independent Assurance (IA) technician will conduct Split Sample Correlation testing as detailed in Subsection 450.75. Split Sample Correlation testing will be conducted on a separate material sample obtained independent from the original sample and the Dispute Resolution sample.

The purpose of the Split Sample Correlation testing is to determine if testing procedures or equipment utilized by the Design-Builder or the Department might be the cause of the disputed result(s).

B. Step 2 – Dispute Resolution Sample Testing.

If a Department Acceptance test value is being disputed, the Department’s Acceptance testing personnel (from the District) will test the Dispute Resolution split sample. If a Design-Builder QC test value is being disputed, the Design-Builder’s QC testing personnel will test the Dispute Resolution split sample. In either case, testing of the Dispute Resolution split sample shall be performed by the same Design-Builder QC testing personnel and Department Acceptance testing personnel that performed the split sample correlation in step 1 above. Testing of the Dispute Resolution split sample shall be performed in the presence of both the Design-Builder and the Department.

C. Step 3 – Additional Dispute Resolution Testing.

If either the Design-Builder or the Department believes that the results of the Dispute Resolution split sample testing in Step 2 above do not conclusively resolve the dispute, additional sampling and testing within the disputed Sublot may be requested. In such case, an independent AASHTO accredited laboratory will be utilized to obtain and test three (3) random samples from the disputed Sublot. The Mean of the three test results will be used as the Dispute Resolution test value.

450.84 Final Disposition.

If the difference between the original test value and the Dispute Resolution test value (as determined under either Step 2 or Step 3 above) is within the maximum test difference values listed in Table 450.21, then the original test value will be used in the acceptance determination for the Lot. If the difference between the original test value and the Dispute Resolution test value exceeds the maximum difference values in Table 450.21, then the Dispute Resolution test value will be used in the acceptance determination. In such case, the record of the original test value will be retained (with notation of the outcome of Dispute Resolution); however, it will not be used in calculating the Lot quality level.

Table 450.21 – Dispute Resolution Maximum Test Difference Values

Quality Characteristic	Maximum Test Difference
Maximum Specific Gravity (G_{mm})	+/- 0.020
Bulk Specific Gravity (G_{mm})	+/- 0.030
PG Asphalt Binder Content	+/- 0.4
Volumetrics - Air Voids	+/- 1.4
In-place HMA Mat Density	+/- 1.4
Thickness	+/- 10% of original value
Ride Quality (IRI)	+/- 10% of original value

450.90 — Method of Measurement.**A. Patching.**

HMA for Patching will be measured for payment by the ton (Megagram) and shall be the actual quantity complete, in place and accepted by the Owner.

B. Tack Coat.

Asphalt Emulsion for Tack Coat, as required by the plans or these specifications, will be measured by the gallon (liter).

C. Joint Sealer.

HMA Joint Sealant used for sealing all longitudinal joints and transverse joints in HMA pavement courses will be measured by the linear foot (linear meter).

D. Hot Mix Asphalt.

Hot Mix Asphalt pavement course mixtures will be measured by the ton (Megagram) and shall be the actual pavement course quantity complete, in place and accepted by the Owner. The quantity shall be determined only by weight slips that have been properly countersigned by the Owner at the time of delivery.

E. Design-Builder Quality Control.

The Design-Builder's Quality Control system as specified in Subsection 450.60 through Subsection 450.69 will be measured by the ton (Megagram) and shall be represented by the actual quantity of HMA for Patching and all HMA pavement courses complete, in place and accepted by the Owner.

450.91 — Basis of Payment.**A. Patching.**

HMA for Patching will be paid for at the contract unit price per ton (Megagram) of the HMA mixture type specified under Pay Item 451. Payment shall include all sawcutting, removal of existing distressed or unsound pavement, applying hot poured rubberized asphalt sealant to vertical faces, and transportation, delivery, placement, and compaction of HMA for Patching in accordance with Subsection 450.53C.

B. Tack Coat.

Asphalt Emulsion for Tack Coat will be paid for at the contract unit price per gallon (liter) of applied tack coat under Pay Item 452. Payment shall include sweeping existing surfaces and applying the tack coat to all required surfaces at the specified rate in accordance with Subsection 450.53F.

C. Joint Sealer.

HMA Joint Sealant will be paid for at the contract unit price per linear foot (linear meter) of joint sealed under Pay Item 453. Payment shall include application of the joint sealer to all longitudinal joints and transverse joints in HMA pavement courses as required and in accordance with Subsection 450.57.

D. Hot Mix Asphalt.

Each Hot Mix Asphalt pavement course will be paid for at the contract unit price per ton (Megagram) of in-place mixture under the HMA Pay Items specified (Pay Items 450.10 through 450.70). Payment shall include sweeping the underlying surface, transportation, delivery, placement (including providing a MTV when required), and compaction of each HMA pavement course in accordance with Subsection 450.54 through Subsection 450.58. All sawcutting required for transverse joints or longitudinal joints in accordance with Subsection 450.57 shall also be included in the contract unit price for each HMA pavement course.

E. Design-Builder Quality Control.

The Design-Builder's Quality Control system will be paid for at the contract unit price per ton (Megagram) under Pay Item 450.90. Payment will be full compensation for all QC activities required under Subsection 450.50 through Subsection 450.69 including; the Construction Quality Meeting, providing the field reference system, preparing and maintaining the approved Quality Control Plan, preparing all HMA mixture designs, performing QC sampling, testing and inspection (including the Control Strip when required), evaluating all QC data, and maintaining proper QC records. No separate payment will be made for any assistance provided by the Design-Builder to the Owner in obtaining Department Acceptance samples. Failure of the Design-Builder to perform adequate Quality Control in accordance with the specifications and the Design-Builder's approved QC Plan will be justification for withholding payment.

450.92 — Pay Adjustment (PA).

Payment for each HMA Category A Lot and Category B Lot will be determined based on the final Lot Quality Level (PWL) computed in accordance with the QLA procedures contained in Subsection 450.78. Pay adjustments will be determined for each of the Acceptance Quality Characteristics identified in Table 450.22. The relative pay adjustment weight assigned to each of the HMA Quality Characteristics is indicated in Table 450.22.

Table 450.22 – Pay Adjustment Weight Assigned to HMA Quality Characteristics

HMA Quality Characteristics	Pay Adjustment Weight
PG Asphalt Binder Content	10 percent
Volumetrics – Air Voids	25 percent
In Place HMA Mat Density	25 percent
Thickness	10 percent
Ride Quality (IRI)	30 percent

A. Lot Pay Factor.

A Pay Factor (PF) will be determined for each HMA Lot using the Quality Level (PWL) computed for the Lot and the equation below:

$$PayFactor(PF) = \frac{55 + 0.5(QualityLevel)}{100}$$

The Lot Pay Factor will be used to determine the pay adjustment for each Quality Characteristic as further outlined below.

B. Pay Adjustment for PG Asphalt Binder Content.

Pay adjustment for PG Asphalt Binder Content shall be applied to Pay Item 999.490 at the completion of the HMA Lot. The total Lot pay adjustment for PG Asphalt Binder Content will be determined as follows:

$$PA_{PGAB} = \sum(PF_i - 1)(Q_i)(P_i)(0.10)$$

Where: PA_{PGAB} = Pay adjustment in dollars for PG Asphalt Binder Content.

PF_i = Pay factor based on Quality Level (PWL) of PG Asphalt Binder Content for individual Lot (i).

Q_i = Quantity represented by individual Lot (i) in tons (Mg).

P_i = Contract unit price per ton (Mg) for individual Lot (i).

0.10 = Weight given to PG Asphalt Binder Content pay adjustment

C. Pay Adjustment for Volumetrics (Air Voids).

Pay adjustment for Volumetrics (Air Voids) shall be applied to Pay Item 999.491 at the completion of the HMA Lot. The total Lot pay adjustment for Volumetrics (Air Voids) will be determined as follows:

$$PA_{Air\ Voids} = \sum(PF_i - 1)(Q_i)(P_i)(0.25)$$

Where: $PA_{Air\ Voids}$ = Pay adjustment in dollars for Volumetrics (Air Voids).

PF_i = Pay factor based on Quality Level (PWL) of Volumetrics (Air Voids) for individual Lot (i).

Q_i = Quantity represented by individual Lot (i) in tons (Mg).

P_i = Contract unit price per ton (Mg) for individual Lot (i).

0.25 = Weight given to Volumetrics (Air Voids) pay adjustment

D. Pay Adjustment for In-Place HMA Mat Density.

Pay adjustment for In-Place HMA Mat Density shall be applied to Pay Item 999.492 at the completion of the HMA Lot. The total Lot pay adjustment for In-Place HMA Mat Density will be determined as follows:

$$PA_{In-Place\ Density} = \sum(PF_i - 1)(Q_i)(P_i)(0.25)$$

Where: $PA_{In-Place\ Density}$ = Pay adjustment in dollars for In-Place HMA Mat Density.

PF_i = Pay factor based on Quality Level (PWL) of In-Place HMA Mat Density for individual Lot (i).

Q_i = Quantity represented by individual Lot (i) in tons (Mg).

P_i = Contract unit price per ton (Mg) for individual Lot (i).

0.25 = Weight given to In-Place HMA Mat Density pay adjustment

E. Pay Adjustment for Thickness.

Pay adjustment for Thickness shall be applied to Pay Item 999.493 at the completion of the HMA Lot. The total Lot pay adjustment for Thickness will be determined as follows:

$$PA_{Thickness} = \sum (PF_i - 1) (Q_i)(P_i) (0.10)$$

- Where: $PA_{Thickness}$ = Pay adjustment in dollars for Thickness.
- PF_i = Pay factor based on Quality Level (PWL) of Thickness for individual Lot (i).
- Q_i = Quantity represented by individual Lot (i) in tons (Mg).
- P_i = Contract unit price per ton (Mg) for individual Lot (i).
- 0.10 = Weight given to Thickness pay adjustment.

B. Pay Adjustment for Ride Quality.

Pay adjustment for Ride Quality shall be applied to Pay Item 999.494 at the completion of all HMA Lots. Although Ride Quality Acceptance testing will be performed only on the final pavement course, the pay adjustment will be applied to the total quantity of all HMA pavement courses placed. Since each wheel path of the final pavement course represents a Lot for Ride Quality, the quantity for each Lot shall be computed by dividing the total quantity of all pavement courses placed by the number of wheel paths for all lanes tested in the final pavement course. The total Lot pay adjustment for Ride Quality will be determined as follows:

$$PA_{Ride\ Quality} = \sum (PF_i - 1) (\sum (Q_{pe})(P_{pe})) / N_{wp} (0.30)$$

- Where: $PA_{Ride\ Quality}$ = Pay adjustment in dollars for Ride Quality.
- PF_i = Pay factor based on Quality Level (PWL) of Ride Quality for individual Lot (i).
- Q_{pe} = Quantity represented by individual pavement course (pe) in tons (Mg).
- P_{pe} = Contract unit price per ton (Mg) for individual pavement course (pe).
- N_{wp} = Total number of wheel paths for all lanes tested.
- 0.30 = Weight given to Ride Quality pay adjustment.

450.93	Payment Items	Payment Unit
450.10	Open Graded Friction Course—Polymer Modified (OGFC P)	Ton (Megagram)
455.21	SUPERPAVE Surface Course—4.75 (SSC—4.75)	Ton (Megagram)
455.22	SUPERPAVE Surface Course—9.5 (SSC—9.5)	Ton (Megagram)
455.23	SUPERPAVE Surface Course—12.5 (SSC—12.5)	Ton (Megagram)
455.24	SUPERPAVE Surface Course—19.0 (SSC—19.0)	Ton (Megagram)
455.31	SUPERPAVE Intermediate Course—12.5 (SIC—12.5)	Ton (Megagram)
455.32	SUPERPAVE Intermediate Course—19.0 (SIC—19.0)	Ton (Megagram)
455.41	SUPERPAVE Base Course—25.0 (SBC—25.0)	Ton (Megagram)
455.42	SUPERPAVE Base Course—37.5 (SBC—37.5)	Ton (Megagram)
455.51	SUPERPAVE Leveling Course—4.75 (SLC—4.75)	Ton (Megagram)
455.52	SUPERPAVE Leveling Course—9.5 (SLC—9.5)	Ton (Megagram)
455.53	SUPERPAVE Leveling Course—12.5 (SLC—12.5)	Ton (Megagram)
455.60	SUPERPAVE Bridge Surface Course—9.5 (SSC B—9.5)	Ton (Megagram)
455.61	SUPERPAVE Bridge Surface Course—12.5 (SSC B—12.5)	Ton (Megagram)
455.70	SUPERPAVE Bridge Protective Course—9.5 (SPC B—9.5)	Ton (Megagram)
455.71	SUPERPAVE Bridge Protective Course—12.5 (SPC B—12.5)	Ton (Megagram)
450.90	Design Builder Quality Control	Ton (Megagram)
451	HMA for Patching	Ton (Megagram)
452	Asphalt Emulsion for Tack Coat	Gallon (Liter)
453	HMA Joint Sealant	Linear Foot (Meter)
999.490	HMA Pay Adjustment—PG Asphalt Binder Content [†]	Dollar
999.491	HMA Pay Adjustment—Volumetrics (Air Voids) [†]	Dollar
999.492	HMA Pay Adjustment—In place Mat Density [†]	Dollar
999.493	HMA Pay Adjustment—Thickness [†]	Dollar
999.494	HMA Pay Adjustment—Ride Quality [†]	Dollar

[†]Not a bid item

SECTION 455
SUPERPAVE HOT MIX ASPHALT PAVEMENT

Section 455 - SUPERPAVE Hot Mix Asphalt Pavement amends Section 450 - Hot Mix Asphalt Pavement. The provisions herein replace the Subsections of Section 450 as indicated.

NOTE: The Pay Adjustment provisions included in Subsection 450.92 will be applied to items under this contract.

DESCRIPTION

Delete Subsection 450.20 - General and replace with the following:

455.20 General.

This work shall consist of producing and placing Hot Mix Asphalt (HMA) pavement. All HMA mixtures shall meet the requirements of the SUPERPAVE volumetric design system. The HMA pavement shall be constructed in courses on the prepared or existing base in accordance with these specifications and in conformance with the lines, grades, compacted thickness and typical cross section as shown on the plans. Each SUPERPAVE HMA pavement course placed shall be comprised of one of the mixture types listed in Table 455.1.

Table 455.1 - SUPERPAVE HMA Pavement Courses & Mixture Types

Pavement Course	Mixture Type	Mixture Designation
Friction Course	<ul style="list-style-type: none"> • Open-Graded Friction Course - Polymer Modified 	OGFC – P
Surface Course	<ul style="list-style-type: none"> • SUPERPAVE Surface Course - 4.75 • SUPERPAVE Surface Course - 9.5 • SUPERPAVE Surface Course - 12.5 • SUPERPAVE Surface Course - 19.0 	SSC - 4.75 SSC - 9.5 SSC - 12.5 SSC - 19.0
Intermediate Course	<ul style="list-style-type: none"> • SUPERPAVE Intermediate Course - 12.5 • SUPERPAVE Intermediate Course - 19.0 	SIC - 12.5 SIC - 19.0
Base Course	<ul style="list-style-type: none"> • SUPERPAVE Base Course - 25.0 • SUPERPAVE Base Course - 37.5 	SBC - 25.0 SBC - 37.5
Leveling Course	<ul style="list-style-type: none"> • SUPERPAVE Leveling Course - 4.75 • SUPERPAVE Leveling Course - 9.5 	SLC - 4.75 SLC - 9.5
Bridge Surface Course	<ul style="list-style-type: none"> • SUPERPAVE Bridge Surface Course - 9.5 • SUPERPAVE Bridge Surface Course - 12.5 	SSC-B - 9.5 SSC-B - 12.5
Bridge Protective Course	<ul style="list-style-type: none"> • SUPERPAVE Bridge Protective Course - 9.5 • SUPERPAVE Bridge Protective Course - 12.5 	SPC-B - 9.5 SPC-B - 12.5

When a SUPERPAVE Surface Course - 19.0 (SSC - 19.0) is specified in the contract, the Laboratory Trial Mix Formula (LTMF) aggregate gradation shall provide a fine-graded HMA mixture as defined in Subsection 455.42F.

MATERIALS

Delete Subsection 450.40 - General and replace with the following:

455.40 General.

SUPERPAVE HMA mixtures shall be composed of the following: Mineral aggregate, mineral filler (if required), Performance Graded Asphalt Binder (PGAB), and as permitted, reclaimed materials (limited to Reclaimed Asphalt Pavement (RAP), Reclaimed Asphalt Shingles (RAS), and Processed Glass Aggregate (PGA)). Materials shall meet the requirements in the following Subsections of Division III, Materials and as otherwise specified herein:

Asphalt Emulsion	M3.03.0
Hot Poured Joint Sealer	M3.05.0
Asphalt Anti-Stripping Additive	M3.10.0
Mineral Aggregate	M3.11.04
Mineral Filler	M3.11.05
Plant Requirements	M3.11.07

Delete Subsection 450.42 - Hot Mix Asphalt Mix Design and replace with the following:

455.42 SUPERPAVE Hot Mix Asphalt Mixture Design.

The Design-Builder shall be responsible for development of all SUPERPAVE HMA mixture designs. All HMA surface courses, intermediate courses, base courses, leveling courses, bridge surface courses, and bridge protective courses shall be supported by volumetric mixture designs using the SUPERPAVE mixture design system. All SUPERPAVE HMA mixture designs shall be developed in accordance with the following AASHTO standards, as modified herein:

AASHTO M 323
AASHTO R 35
AASHTO T 312

Volumetric mixture designs are not required for OGFC. The aggregate gradation structure and target PG Asphalt Binder content for Open-Graded Friction Course - Polymer Modified (OGFC-P) shall conform to the master ranges in M3.11.03 – Table B.

A. Development of Laboratory Trial Mix Formula (LTMF).

The Design-Builder shall develop and submit for Department approval, a minimum of forty-five (45) days prior to the start of SUPERPAVE HMA pavement construction, a Laboratory Trial Mix Formula (LTMF) as the proposed Job Mix Formula (JMF) for each SUPERPAVE mixture type to be used on the project. Two or more JMFs per HMA mixture type may be approved for a particular plant, however, only HMA conforming to one JMF is permitted to be produced and placed on any given day.

The following is a general outline of the steps for developing an LTMF and an approved JMF:

1. Estimate Percentage of RAP to be utilized and select PG Asphalt Binder as required by the specifications (Subsection 455.42C.);
2. Evaluate aggregates (and reclaimed materials) for conformance with Consensus Properties (Subsection 455.42D.) and Source Properties (Subsection 455.42E.);
3. Develop trial aggregate blends and estimate PG Asphalt Binder content in accordance with AASHTO R 35. Compact each of the blends. Based on volumetric analysis, select the best trial blend that meets the requirements of M 323 (Subsections 455.42F and 455.42G.);
4. Determine volumetric properties of LTMF and select PG Asphalt Binder content (Subsection 455.42H.);
5. Evaluate Moisture Sensitivity of the mixture (Subsection 455.42I.);
6. LTMF to be verified in the laboratory by the Department (Subsection 455.43);
7. Through production of a Control Strip Lot, verify that LTMF can be produced through the plant. (Subsection 450.66B.). Verification of the LTMF results in an approved JMF;
8. Repeat process for all mixtures to be utilized.

B. Estimated Design Traffic.

The estimated traffic level to be used for SUPERPAVE HMA mixture designs for this contract, expressed in Equivalent Single Axle Loads (ESALs) for the design travel lane over a 20-year period, is as indicated in Part 1 GENERAL Section 1.1 DESCRIPTION OF WORK .Subsection A Paragraph 2 of this specification

C. Performance Graded Asphalt Binder.

The Asphalt Binder used for all HMA mixtures under this contract shall comply with the requirements of Subsection 450.48. The PGAB Grade selected for this Contract is as indicated in Part 1 GENERAL Section 1.1 DESCRIPTION OF WORK .Subsection A Paragraph 2 of this specification.

D. Aggregate Consensus Properties.

Aggregates utilized in SUPERPAVE HMA mixtures, including RAP if used in the mixture, shall be tested for conformance with the following Consensus Property requirements:

- Determining the Percentage of Fractured Particles in Coarse Aggregate (ASTM D 5821)
- Uncompacted Void Content of Fine Aggregate (AASHTO T 304 - Method A)
- Flat or Elongated Particles (ASTM D 4791)
- Clay Content/Sand Equivalent Test (AASHTO T 176)

The Consensus Property test results shall be submitted with the LTMF for each SUPERPAVE HMA mixture. The Design-Builder shall provide aggregate samples a minimum of forty-five (45) days prior to production for each LTMF to the Department for LTMF verification prior to SUPERPAVE HMA production. The required minimum or maximum criteria for each of the Consensus Property tests for the total aggregate blend are specified below in Table 455.2 below.

Table 455.2 - Aggregate Consensus Property Requirements

Traffic Level	Design ESALS 18-kip (80-kn)) (million)	Coarse Aggregate Angularity (1) (2) ASTM D5821 (Percent Minimum)		Fine Aggregate Angularity (1) AASHTO T 304 - Method A (Percent Minimum)		Flat or Elongated Particles (2) ASTM D4791 (Percent Maximum)	Sand Equivalent AASHTO T 176 (Percent Minimum)
		(Depth from final surface) ≤ 4 in (100 mm)	(Depth from final surface) > 4 in (100 mm)	(Depth from final surface) ≤ 4 in (100 mm)	(Depth from final surface) > 4 in (100 mm)		
-----						> # 4 (4.75 mm)	----
1	< 0.3	55/--	--/--	--	--	--	40
2	0.3 to < 3.0	75/--	50/--	40	40	10	40
3	3 to < 10	85/80	60/--	45	40	10	45
4	10 to < 30.0	95/90	80/75	45	40	10	45
5	≥ 30.0	100/100	100/100	45	45	10	50
	Design ESALS are the anticipated project traffic level expected on the design lane, projected over a 20 year period, regardless of the actual expected design life of the roadway.	Criteria presented as minimum values. 95/90 denotes that a minimum of 95% of the coarse aggregate, by mass, shall have one fractured face and that a minimum of 90% shall have two fractured faces.		Criteria presented as minimum percent air voids in loosely compacted fine aggregate passing the #8 (2.36 mm) sieve.		Criteria presented as maximum percent by mass of flat or elongated particles of materials retained on the #4 (4.75 mm) sieve, determined at 5:1 ratio.	Criteria presented as minimum values for fine aggregate passing the #4 (4.75 mm) sieve.

Notes:

(1) If less than 25% of a given layer is within 4 inches (100 mm) of the anticipated top surface, the layer may be considered to be below 4 inches (100 mm) for mixture design purposes.

(2) This criterion does not apply to #4 (4.75 mm) nominal maximum size mixtures.

E. Aggregate Source Properties.

The coarse mineral aggregate utilized in SUPERPAVE HMA mixtures shall be clean, crushed rock consisting of the angular fragments obtained by breaking and crushing shattered natural rock. It shall be free from dirt or other objectionable materials. The coarse aggregate, including RAP if used in the mixture, shall be tested for conformance with the following Source Property requirements:

- Toughness as Determined by: Los Angeles Abrasion (AASHTO T 96)
- Soundness as Determined by: Soundness (AASHTO T 104)
- Deleterious Materials as Determined by: Clay Lumps & Friable Particles (AASHTO T 112)
- Specific Gravity (AASHTO T 8)

Testing for each of the Source Properties shall be performed for each SUPERPAVE HMA mixture design developed for the project. The Source Property test results shall be submitted with the LTMF for each SUPERPAVE HMA mixture. The Design-Builder shall provide samples of each aggregate material from each stock pile, a minimum of forty-five (45) days prior to production for each LTMF to the Department for LTMF verification prior to SUPERPAVE HMA production. The requirements for each of the Source Properties are as indicated in Table 455.3 below.

Table 455.3 - Aggregate Source Property Requirements

Source Property Test	Limit
Toughness (AASHTO T 96)	Maximum Loss < 30 %
Soundness (AASHTO T 104)	Maximum Loss < 10 %
Deleterious Materials (AASHTO T 112)	Maximum Permissible < 0.5 %

F. SUPERPAVE Aggregate Gradation and Specific Gravity Requirements.

The combined aggregate blend for each SUPERPAVE HMA mixture shall conform to the Gradation Control Point requirements specified in Table 455.6 below. The results of the selected optimum Design Aggregate Structure shall be plotted on a 0.45 Power Chart and included with the LTMF.

The combined aggregate gradation shall be classified as coarse-graded when it passes below the Primary Control Sieve (PCS) control point as defined in Table 455.4. All other gradations shall be classified as fine graded.

The specific gravity of each coarse and fine aggregate component shall be determined in accordance with AASHTO T 85 and T 84 respectively, and the specific gravity of the mineral filler shall be determined in accordance with AASHTO T 100. The individual aggregate specific gravities shall be included with the LTMF. The Design-Builder shall provide samples of each aggregate material a minimum of forty-five (45) days prior to production for each LTMF to the Department for verification of the selected optimum Design Aggregate Structure and specific gravity of each stock pile.

Table 455.4 - Gradation Classification

PCS Control Point for Mixture Nominal Maximum Aggregate Size % Passing					
Nominal Maximum Aggregate Size	1-1/2"	1"	3/4"	1/2"	3/8"
	(37.5 mm)	(25.0 mm)	(19.0 mm)	(12.5 mm)	(9.5 mm)
Primary Control Sieve	3/8"	#4	#4	#8	#8
	(9.5 mm)	(4.75 mm)	(4.75 mm)	(2.36 mm)	(2.36 mm)
PCS Control point (% Passing)	47	40	47	39	47

G. Gyratory Compaction Criteria.

Each SUPERPAVE HMA mixture shall be designed and controlled during production using an approved Gyratory Compactor which meets the requirements of AASHTO T 312. Compaction shall be in accordance with the requirements of AASHTO T 312. The density of each SUPERPAVE HMA mixture shall be evaluated at the initial number of gyrations ($N_{initial}$), the design number of gyrations (N_{design}), and the maximum number of gyrations (N_{max}). The gyratory-compacted specimens for each LTMF shall meet the density requirements specified in Table 455.5 below.

H. Volumetric Design Requirements.

Each SUPERPAVE HMA mixture shall be designed in accordance with the volumetric mixture design specifications contained in AASHTO M 323 and procedures contained in AASHTO R 35, as modified herein. Each HMA mixture LTMF shall be tested for conformance with the following volumetric properties:

- Air Voids at N_{design} (V_a)
- Voids in the Mineral Aggregate at N_{design} (VMA)
- Voids Filled with Asphalt at N_{design} (VFA)
- Fines to Effective Asphalt Ratio ($P_{0.075} / P_{be}$)

The volumetric property test results shall be submitted with the LTMF for each SUPERPAVE HMA mixture. The required minimum or maximum criteria for each of the volumetric property tests are specified in Table 455.6 below.

Table 455.5 - SUPERPAVE HMA Design Requirements

Traffic Level	Design ESALs (million)	Number of Gyration by Superpave Gyrotory Compactor			Percent Density of Gmm from HMA Specimen			Voids Filled with Asphalt (VFA)* Based on Nominal Maximum Aggregate Size					
		Nini	Ndes	Nmax	Nini	Ndes	Nmax	#4 (4.75 mm)	3/8" (9.5 mm)	1/2" (12.5 mm)	3/4" (19.0 mm)	1" (25.0 mm)	1-1/2" (37.5 mm)
1	< 0.3	6	50	75	≤ 91.5	96.0	≤ 98.0	70 - 80	70 - 80	70 - 80	70 - 80	67 - 80	64 - 80
2	0.3 to < 3.0	7	75	115	≤ 90.5	96.0	≤ 98.0	65 - 78	65 - 78	65 - 78	65 - 78	65 - 78	64 - 78
3	3.0 to < 10	8	100	160	≤ 89.0	96.0	≤ 98.0	75 - 78	73 - 76	65 - 75	65 - 75	65 - 75	64 - 75
4	10 to < 30.0	8	100	160	≤ 89.0	96.0	≤ 98.0	75 - 78	73 - 76	65 - 75	65 - 75	65 - 75	64 - 75
5	≥ 30.0	9	125	205	≤ 89.0	96.0	≤ 98.0	75 - 78	73 - 76	65 - 75	65 - 75	65 - 75	64 - 75

*The VFA values contained in Table 455.5 have been modified from AASHTO M 323 to ensure adequate PG Asphalt Binder content in each SUPERPAVE HMA mixture.

Table 455.6 - Gradation and Volumetric Requirements

Sieve	SUPERPAVE HMA Mixture Nominal Maximum Aggregate Size														LTMF Verification Limits		
	#4 (4.75 mm)		3/8" (9.5 mm)		1/2" (12.5 mm)		3/4" (19.0 mm)		1" (25.0 mm)		1-1/2" (37.5 mm)		Target ±				
	CONTROL POINTS	Min (%)	Max (%)	CONTROL POINTS	Min (%)	Max (%)	CONTROL POINTS	Min (%)	Max (%)	CONTROL POINTS	Min (%)	Max (%)				CONTROL POINTS	Min (%)
Inches																	
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0
1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0
3/4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0
1/2	100	-	-	100	-	-	100	-	-	90	-	-	-	-	-	-	6.0
3/8	95	100	-	90	100	-	90	-	-	-	-	-	-	-	-	-	6.0
#4	90	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0
#8	-	-	35	67	31	58	26	49	19	45	15	41	-	-	-	-	5.0
#16	30	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0
#30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0
#50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0
#100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
#200	6	12	2	10	2	10	2	8	1	7	0	6	-	-	-	-	1.0
PB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
VMA (3)	17.0	16.0	15.0	14.0	13.0	12.0	-	-	-	-	-	-	-	-	-	-	1.0
Va (%)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.0
VFA	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	Per Table 455.5 ± 5 off LTMF	0.02
Gse	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	0.02
Gmm	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	LTMF value	0.02
Dust/Pbe(2) Mixture Temp	0.9 - 2.0	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.6 - 1.2	0.02
PCS (4)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	265 - 325F(1)	0.02

(1) Based on the final design PG Asphalt Binder certification. (2) Dust is considered to be the percent of material passing the #200 (75 µm) sieve. The calculated effective asphalt content (Pbe) shall be used for this calculation. (3) Voids in Mineral Aggregates shall be computed as specified by AASHTO R 35. (4) If the aggregate gradation passes beneath the PCS Control Point specified in Table 455.4, the dust-to-binder ratio range may be increased from 0.6-1.2 to 0.8-1.6 at the Engineer's discretion. (5) When used as a Surface Course under OGFC the Min % for the #8 (2.36 mm) Sieve should be 40.

I. Evaluation of Moisture Sensitivity.

Each SUPERPAVE HMA mixture shall be tested by the Design-Builder for Moisture Sensitivity in accordance with the requirements of AASHTO T 283. The compacted specimens for each LTMF shall exhibit a minimum tensile strength ratio of 80% as determined by AASHTO T 283. A minimum tensile strength ratio of 80% is required. The use of approved anti-stripping agents (either liquid or mineral) can be used to meet this requirement. If an anti-strip agent is required, it shall be included in the Design-Builder’s cost.

The Moisture Sensitivity test results shall be submitted with the LTMF for each SUPERPAVE HMA mixture. The Department will perform testing of the Moisture Sensitivity prior to SUPERPAVE HMA production as part of the verification of each LTMF.

Delete Subsection 450.66A. - Laboratory Verification of HMA Mix Design and replace with the following:

455.43 Verification of Laboratory Trial Mix Formula (LTMF)

The Design-Builder shall submit a LTMF with supporting documentation, a minimum of forty-five (45) days prior to production, to the Owner with samples of blended aggregate material and PG Asphalt Binder. An adequate amount of the blended aggregate material and PG Asphalt Binder shall be supplied in order to verify the LTMF selected for production (proposed JMF).

If the Owner is unable to verify the Design-Builder’s LTMF in accordance with the LTMF Verification Limits in Table 455.7, then the Owner will work with the Design-Builder to resolve the verification issue(s). **The Design-Builder shall not proceed with production and placement of the Control Strip (Section 450.66B.) until the LTMF is verified by the Owner.**

Table 455.7 - SUPERPAVE HMA LTMF Verification Limits

Properties	LTMF Verification Limit
Asphalt Binder Content (P_b)	Target \pm 0.3 percent
Gradation Passing #4 (4.75 mm) and Larger Sieves	Target \pm 6.0 percent
Gradation Passing #8 (2.36 mm) Sieve	Target \pm 5.0 percent
Gradation Passing #16 (1.18 mm) to #50 (0.30 mm) Sieve	Target \pm 3.0 percent
Gradation Passing #100 (0.15 mm) Sieve	Target \pm 2.0 percent
Gradation Passing #200 (75 μ m) Sieve	Target \pm 1.0 percent
Max. Theo. Specific Gravity (G_{mm})	Target \pm 0.02
Air Voids (V_a)	Target \pm 1.0 percent
Voids in Mineral Aggregate (VMA)	Target \pm 1.0 percent
Voids Filled With Asphalt (VFA)	Target \pm 5.0 percent
Bulk Specific Gravity (G_{mb})	Target \pm 0.022

CONSTRUCTION PROCEDURES

Delete Subsection 450.53F. - Tack Coat and replace with the following:

G. Tack Coat.

A tack coat of asphalt emulsion, grade RS-1 shall be uniformly applied to existing or new pavement surfaces prior to placing pavement courses as specified below. The existing surface shall be swept clean of all foreign matter and loose material using a mechanical sweeper and shall be dry before the tack coat is applied.

(1) Tack Distributor System.

A pressure distributor shall be used to apply the tack coat. The tack distributor system shall be equipped with the following to control and monitor the application:

- (f) System for heating the asphalt emulsion uniformly to specified temperature.
- (g) Thermometer for measuring the asphalt emulsion temperature.
- (h) Adjustable full circulation spray bar.
- (i) Positive controls including tachometer, pressure gauge, and volume measuring device.

(2) Tack Application Requirements.

The tack coat material shall be applied by a pressure distributor. All nozzles on the distributor shall be open and functioning. All nozzles shall be turned at the same angle to the spray bar. Proper nozzle angle shall be as determined by the manufacturer of the distributor spray bar. The spray bar shall be adjusted so that it is at the proper height above the pavement surface to provide a double overlap spray for a uniform coverage of the pavement surface. A double lap application requires that the nozzle spray patterns overlap one another such that every portion of the pavement receives spray from exactly two nozzles.

When an HMA pavement course is placed on an existing tight smooth pavement surface, a tack coat shall be applied at the rate of 1/20 gal/s.y. (0.20 liters/square meter). All existing surfaces subjected to milling shall receive a tack coat at the rate of 1/15 gal/s.y. (0.28 liters/square meter). Tack coat shall be applied to cover approximately 90% of the pavement surface.

Any new HMA pavement course that has been open to traffic, or that was placed 30 days prior to placement of the subsequent pavement course, shall receive a tack coat at an application rate of 1/20 gal/s.y. (0.20 liters/square meter).

When the surface of a new HMA pavement course is in a condition which in the Owner's judgment is unsatisfactory for the direct placement of the subsequent pavement course, a tack coat shall be applied at the applicable rate specified above for the particular pavement surface condition.

In addition to the requirements above, all vertical surfaces of curbs, edging, utilities, and drainage structures shall receive a thorough tack coat application immediately prior to placing each HMA pavement course.

(3) Tack Inspection.

The asphalt emulsion temperature and application rate shall be periodically measured and properly recorded by the Design-Builder on NETTCP Inspection Report Forms. If the temperature or application rate is determined to not be in conformance with the specification requirements above, the Design-Builder shall make appropriate adjustments to the tack application operations.

COMPENSATION

The Pay Adjustment provisions included in Subsection 450.92 – Pay Adjustment shall be applied to items under this contract.

Delete Subsection 450.91D. – Hot Mix Asphalt and replace with the following:

D. Hot Mix Asphalt.

Each Hot Mix Asphalt pavement course will be paid for at the contract unit price per ton (Megagram) of in-place mixture under the HMA Pay Items specified in Subsection 455.93. Payment shall include sweeping the underlying surface, transportation, delivery, placement including providing a Material Transfer Vehicle (MTV), and compaction of each HMA pavement course in accordance with Subsection 450.54 through Subsection 450.58.

All sawcutting required for transverse joints or longitudinal joints in accordance with Subsection 450.57 shall also be included in the contract unit price for each HMA pavement course.

Delete Subsection 450.93 – Payment Items and replace with the following:

455.93	Payment Items	Payment Unit
450.10	Open Graded Friction Course – Polymer Modified (OGFC – P)	Ton (Megagram)
455.21	SUPERPAVE Surface Course – 4.75 (SSC – 4.75)	Ton (Megagram)
455.22	SUPERPAVE Surface Course – 9.5 (SSC – 9.5)	Ton (Megagram)
455.23	SUPERPAVE Surface Course – 12.5 (SSC – 12.5)	Ton (Megagram)
455.24	SUPERPAVE Surface Course – 19.0 (SSC – 19.0)	Ton (Megagram)
455.31	SUPERPAVE Intermediate Course – 12.5 (SIC – 12.5)	Ton (Megagram)
455.32	SUPERPAVE Intermediate Course – 19.0 (SIC – 19.0)	Ton (Megagram)
455.41	SUPERPAVE Base Course – 25.0 (SBC – 25.0)	Ton (Megagram)
455.42	SUPERPAVE Base Course – 37.5 (SBC – 37.5)	Ton (Megagram)
455.51	SUPERPAVE Leveling Course – 4.75 (SLC – 4.75)	Ton (Megagram)
455.52	SUPERPAVE Leveling Course – 9.5 (SLC – 9.5)	Ton (Megagram)
455.60	SUPERPAVE Bridge Surface Course – 9.5 (SSC B – 9.5)	Ton (Megagram)
455.61	SUPERPAVE Bridge Surface Course – 12.5 (SSC B – 12.5)	Ton (Megagram)
455.70	SUPERPAVE Bridge Protective Course – 9.5 (SPC B – 9.5)	Ton (Megagram)
455.71	SUPERPAVE Bridge Protective Course – 12.5 (SPC B – 12.5)	Ton (Megagram)
450.90	Design Builder Quality Control	Ton (Megagram)
451	HMA for Patching	Ton (Megagram)
452	Asphalt Emulsion for Tack Coat	Gallon (Liter)
453	HMA Joint Sealant	Linear Foot (Meter)

999.490	HMA Pay Adjustment—PG Asphalt Binder Content[‡]	Dollar
999.491	HMA Pay Adjustment—Volumetrics (Air Voids)[‡]	Dollar
999.492	HMA Pay Adjustment—In place Mat Density[‡]	Dollar
999.493	HMA Pay Adjustment—Thickness[‡]	Dollar
999.494	HMA Pay Adjustment—Ride Quality[‡]	Dollar

~~[‡]Not a bid item~~

END OF SECTION

SECTION 02524

CURBS, GUTTERS AND

WALKS PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the construction of Portland cement concrete curbs, gutters, and walks.
- B. Related Work:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 02525 – GRANITE CURBS
 - 3. Section 02509 – PAVEMENT BASE COURSES
 - 4. Section 02513 – BITUMINOUS CONCRETE PAVEMENT
 - 5. Section 02526 – DETECTABLE WARNING STRIPS
 - 6. Section 03300 - CAST-IN-PLACE CONCRETE; for concrete, reinforcement, and incidentals pertaining thereto.

1.2 QUALITY ASSURANCE

- A. Installer Qualifications: Engage an experienced installer who has completed type of work similar in material, design, and extent to that indicated for this Project and with a record of successful in-service performance.
- B. Source Limitations: Obtain each variety of material from a single source with resources to provide materials of consistent quality in appearance and physical properties without delaying the work.
- C. Unless otherwise indicated, materials and construction shall conform to applicable portions of the following:
 - 1. MassDOT Specification Section 500, “Curb and Edging”.
 - 2. MassDOT Specification Section 701, “Sidewalks, Wheelchair Ramps, and Driveways”.
- D. Curb Layout: After staking and laying out the curb work, and before beginning curb installation, obtain the MBTA’s approval of layout. Design-Builder shall make minor adjustments as determined by the MBTA.
- E. The Design-Builder and his Subcontractors shall inspect all sub-bases for unstable, unsuitable or improperly prepared areas. Do not begin work over unacceptable areas. Beginning work means the Design-Builder and his Subcontractors accept the sub-base, previous work and conditions and shall be held responsible for any corrections required to properly implement the Construction Documents.
- F. Tolerances. Construct cement concrete surfaces within 1/4 inch of the indicated elevation, and deviating not more than 1/8 inch from a ten-foot straightedge placed anywhere on the surface.
- G. Walks shall be constructed to meet MassDOT, ADA requirements, and within the City of Cambridge the City of Cambridge requirements.

- H. Provide strict compliance with requirements for air entrainment and curing of cement concrete.

1.3 SUBMITTALS

- A. Product Data: For each material and manufactured product specified.
 - 1. Manufacturer's standard product literature.
 - 2. Data on physical properties required by referenced ASTM standards.
- B. Shop Drawings: Supply shop drawings at an approved scale for location, installation and erection of all parts of the work under this section including but not limited to the following items:
 - 1. Cast In Place Concrete Curb

1.4 PROJECT CONDITIONS

- A. Protection: The Design-Builder shall use all means necessary to protect the materials of this Section before, during and after installation. In the event of damage, make all repairs and replacements necessary to approval of the MBTA and at no additional cost to the MBTA. All work shall be executed in such a manner as to prevent any damage to existing streets, curbs, paving to remain, existing plant materials, and adjoining properties.
- B. The Design-Builder shall remove all debris, construction equipment and waste material from within the limit of work prior to inspection for acceptance.
- C. The Drawings indicate, in general, the alignment and finished grade elevations. The MBTA however, may make minor adjustments in grades and alignment as are found necessary.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Cement Concrete: (4000 psi, ¾", 610) MassDOT M4.02
- B. Preformed Expansion Joint Filler: AASHTO M153.
- C. Hot-Poured Joint Sealer: AASHTO M173.
- D. Gravel Borrow: MassDOT M1.03.0, (Type b).

PART 3 - EXECUTION

3.1 PREPARATION

- A. Excavate for and prepare the subgrade as specified in Section 02300 - EARTHWORK, true to the indicated grade and cross section.
- B. Place and compact a foundation of gravel borrow to the indicated thickness upon the prepared subgrade.
- C. Test completed gravel foundation with a template supported on the side forms, prior to concreting.

3.2 JOINTS

- A. Expansion Joints and Contraction (Control) Joints shall be installed to meet all municipal, MassDOT standard requirements.

3.3 FINISHES

- A. Pedestrian and Wheelchair Accessible Ramps: Non-slip finish with a Tactile Warning Surface tile as defined in Specification Section 02526.
- B. All Other: Broom finish.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02525

GRANITE CURBS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This Section specifies furnishing and installing granite curb, granite curb transitions and sloped granite edging, as indicated on the Contract Plans and in accordance with these Specifications or as a replacement for existing curb which is damaged or removed during the course of the work.
- B. The work under this section also includes removing and resetting, and removing and discarding existing curbing, as indicated on the contract plans and/or as directed by the MBTA.
- C. Related Work:
 - 1. Section 02300 - EARTHWORK
 - 2. Section 02524 – CURBS, GUTTERS AND WALKS
 - 3. Section 03300 - CAST-IN-PLACE CONCRETE

1.2 QUALITY CONTROL

- A. Tolerances. Place curbing within ¼ inch of the indicated elevations or dimensions, deviating not more than ¼ inch from a ten-foot straight-edge placed anywhere on the surface.

1.3 SUBMITTALS

- A. Product Data:
 - 1. Manufacturer’s standard product literature.
 - 2. Data on physical properties required by referenced standards.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. All curbing work shall be in accordance with the Commonwealth of Massachusetts, Department of Transportation (MassDOT) "Standard Specifications for Highways and Bridges," Section 500. Curb and Edging, and Materials Section M9.04.1, Granite Curb, Type VA 4.
- B. All curbing to be removed and reset shall be in accordance with the Commonwealth of Massachusetts, Massachusetts (MassDOT) "Standard Specifications for Highways and Bridges," Section 580, and shall be reused with the MBTA’s approval.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Excavate for and prepare the subgrade as specified in Section 02300 – EARTHWORK, true to the indicated grade and cross section.
- B. Place and compact a foundation to the indicated material and thickness upon the prepared subgrade.
- C. Test the complete foundation with a template supported on the side forms, prior to placing the curbing.
- D. Install High-Early strength concrete setting bed as indicated on the contract plans and/or as directed by the MBTA.
- E. All transition curbing shall be cut at the end adjoining adjacent curbing so that ends are vertically flush.
- F. The corner curbs shall be cut so they are constructed with flush joints.
- G. Transition curbing at ramps, as shown on the Contract Drawings.
- H. Curbing which is to be removed and reset, will be installed as indicated above.
- I. Curbing which is removed and stacked and not wanted by the MBTA shall be satisfactorily disposed of by the Design-Builder.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02526

DETECTABLE WARNING STRIPS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work under this section shall consist of furnishing and installing detectable warning strips as indicated on the plans or as directed by the MBTA.
- B. The detectable warning strips shall be placed at all new or modified wheel chair ramps throughout the project.
- C. Related Work:
 - 1. Section 02524 – CURBS, GUTTERS AND WALKS
 - 2. Section 03300 - CAST-IN-PLACE CONCRETE
 - 3. Section 09360 – MODULAR TACTILE SURFACES

1.2 SUBMITTALS

- A. Product Data: For each material and manufactured product specified.
 - 1. Manufacturer's catalog cuts, material specifications, installation and maintenance instructions, and other data pertinent to the work of this Section.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. The detectable warning panels shall comply with MassDOT Engineering Directive E-12-005 and MassDOT Standard Drawings E 107.6.5R and M/E 107.6.5R dated March, 2012.
- B. Color shall be homogeneous throughout the composite. Color shall conform to the applicable City of Medford, City of Cambridge, or City of Somerville, MBTA, or DCR standard specification.

PART 3 - EXECUTION

3.1 PERFORMANCE

- A. All work shall be performed in accordance with the applicable requirements of Section 700 of the MassDOT Standard Specifications and the Manual on Uniform Traffic Control Devices. Detectable warning panels shall be installed at all wheelchair ramp locations and median cut-throughs

in accordance with ADA requirements, the MassDOT Construction Standards, and the details shown on the plans.

- B. Design-Builder will not be allowed to install Tactile Warning Surface Product until all submittals have been reviewed and approved by the MBTA.
- C. Tactile warning surface product shall be installed per manufacturer's instructions.
- D. To the maximum extent possible, the tactile Warning Surface Units shall be oriented such that the rows of in-line truncated domes are parallel with the direction of the ramp. When multiple tactile Warning Surface Units regardless of size are used, the truncated domes shall be aligned between the tactile Warning Surface Units and throughout the entire tactile warning surface installation.
- E. In accordance with the latest Draft Guidelines for Accessible Public the tactile warning surface product shall be located so that the edge nearest the curb line is 6" minimum and 8" maximum from the curb line.
- F. The tactile Warning Surface Units shall be tamped or vibrated into the fresh concrete to ensure that there are no voids or air pockets, and the field level of the tactile warning surface unit is flush to the adjacent concrete surface or as the Drawings indicate to permit proper water drainage and eliminate tripping hazards between adjacent finishes.

3.2 CLEANING AND PROTECTION

- A. Protect tactile warning surface unit against damage during construction period to comply with tactile warning surface unit manufacturer's Specifications.
- B. During and after the tactile warning surface unit installation and the concrete curing stage, it is imperative that there are no walking, leaning or external forces placed on the tactile warning surface unit to rock the tactile warning surface unit, causing a void between the underside of the tactile warning surface unit and the concrete substrate.
- C. Prohibit construction vehicle traffic from riding on newly tiled surfaces. Do not place or store construction equipment or tools directly on tiled surfaces.
- D. Provide snow removal as required using equipment that will not damage tile.
- E. If requested by the Project Manager, clean tactile Warning Surface Units not more than four (4) days prior to date scheduled for inspection intended to establish date of substantial completion in each area of project. Clean tactile warning surface unit by method specified by tactile warning surface manufacturer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02577

PAVEMENT MARKING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the furnishing and application of reflectorized pavement markings.
- B. All work shall be in accordance with the relevant provisions of Section 860 of the MassDOT Standard Specifications.
- C. Related Work:
 - 1. Section 02052 – MAINTENANCE OF TRAFFIC THROUGH WORK AREAS
 - 2. Section 02296 – TRAFFIC DECKING
 - 3. Section 02298 – TEMPORARY PEDESTRIAN FACILITIES

1.2 SUBMITTALS

- A. Submit a schedule of pavement marking operations to the MBTA, for approval, not less than ten business days prior to the proposed date of application of any pavement marking.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Thermoplastic Striping: Design-Builders shall comply with MassDOT requirements. Pavement striping material shall be applied to the pavement in a molten state by mechanical means with a surface application of glass spheres.
 - 1. White Color: Composition by weight:

Binder:	22 % minimum
Glass Beads:	30-40 %
Titanium Dioxide:	10% minimum
Calcium Carbonate and Filler:	38 % maximum
 - 2. Yellow Color: Composition by weight:

Binder:	22 % minimum
Glass Beads:	30-40 %
Titanium Dioxide:	10% minimum Yellow Pigment
Calcium Carbonate and Filler:	To be determined by manufacturer.

3. Glass Beads: Beads shall be transparent, clean, colorless glass, smooth and properly shaped, and contain no pits or bubbles, and meeting the following gradation:

Sieve	Percent Passing
No. 20	100
No. 30	75 - 95
No. 50	15 - 35
No. 80	0 - 5

- a. When tested by the liquid immersion method, the beads shall have a minimum refraction of 1.50.
- B. Acrylic Striping: Comply with MassDOT requirements. Pavement striping material shall be an acrylic type, low VOC, water based paint.

1. White Color: Composition by weight:

Pigment:	58 percent minimum
Total Solids:	76 percent minimum
Titanium Dioxide:	1 pound/gallon minimum

2. Yellow Color: Composition by weight:

Pigment:	56 percent minimum
Total Solids:	75 percent minimum
Titanium Dioxide:	0.3 pounds/gallon minimum

PART 3 - EXECUTION

3.1 EQUIPMENT

- A. Use standard commercial-quality equipment of the type normally required for application of pavement markings. Operate the equipment in accordance with the manufacturers' instructions. Truck-mounted equipment is approved for the application of pavement marking except where in the MBTA's judgment travel will be unreasonably delayed or the quality of the work performed by the equipment is unsatisfactory.

3.2 LAYOUT OF WORK

- A. The Design-Builder shall provide a line of reference on the roadway for use in establishing the location of markings to be approved by the MBTA prior to applying to any pavement markings. This line of reference shall be at a maximum of 50-foot intervals by means deemed satisfactory by the MBTA. Follow this line of reference without deviation. Reapply any line deviating from the establishing control or of incorrect width, as directed by the MBTA.

3.3 APPLICATION OF MARKINGS

A. Apply pavement markings as follows:

MATERIAL	MATERIAL APPLICATION TEMPERATURE DEGREES F	LINE THICKNESS MILS	REFLECTORIZED BEAD APPLICATION
M7.01.08	180-195	15	6 LBS/GAL
M7.01.09	180-195	15	6 LBS/GAL
M7.01.10	40-120	15	6 LBS/GAL
M7.01.11	40-120	15	6 LBS/GAL
M7.01.03	400-425	6-188	1 LB/20 SF DROP ON
M7.01.04	400-425	5-188	1 LB/20 SF DROP ON

- B. Use no thinners for the above-listed pavement marking applications except in accordance with the manufacturer's specifications and at the direction of the MBTA.
- C. Heat no paint or pavement marking material above the temperature marked on the container.
- D. Apply markings only in seasonable weather and in accordance with good painting practices. The surface shall be dry and free of sand, grease, oil, or other foreign substances prior to the application. Prepare the surface to accept the application as part of the work of this section. The MBTA will make the final determination for all of the foregoing.
- E. Bituminous concrete pavements shall have been in place for 48 hours prior to the application of pavement markings. When it is necessary to expedite the flow of traffic, the MBTA may reduce the waiting period as is deemed necessary.
- F. The ambient (air) temperature for thermoplastic application is to be a minimum of 45 Degrees F and rising at the time of marking operations. If work has started and air temperatures fall below 45 Degrees F and continuous cooling is indicated, work shall be stopped. In cool weather conditions, temporary drops down to 40 Degrees F will be tolerated providing temperatures also vary upwards. Sustained striping (greater than one hour) at 40 Degrees F shall not be allowed. Starting work at air temperatures lower than 45 Degrees F shall not be allowed. Design-Builder shall remove and replace thermoplastic applications made at below 40 Degrees F at no expense to the MBTA.
- G. If for any reason material is spilled or tracked on the roadway, or any markings applied by the Design-Builder, in the MBTA's judgment, are of incorrect width or pattern or fail to conform to the established line of reference, remove such material by a method that is not injurious to the roadway surface and is acceptable to the MBTA, clean the roadway surface, prepare the surface for a reapplication of markings, and reapply the markings as directed without additional compensation for any of the foregoing corrective operations.

3.4 PROTECTION OF MARKINGS

- A. Protect markings until sufficiently dry to bear traffic on roadways that are open to traffic. Protect markings by traffic cones not less than 18 inches in height except in the case of markings which cure to a no-track condition in 180 seconds or less. In the latter case, protection may be provided by a convoy of vehicles with suitable warning devices to warn overtaking or on-coming traffic that the pavement marking operation is in progress.
- B. Broken Lines. On tangents and on curves of 1,000 foot radius or greater place at least one cone on every other bar. On curves of less than 1,000 foot radius place one cone on every bar unless otherwise directed by the MBTA.
- C. Solid Lines. On tangents and on curves space cones not over 50 feet unless otherwise directed by the MBTA. On edge lines adjacent to the median, wider spacing may be used as directed by the MBTA. In order to control the proper positioning of the cones during the drying period, assign sufficient personnel as determined by the MBTA. Such control is dependent on traffic density, cone widths, and other factors.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02615

DUCTILE IRON PIPE AND FITTINGS FOR STORMWATER PUMP STATIONS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Provide and test ductile iron pipe, fittings and appurtenances as indicated and in compliance with Contract Documents.
- B. Options:
 - 1. For buried exterior pipelines provide push-on joint pipe.
 - a. Provide restrained push-on pipe as specified.
 - b. Provide either restrained push-on joint fittings as specified and indicated or provide mechanical joint fittings with restraint system as specified herein.
 - 2. For piping exposed as in buildings and galleries, provide flanged or rigid-joint, grooved-coupled pipe and fittings.
 - 3. Cast iron pipe and fittings are not acceptable.
- C. Construction of the Red Bridge and Washington street pump stations (RPS and WSP, respectively) was initiated under IGMP-03, a previous GLX construction contract. That work was advanced to near completion of the basic structure. The pumps, variable frequency motor controllers, communication programmable logic controllers, piping and pump station controls were not (or may not have been) completed, however certain items of that equipment were procured by the Owner and will be provided to the Design-Builder. The Design-Builder shall complete the construction of these two pump stations in full compliance with the specifications. The Design-Builders shall complete all work within this Section and all related work, to provide complete operable pump station facilities.
- D. The specifications relative to the WPS and RPS pump stations, including all operating parameters, control logic and other parameters, shall not be modified in any way.
- E. The Design-Builder may elect to adapt these specifications, if appropriate, to any pump station it may propose at Gilman Square.
- F. Certain work under this Section was, or may have been, completed by the previous GLX contractor. The Design-Builder shall be responsible for making its own assessments and evaluations as to the exact scope and limits of the completed and the uncompleted work. The Design-Builder shall complete any and all work associated with this Section and all Related Sections, including any and all uncompleted and/or partially completed work. The Design-Builder shall coordinate all related work, to provide complete and operable stormwater pumping facilities.
- G. The use of the word "Contractor" has been retained in this Section; however, it shall be interpreted to mean the Design-Builder for any and all work remaining to be completed. Likewise, the word "Engineer" has been retained; however, it shall be interpreted to mean the Owner for any and all work remaining to be completed.

- H. The specifications relative to the pipe layouts and design and other parameters, shall not be modified in any way.
- I. The Design-Builder may elect to adapt these specifications, if appropriate, to any pump station it may propose at Gilman Square.

1.2 REFERENCES

- A. American Society of Mechanical Engineers (AMSE):
 - 1. B16.1: Cast-Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800.
 - 2. B16.21: Nonmetallic Flat Gaskets for Pipe Flanges.
 - 3. B16.42: Ductile Iron Pipe Flanges and Flanged Fittings.
 - 4. B31.1: Power Piping.
- B. American Society for Testing and Materials International (ASTM):
 - 1. A240: Specification for Heat Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels.
 - 2. A307: Carbon Steel Bolts and Studs, 60,000 psi Tensile.
 - 3. A380: Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment and Systems.
 - 4. A530: Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe.
 - 5. A774: Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures.
 - 6. A778: Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products.
- C. American Water Works Association (AWWA):
 - 1. A21.4: Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water.
 - 2. A21.10: Ductile-Iron and Gray-Iron Fittings, 3 in. through 48 in., for Water and Other Liquids.
 - 3. A21.11: Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe Fittings.
 - 4. A21.15: Flanged Ductile-Iron Pipe with Threaded Flanges.
 - 5. A21.50: Thickness Design of Ductile-Iron Pipe.
 - 6. A21.51: Ductile-Iron Pipe, Centrifugally Cast in Metal Molds, or Sand-Lined Molds, for Water or Other Liquids.
 - 7. A21.53: Ductile-Iron Compact Fittings, 3-in through 16-in. for Water and Other Liquids.
- D. Fluid Sealing Association: Technical Handbook.

1.3 SUBMITTALS

- A. Submit the following in accordance with Section 01300 – SUBMITTALS.
1. Pipe manufacturer’s technical specification and product data.
 2. Certified shop and erection drawings. Contractor shall submit electronic files of the piping layout including the following.
 - a. Pipe layouts in full detail.
 - b. Location of hangers and supports.
 - c. Location and type of anchors.
 - d. Location of couplings and expansion joints.
 - e. 1/2-inch = 1 foot-0 inch scale details of all wall penetrations and special fittings.
 - f. Schedules of pipe, fittings, special castings, couplings, expansion joints and other appurtenances.
 3. Certificates: Sworn certificates in duplicate showing compliance with material used and shop tests performed.
 4. Catalog cuts and technical data for expansion joints, couplings, gaskets, pipe supports and other accessories.
 5. Brochures and technical data on coatings and linings and proposed method of application.
 6. Manufacturer's descriptive literature and technical data on insulation and proposed method of installation.
- B. Material Certification:
1. Provide certification from the pipe and fittings manufacturer that the materials of construction specified are recommended and designed for the service conditions specified and indicated. If materials other than those specified are proposed based on incompatibility with the service conditions, provide technical data and certification that the proposed materials are recommended and designed for the service conditions specified and indicated including an installation list of a minimum of five (5) installations in operation for a minimum of five (5) years. Provide proposed materials at no additional cost to the Owner.
 2. Where materials are not specified, provide technical data and certification that the proposed materials are recommended and designed for the service conditions specified and indicated.
- C. A copy of the contract mechanical process, civil and structural drawings, with addenda that are applicable to the equipment specified in this section, marked to show all changes necessary for the equipment proposed for this specification section. If no changes are required, mark all drawings with “No changes required” or provide a statement that no changes are required.
1. Failure to include all drawings or a statement applicable to the equipment specified in this section will result in submittal return without review until a complete package is submitted.
 2. A copy of this specification section with addenda and all referenced specification sections with addenda, with each paragraph check-marked to indicate specification compliance or marked and indexed to indicate requested deviations and clarifications from the specified requirements.

- a. If deviations and clarifications from the specifications are indicated, therefore requested by the Contractor, provide a detailed written justification for each deviation and clarification.
- b. Failure to include a copy of the marked-up specification sections and or the detailed justifications for any requested deviation or clarification will result in submittal return without review until marked up specifications and justifications are submitted in a complete package.

1.4 QUALITY ASSURANCE

- A. Provide in accordance with Section 01400 – QUALITY ASSURANCE and as specified.
- B. Provide manufacturer's certification in writing, that materials meet or exceed minimum requirements as specified.
- C. Inspect and test at foundry according to applicable standard specifications.
- D. Owner reserves right to inspect and test by independent service at manufacturer's plant or elsewhere at his own expense.
- E. Visually inspect before installation.
- F. Job Conditions:
 1. Coordinate dimensions and drillings of flanges with flanges for valves, pumps and equipment to be installed in the piping systems.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Comply with the requirements specified in Section 01600 – MATERIALS AND EQUIPMENT.
- B. During loading, transportation and unloading, prevent damage to pipes and fittings. Load and unload each pipe under control at all times. Under no circumstances will a dropped pipe be used unless inspected and accepted by CMGC. Place skids or blocks under each pipe in the shop and securely wedge pipe during transportation.

PART 2 - PRODUCTS

2.1 PIPE

- A. Ductile Iron:
 1. Design conforming to AWWA A21.50.
 2. Manufacture conforming to AWWA A21.15 or AWWA A21.51.
 3. Thickness class, unless otherwise indicated or specified:
 - a. Minimum Thickness Class 52.
 - b. Minimum thickness Class 53 for use with threaded flanges.

- c. Minimum thickness Class 53 for use with flanged pipe.
- d. Minimum thickness for use with grooved couplings conforming to AWWA C606.

2.2 PIPE FOR USE WITH COUPLINGS

- A. As specified above except ends shall be plain.
- B. With bolted split sleeve couplings, ends cast or machined at right angles to axis.
- C. With grooved type coupling:
 - 1. Ductile-Iron of thickness class specified above.
 - 2. Grooved End dimensions conforming to AWWA C606 for flexible or rigid joints to suit joint requirements.

2.3 FITTINGS

- A. Provide fittings conforming to AWWA A21.10 or AWWA A21.53, at least Class 150 and match piping class.
- B. Provide all bell push-on or mechanical-joint fittings unless otherwise indicated or specified.
- C. Face and drill flanged fittings conforming to AWWA A21.10 except special drilling or tapping for correct alignment and bolting.
- D. If flanged fittings are not available under AWWA A21.10 provide fittings conforming to ASME B16.1 in 125 lb. pressure class.
- E. Provide standard base fittings where indicated.
- F. Provide grooved-end fittings ductile-iron conforming to AWWA A21.10 for center-to-face dimensions.
 - 1. End preparation for grooved-ends conforming to AWWA C606 for flexible or rigid joints as required by type of joint.

2.4 NONSTANDARD FITTINGS

- A. Acceptable design.
- B. Same diameter and thickness as standard fittings.
- C. Manufactured to meet requirements of same specifications as standard fittings except for laying length and types of ends.

2.5 WALL CASTINGS

- A. Provide size and type indicated and specified.
 - 1. Piping 24-inches and Smaller: Mechanical Joint with specified restraint or Restrained Push-On.

2. Piping 30-inches and Larger: Restrained Push-On.

- B. Wall Castings: Conform to requirements of AWWA A21.10 or fabricate of Class 53 ductile iron pipe with screwed on flanges and welded on waterstop. Screwed on mechanical or push-on joints are not acceptable.
- C. Provide water stop centered in wall. Weld water stops on in factory under controlled conditions to ensure adequate strength to permit waterstop to absorb thrust up to the pressure rating of the pipe.

Wall Castings with annealed ductile iron water stops	
Pipe Size	Waterstop thickness, in
4 inch-12 inch (100-300 mm)	0.50 (13 mm)
14 inch-24 inch (350 -600 mm)	0.75 (19 mm)
30 inch-36 inch (750-900 mm)	1.00 (25 mm)
42 inch-48 inch (1100-1200 mm)	1.25 (32 mm)

Wall Castings with fabricated steel water stops	
Pipe Size	Waterstop thickness, in
4 inch-16 inch (100-400 mm)	0.25 (6 mm)
18 inch-24 inch (450 -600 mm)	0.38 (0 mm)
30 inch-36 inch (750-900 mm)	0.50 (13 mm)
42 inch-48 inch (1100-1200 mm)	0.75 (19 mm)
54 inch-64 inch (1100-1200 mm)	1.00 (25 mm)

- D. On flanged wall castings, provide space between the wall and flange to permit mounting the nuts on the flange bolts.
- E. Flanged wall castings located with the flange flush with the wall are not acceptable.
- F. Locate push-on joint wall castings with space between the bell and the wall to insert the follower bolts.
- G. Testing: Factory pressure test all wall castings to pipe and joint pressure rating for a minimum of 5 minutes. No visible leakage is acceptable.

2.6 ADAPTERS

- A. Furnish and install for joining pipe of different types, unless solid sleeves indicated.
 - 1. Provide ends conforming to above specifications for the correct type of joint, to receive adjoining pipe.
 - 2. Joining two classes of pipe may be of lighter class provided annular space in bell-and-spigot type joints sufficient for jointing.

2.7 JOINTS

- A. Provide push-on joint and mechanical joint pipe with necessary accessories, conforming to AWWA A21.11.
 - 1. Provide gasket composition designed for exposure to liquid within pipe.

- B. Provide pipe flanges and accessories conforming to AWWA A21.15.
 - 1. Provide flat faced flanges.
 - 2. Provide 1/8-inch thick, full faced gaskets designed for exposure to liquid within pipe.
- C. Provide restrained joint on pipe and fittings where indicated. Provide restrained joint which is:
 - 1. Boltless
 - 2. Capable of being deflected after assembly
 - 3. Designs using set screws or requiring field welding are not acceptable.
 - 4. Manufacturers:
 - a. American Cast Iron Pipe Co. Flex-Ring.
 - b. U.S. Pipe TR FLEX.
 - c. Clow Super-Lock.

2.8 MECHANICAL JOINT FITTINGS – RESTRAINT SYSTEM

- A. Provide restraint devices for pipe consisting of multiple gripping wedges incorporated into a follower gland meeting requirements of AWWA A21.10.
 - 1. Mechanical joint restraint shall require conventional tools and installation procedures per AWWA C600, retaining full mechanical joint deflection during assembly and allowing joint deflection after assembly.
 - 2. Provide actuation of the gripping wedges ensured with torque limiting twist off nuts.
 - 3. Provide restraint devices Listed by Underwriters Laboratories (3 inch through 24 inch) and Designed by Factory Mutual (3 inch through 12 inch size).
 - 4. Gland body, wedges and wedge actuating components must be domestic manufacture (USA).
- B. Working Pressure Rating:
 - 1. 16-inch and Smaller: 350 psi.
 - 2. 18-inch and Larger: 250 psi
 - 3. Minimum safety factor of 2 to 1.
- C. Materials:
 - 1. Gland body, wedges and wedge actuating components: Grade 65-45-12 ductile iron in accordance with ASTM A536.
 - 2. Ductile iron gripping wedges: Heat treated, 370 to 470 BHN.
 - 3. Provide three (3) test bars incrementally poured per production shift as per Underwriter’s Laboratory (U.L.) specifications and ASTM A536. Testing for tensile, yield and elongation in accordance with ASTM E8.

4. Provide chemical and nodularity tests performed as recommended by the Ductile Iron Society, on a per ladle basis.
5. Provide an identification number consisting of year, day, plant and shift (YYDDD)(plant designation)(Shift number) cast into each gland body.
6. Record all physical and chemical test results such that they can be accessed via the identification number on the casting. Provide the Material Traceability Records (MTRs) available, in hard copy.
7. Provide coating for restraint devices consisting of the following:
 - a. Process all wedge assemblies and related parts through a phosphate wash, rinse and drying operation prior to coating application.
 - b. Coating: A minimum of two coats of liquid thermoset epoxy coating with heat cure to follow each coat.
 - c. Surface pretreat all casting bodies with a phosphate wash, rinse and sealer before drying.
The coating shall be electrostatically applied and heat cured. Coating: Polyester based powder to provide corrosion, impact and UV resistance.
 - d. Coating system: MEGA-BOND by EBAA Iron, Inc.

D. Manufacturer:

1. EBAA Iron MegaLug Series 1100

2.9 FLANGE ADAPTORS

- A. Provide restrained flange adaptors for pipe consisting of multiple individual gripping wedges incorporated into a follower gland meeting requirements of AWWA A21.10.
 1. Provide actuation of the gripping wedges ensured with torque limiting twist off nuts.
 2. Provide restraint devices Listed by Underwriters Laboratories (3-inch through 12 inch size) and Designed by Factory Mutual (4-inch through 12-inch size).
 3. Gland body, wedges and wedge actuating components must be domestic manufacture (USA).
- B. Joint Deflection capability:
 1. 3-inch thru 8-inch: 5 degrees
 2. 10-inch and 12-inch: 3 degrees
 3. 14-inch and 16-inch: 2 degrees
 4. 18-inch and 20-inch: 1.5 degrees
 5. 20-inch, 42-inch and 48-inch: 1 degrees
 6. 30-inch and 36-inch: 3 degrees
- C. Provide flange adaptor to maintain seal with and 0.6 inch gap between end of pipe and mating flange.

D. Working Pressure Rating:

1. 16-inch and Smaller: 350 psi
2. 18-inch: 300 psi
3. 20-inch: 250 psi
4. 24-inch: 200 psi
5. 30-inch thru 48-inch: 150 psi
6. Minimum safety factor of 2 to 1.

E. Materials:

1. Gland body, wedges and wedge actuating components: Grade 65-45-12 ductile iron in accordance with ASTM A536.
2. Ductile iron gripping wedges: Heat treated, 370 to 470 BHN.
3. Provide three (3) test bars incrementally poured per production shift as per Underwriter's Laboratory (U.L.) specifications and ASTM A536. Testing for tensile, yield and elongation in accordance with ASTM E8.
4. Provide chemical and nodularity tests performed as recommended by the Ductile Iron Society, on a per ladle basis.
5. Provide an identification number consisting of year, day, plant and shift (YYDDD)(plant designation)(Shift number) cast into each gland body.
6. Record all physical and chemical test results such that they can be accessed via the identification number on the casting. Provide the Material Traceability Records (MTRs) available, in hard copy.
7. Provide coating for restraint devices consisting of the following:
 - a. Process all wedge assemblies and related parts through a phosphate wash, rinse and drying operation prior to coating application.
 - b. Coating: A minimum of two coats of liquid thermoset epoxy coating with heat cure to follow each coat.
 - c. Surface pretreat all casting bodies with a phosphate wash, rinse and sealer before drying.
The coating shall be electrostatically applied and heat cured. Coating: Polyester based powder to provide corrosion, impact and UV resistance.
 - d. Coating system: MEGA-BOND by EBAA Iron, Inc.

F. Manufacturer:

1. EBAA Iron Mega-Flange Series 2100

2.10 FLEXIBLE CONNECTIONS

A. Use as specified or indicated:

1. Bolted split sleeve couplings
2. Grooved couplings

2.11 BOLTED SPLIT SLEEVE COUPLINGS

- A. Provide in accordance with Section 15103 – PROCESS PIPING AND APPURTENANCES.
- B. Pressure rating at least equal to that of related pipeline.
- C. Provide with gaskets of composition designed for exposure to liquid within pipe.

2.12 GROOVED COUPLINGS

- A. Conform to AWWA C606.
- B. Minimum pipe wall thickness specified under "Pipe For Use With Couplings."
- C. Where grooved couplings are indicated to provide for expansion or flexibility, cut pipe grooves to provide necessary expansion or flexibility.
- D. Where grooved couplings are used instead of flanged joints, joint to be of rigid type with pipe grooves cut to bring pipe ends together. Beam strength of joint shall be equal to or greater than that of flanged joint.

2.13 FILLING RINGS

- A. Provide where necessary.
- B. Materials, workmanship, facing, and drilling, conforming to 125-lb. ANSI.
- C. Suitable length with nonparallel faces and corresponding drilling, if necessary, for correct assembly of adjoining piping or equipment.

2.14 CONNECTIONS – TAPPED

- A. Provide service saddles for all taps for lines 24-inch and smaller.
 - 1. Body: Ductile iron ASTM A395 or Bronze.
 - 2. Straps and Hardware: Type 316 stainless steel.
- B. For 30-inch and larger provide watertight joint with adequate strength against pullout. Use only tapered thread taps.
 - 1. Maximum size of taps in pipe or fittings without bosses not to exceed that listed in table of Appendix to AWWA A21.51 based on: 2 full threads Where size of connection exceeds that given above for pipe, provide boss on pipe barrel or use tapping saddle. Make tap in flat part of intersection of run and branch of tee or cross, or connect by means of tapped tee, branch fitting and tapped plug or reducing flange, or tapping tee and tapping valve, or permitted.
 - 2. Provide taps and piping for gauges and pressure sensing instruments in accordance with ANSI/HI standards so that there are no erroneous readings.

2.14 PIPE COATING

- A. Outside of pipe and fittings within structures: Clean and apply one shop coat with a 3 to 5 mil DFT of moisture cured urethane.
- B. Outside surfaces of castings to be encased in concrete: No coating.
- C. Machined surfaces cleaned and coated with rust-preventative compound at shop.
- D. Outside of buried pipe and fittings: Standard bituminous coating conforming to AN Standard.

2.15 CEMENT LINING

- A. Inside of pipe and fittings: Provide double thickness cement lining and bituminous seal coat conforming to AWWA A21.4.

2.16 GASKETS, BOLTS, AND NUTS

- A. Provide ring or full face synthetic rubber gaskets for flanged joints and neoprene faced phenolic for insulating gaskets in accordance with AWWA A21.11 and ASME B16.21.
 - 1. 1/8 inch thick
- B. Make flanged joints with:
 - 1. Bolts
 - 2. Bolt studs with nut on each end
 - 3. Studs with nuts where flange is tapped
 - 4. Plastic bolt sleeves and washers for insulating joints.
- C. Number and size of bolts conform to same ANS as flanges.
- D. Provide Type 316 stainless steel bolts, washers and nuts for all services.

PART 3 - EXECUTION

3.1 HANDLING AND CUTTING

- A. Mark pipe and fittings "Rejected" and remove from site when cracked or has received a severe blow.
- B. If permitted, cut on sound barrel at a point at least 12 inch from visible limit of crack, at Contractor's expense.
- C. Machine cut with milling type cutters, knives, or saws. Snap cutters, torch, or hammer and chisel NOT ALLOWED. Examine for possible cracks.
- D. Chamfer cut ends if used for push-on joints.

3.2 INSTALLATION

- A. Visually inspect before installation.
- B. Ensure pipelines parallel to building walls wherever possible. Install piping to accurate lines and grades. Where temporary supports are used, ensure rigidity to prevent shifting or distortion of pipe. Provide for expansion where necessary.
- C. Pitch piping toward low points. Provide for draining low points.
- D. Before assembly, remove dirt and chips from inside pipe and fittings.
- E. Piping Support: Provide in accordance with Section 15105 – PIPE SUPPORTS FOR PROCESS PIPING.
- F. Pipe and Fittings:
 - 1. Remove and replace defective pieces.
 - 2. Clear of all debris and dirt before installing and keep clean until accepted.
 - 3. Lay accurately to lines and grades indicated or required. Provide accurate alignment, both horizontally and vertically.
 - 4. Provide firm bearing along entire length of buried pipelines.
 - 5. Do not allow deflection of alignment at joints to exceed permissible deflection as specified below:

PIPE DEFLECTION ALLOWANCES

Maximum permissible deflection, in.* (mm)		
Size of pipe, in (mm)	Push-on joint	Mechanical joint
4 (100)	19 (482)	31 (787)
6 (150)	19 (482)	27 (685)
8 (200)	19 (482)	20 (508)
10 (250)	19 (482)	20 (508)
12 (300)	19 (482)	20 (508)
14 (350)	11 (279)	13-1/2 (343)
16 (400)	11 (279)	13-1/2 (343)
18 (450)	11 (279)	11 (279)
20 (500)	11 (279)	11 (279)
24 (600)	11 (279)	9 (228)
30 (750)	11 (279)	9 (228)
36 (900)	11 (279)	8 (203)
42 (1100)	7-1/2 (190)	7-1/2 (190)
48 (1200)	7-1/2 (190)	7-1/2 (190)
54 (1400)	7-1/2 (190)	0 (0)

* Maximum permissible deflection for 20-foot (6 meters) lengths; for other lengths in proportion of such lengths to 20-foot (6 meters).

- a. For push-on joint or similar pipe, clean bell of excess tar or other obstruction and wipe out before inserting next pipe spigot. Shove new pipe into place until properly seated and hold securely until joint completed.
- b. Set castings to be encased in concrete accurately with bolt holes, if any, carefully aligned. Clean off rust and scale before setting.

- G. Temporary Plugs: When pipe laying not in progress, close open ends of pipe with temporary watertight plugs. If water in trench, do not remove plug until danger of water entering pipe passed.
- H. Appurtenances: Set valves, fittings and appurtenances as indicated.

3.3 JOINTS AND COUPLINGS

A. Push-on Joints:

1. Insert gasket into groove bell. Apply thin film of nontoxic gasket lubricant over inner surface of gasket in contact with spigot end.
2. Insert chamfered end into gasket. Force pipe past it until it seats against socket bottom.

B. Flanged Joint:

1. Make up tight.
2. Do not put strain on nozzles, valves, and other equipment.
3. Bolt threads must fully engage the nuts. At a minimum the bolt must be flush with the nut and no more than 1/2-inch excess thread protruding from the nut.

C. Mechanical Joints:

1. Wire brush surfaces in contact with gasket and clean gasket.
2. Lubricate gasket, bell, and spigot with soapy water.
3. Slip gland and gasket over spigot, and insert spigot into bell until seated.
4. Seat gasket and press gland firmly against gasket.
5. After bolts inserted and nuts made finger-tight, tighten diametrically opposite nuts progressively and uniformly around joint by torque wrench. Torque bolts to values recommended by manufacturer.

D. Grooved Couplings:

1. Clean grooves and other parts.
2. Coat ends of pipe and outside of gasket with soft soap or silicone and slip gasket over one pipe end.
3. Bring pipes to correct position and center gasket over pipe ends with lips against pipe.
4. Place housing sections, insert bolts and tighten nuts until housing sections in metal-to-metal contact.
5. After assembly and inspection and before backfilling, coat exterior surfaces of buried couplings, including bolts and nuts, with heavy-bodied bituminous mastic.

E. Tapped Connection:

1. Drill and tap normal to longitudinal axis.

2. Drilled by skilled mechanics using proper tools.
3. Use only tapered threads.

3.4 FIELD TESTING

- A. Provide in accordance with Section 15103 – PROCESS PIPING AND APPURTENANCES.
- B. Clean of all dirt, dust, oil, grease and other foreign material, before conducting pressure and leakage tests.
- C. Pressure and Leakage Tests:
 1. Conduct combined pressure and leakage test in pipelines.
 2. Furnish and install temporary testing plugs or caps; pressure pumps, pipe connections, meters, gages, equipment, and labor.
 3. Test when desired and comply with specifications.
 4. Test pipelines in excavation or embedded in concrete before backfill or placing of concrete and test exposed piping before field painting.
 5. Fill section of pipe with water and expel air. If hydrants or blow offs are not available at high points for releasing air, make necessary taps and plug after test completion.
 6. Maintain section full of water for 24 hours before conducting combined pressure and leakage test.
 7. Conduct pressure and leakage test consisting of first raising water pressure (based on elevation of lowest point of section under test and corrected to gage location) to pressure in psi numerically equal to pipe pressure rating, but not more than 150 psi.
 - a. No visible leakage in joints.
 8. If section fails pressure and leakage test, locate, uncover, and repair or replace defective pipe, fitting, or joint, at no additional expense and without time extension. Conduct additional tests and repairs until section passes test.
 9. Modify test procedure only if permitted by Owner’s Representative.

3.5 FIELD PAINTING

- A. Provide in accordance with Section 09900 - PAINTING.

3.6 CONTRACT CLOSEOUT

- A. Provide in accordance with Section 01700 – CONTRACT CLOSEOUT.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02632

STORMWATER BYPASS PUMPING SYSTEMS

PART 1 - GENERAL

1.1 SCOPE OF WORK

- A. The work of this section consists of furnishing all labor, materials, tools and equipment required to temporarily bypass stormwater flows around various work zones of the project, thus enabling other project work to proceed.
- B. The Design-Builder shall be responsible for maintaining all stormwater flows through the project area for the duration of the project, without surcharging upstream or downstream portions of the existing systems, such work being at no additional cost to the MBTA.
- C. The Project includes the construction of new drainage systems and relocation of existing drainage systems throughout the project corridor. The Project work also includes the CCTV inspections and lining of existing storm drain piping and structures as shown or as noted on the Contract Documents.
- D. Project work includes new and relocated gravity drainage conduits, track underdrains, stormwater pump stations with associated force mains and stormwater storage systems, including an open detention basin and a twin 90-inch diameter underground pipe storage system. In order to construct various elements of the Project, including the above referenced drainage improvements, certain portions of the existing drainage system will have to be temporarily removed from service to allow other Project work to proceed and all flow to that location must be temporarily bypassed around the work site
- E. A major existing gravity drainage system that will be impacted by the work generally follows the Fitchburg Commuter Rail corridor starting at a point west of the Red Bridge area near Medford Street and flows easterly to an existing outlet structure at the Millers River. A number of lateral drainage systems, including systems from surrounding neighborhoods, connect into this main trunk drain.
- F. The design, installation and operation of temporary bypass systems, including pumping systems, shall be the Design-Builder's responsibility. The Design-Builder may employ the services of a vendor who can demonstrate to the MBTA that it specializes in the design and operation of temporary bypass pumping systems.
- G. The Design-Builder shall provide bypass systems for all storm drainage systems that may be encountered on the project, whether shown on the plans or not.
- H. The bypass system and its operation shall meet the requirements of all local, state and federal codes and regulatory agencies having jurisdiction.

1.2 RELATED WORK

- A. Related Work:
 - 1. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 - 2. Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
 - 3. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 4. Section 02756 – STORM DRAIN LINING

1.3 SUBMITTALS

- A. Submittals shall be provided under the provisions of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. The Design-Builder shall prepare a specific, detailed description of all proposed temporary bypass pumping systems and submit them for review and approval.
- C. The submittal shall include detailed plans and descriptions outlining all provisions and precautions to be taken by the Design-Builder regarding the handling of existing drainage. This plan must be specific and complete, including such items as schedules, locations, sketches, elevations, capacities of equipment, materials and all other incidental items required to insure proper protection of the facilities, including protection of the access and bypass pumping locations from damage due to widely varying flows and site conditions.
- D. The plan shall include but not limited to details of the following:
 - 1. Conduit plugging method and types of plugs.
 - 2. Plan indicating location of pump(s), check valves and other valves; type and size of all piping and method of pipe coupling; layout of suction and discharge piping including access points and all associated appurtenances. Aluminum “irrigation” type piping and glued PVC pipe shall not be used under any circumstance.
 - 3. Bypass pump(s) sizes, capacity, and power requirements, including standby power.
 - 4. Method of noise control for each location.
 - 5. Proposed phasing of temporary bypass systems, as required.
 - 6. Contingency plan to be implemented during extreme flow condition (i.e., conditions that exceed the capacity of the temporary bypass system). This shall include a description of standby equipment.

1.4 DESIGN CRITERIA AND FLOWS

- A. Flows in the various drainage systems are anticipated to be highly variable. Historical and/or estimated information regarding flows, if available and used, will require the Design-Builders judgment.
- B. Bypass systems shall be capable of bypassing stormwater flows around the work area without increasing flooding or ponding, including flooding or ponding off-site, that would have occurred otherwise if Project construction was not underway, all as determined by the MBTA.
- C. The work covered by this specification shall be in accordance with the best practice of the industry. The specifications call attention to certain features but do not purport to cover all details entering into the required work.

- D. The temporary bypass systems shall be designed to prevent flows from surcharging within the upstream and downstream conduits to an unacceptable or unsafe condition. The surcharge shall not exceed the hydraulic grade line, either upstream or downstream, that would occur in the drainage system if the bypass system were not there, all as determined by the MBTA.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All temporary plugs, pumps, piping, valves and other appurtenant products used to conduct the work shall be supplied by the Design-Builder and retained by the Design-Builder at the completion of the work.
- B. All products shall be in good serviceable condition and suitable for the intended use as determined by the MBTA and meet all applicable codes and regulatory requirements.

PART 3 - EXECUTION

3.1 GENERAL

- A. When the depth of flow in the drain line is above the maximum allowable for the type of work being performed in the applicable section(s) of these specifications, one or more of the following methods of flow control shall be used:
 - 1. Plugging or Blocking
 - a. A drain line plug shall be inserted into the drain line(s) at a location upstream from the section in which the work is to be performed.
 - b. The plug shall be so designed that all or any portion of the flow can be released.
 - c. All temporary devices placed or installed in the drainage system shall be adequately secured to prevent sudden release due to unanticipated pressure build-up behind the device.
 - d. Plugging or blocking of the drain line(s) shall be performed during dry weather only and shall be removed at the end of each workday if practicable, unless otherwise allowed by the MBTA. No plugs shall be left in place unattended, unless conditions are monitored by the Design-Builder at a maximum of 6-hour intervals during non-working hours or as otherwise approved by the MBTA. If rain is forecast, monitoring shall be conducted at 2-hour intervals unless otherwise permitted by the MBTA.
 - e. During wet weather conditions the Design-Builder shall closely monitor the impacts of the plug(s) on the system and implement appropriate corrective action, including actions as directed by the MBTA.

- f. All temporary devices placed or installed in the drainage system shall be removed when no longer required and the downstream system has been cleared of all personnel and equipment. Removal shall be completed in a manner that will not result in a surge or major disturbance downstream.
- g. Design-Builder shall evaluate the surcharge capacity on a per location basis.

2. Pumping and Bypassing

- a. When pumping/bypassing is required, the Design-Builder shall supply the pumps, conduits and other equipment to divert the flow in the drainage system around the missing section of the system where other work is being performed. The Design-Builder shall be responsible for furnishing the labor and supervision to set up, operate and maintain the temporary pumping and bypassing system.
 - b. Bypass pumping shall normally be operated 24 hours per day (or installed and available to be put into service) until the bypass is no longer required and work requiring the bypass has been completed. The bypass pumping system shall be attended by qualified worker(s) whenever in operation and until flows recede and pumping is not required.
 - c. When pumping systems are not in service, the Design-Builder shall monitor flow conditions at each bypass location and, based on actual flow conditions and compliance with these specifications, activate and operate the pumping equipment already installed by the Design-Builder and available at each site. Conditions shall normally be monitored by visiting each bypass site on a 6-hour frequency unless otherwise allowed by the MBTA.
 - d. No leaking bypass piping shall be allowed. Any leaking or damaged pumps and piping shall be immediately repaired or replaced. All work shall be stopped until the leaking or damaged pumps and piping is repaired or replaced.
 - e. At no time shall flow from the drainage system be discharged into a sanitary sewer or combined sewer system, either by pumping or by gravity flow. If such an incident were to occur, whether intentional or unintentional, the Design-Builder shall be responsible for all costs associated with damages to those other systems and any impacted water courses and water bodies, whether within the Project site or not, to the complete satisfaction of the MBTA and at no additional cost to the MBTA.
 - f. Prior to activation of the pumping system(s), the Design-Builder shall conduct field tests to demonstrate the adequacy of each temporary pumping system as required by the MBTA. MBTA shall be notified two (2) days in advance of field testing.
- B. The Design-Builder shall conduct his work so as to not cause excessive surcharging of the drainage system as defined in this Section and shall not cause damage to the drainage system, its connections and/or apparatus. Any damage caused by the Design-Builder's operations shall be repaired to the complete satisfaction of the MBTA and at no additional cost to the MBTA.
- C. Flow bypassing and control may be required at multiple locations at the same time. The Design-Builder shall have adequate equipment available to meet the project demands.
- D. At no time shall stormwater be discharged onto the ground, the tracks or private property. Stormwater bypass systems shall not foul the track.
- E. Measures shall be taken to protect water resources, wetlands and other natural resources.

3.2 CLEAN-UP

- A. The Design-Builder shall be responsible for the legal disposal of excess material and general clean-up of the work area which will be subject to the approval of the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02633

WASTEWATER BYPASS PUMPING SYSTEMS

PART 1 - GENERAL

1.1 SCOPE OF WORK

- A. The work of this section consists of furnishing all labor, materials, tools and equipment required to temporarily bypass sewage (wastewater) and/or combined sewage flows around various work zones of the project, thus enabling other project work to proceed.
- B. The work under this Section includes control of flow in combined sewer overflow (CSO) systems as described below. The terms sewer, sewage and wastewater as used herein shall include sanitary sewage, combined sewage and combined sewer overflow systems.
- C. The Design-Builder shall be responsible for maintaining all sanitary sewer and combined sewer flows through the project area for the duration of the project, without surcharging upstream or downstream portions of the existing systems, such work being at no additional cost to the MBTA.
- D. The design, installation and operation of temporary bypass systems, including pumping systems, shall be the Design-Builder's responsibility. The Design-Builder may employ the services of a vendor who can demonstrate to the MBTA that it specializes in the design and operation of temporary bypass pumping systems.
- E. The Design-Builder shall provide bypass systems for all sanitary sewer and combined sewer overflow systems that may be encountered on the project, whether shown on the plans or not. Customers have sewer connections along the sanitary sewer and combined sewer overflow systems that shall not be impacted by the sewer and/or combined sewer bypassing work, unless otherwise allowed by the MBTA.
- F. Any service connections encountered shall remain in continuous service unless otherwise allowed by the MBTA.
- G. The bypass system and its operation shall meet the requirements of all local, state and federal codes and regulatory agencies having jurisdiction.

1.2 RELATED WORK

- A. The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 - 2. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 3. Section 02240 – DEWATERING
 - 4. Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER

1.3 SUBMITTALS

- A. Submittals shall be provided under the provisions of Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. The Design-Builder shall prepare a specific, detailed description of all proposed temporary bypass pumping systems and submit them for review and approval.
- C. The submittal shall include detailed plans and descriptions outlining all provisions and precautions to be taken by the Design-Builder regarding the handling of existing sewage (wastewater) and combined sewage flows. This plan must be specific and complete, including such items as schedules, locations, sketches, elevations, capacities of equipment, materials and all other incidental items required to insure proper protection of the facilities, including protection of the access and bypass pumping locations from damage due to widely varying flows and site conditions.
- D. The plan shall include but not limited to details of the following:
 - 1. Conduit plugging method and types of plugs.
 - 2. Plan indicating location of pump(s), check valves and other valves; type and size of all piping and method of pipe coupling; layout of suction and discharge piping including access points and all associated appurtenances. Aluminum “irrigation” type piping and glued PVC pipe shall not be used under any circumstance.
 - 3. Bypass pump(s) sizes, capacity, and power requirements, including standby power.
 - 4. Method of noise control for each location.
 - 5. Proposed phasing of temporary bypass systems, as required.
 - 6. Contingency plan to be implemented during extreme flow condition (i.e., conditions that exceed the capacity of the temporary bypass system). This shall include a description of standby equipment.
- E. Other submittals as may be required by the system owner, including the BWSC.

1.4 DESIGN CRITERIA AND FLOWS

- A. The work covered by this specification shall be in accordance with the best practices of the industry. The specifications call attention to certain features but do not purport to cover all details entering into the required work.
- B. The temporary bypass systems shall be designed to prevent flows from surcharging within the upstream and downstream conduits to an unacceptable or unsafe condition. The surcharge shall not exceed the hydraulic grade line, either upstream or downstream, that would occur in the system if the bypass system were not there, all as determined by the MBTA.
- C. Bypass systems shall be capable of bypassing all flows around the work area without increasing flooding or ponding, including flooding or ponding off-site, that would have occurred otherwise if Project construction was not underway, all as determined by the MBTA.
- D. Flows in the various sewer and combined sewer systems are anticipated to be highly variable. Historical and/or estimated information regarding flows, if available and used, will require the Design-Builder's judgment.

PART 2 - PRODUCTS

2.1 GENERAL

- A. All temporary plugs, pumps, piping, valves and other appurtenant products used to conduct the work shall be supplied by the Design-Builder and retained by the Design-Builder at the completion of the work.
- B. All products shall be in good serviceable condition as determined by the MBTA and meet all applicable codes and regulatory requirements.

PART 3 - EXECUTION

3.1 GENERAL

- A. When the depth of flow in the sewer line is above the maximum allowable for the type of work being performed in the applicable section(s) of these specifications, one or more of the following methods of flow control shall be used:
 - 1. Plugging or Blocking
 - a. A sewer line plug shall be inserted into the sewer line(s) at a location upstream from the section in which the work is to be performed.
 - b. The plug shall be so designed that all or any portion of the sewage flow can be released.
 - c. All temporary devices placed or installed in the sewer system shall be adequately secured to prevent sudden release due to unanticipated pressure build-up behind the device.
 - d. Plugging or blocking of the drain line(s) shall be performed during dry weather only and shall be removed at the end of each workday if practicable, unless otherwise allowed by the MBTA. No plugs shall be left in place unattended, unless conditions are monitored by the Design-Builder at a maximum of 6-hour intervals during non-working hours or as otherwise approved by the MBTA. If rain is forecast, monitoring shall be conducted at 2-hour intervals unless otherwise permitted by the MBTA.
 - e. During wet weather conditions the Design-Builder shall closely monitor the impacts of the plug(s) on the system and implement appropriate corrective action, including actions as directed by the MBTA.
 - f. All temporary devices placed or installed in the sewer and/or combined sewer system shall be removed when no longer required and the downstream system has been cleared of all personnel and equipment. Removal shall be completed in a manner that will not result in a surge or major disturbance downstream.
 - g. Design-Builder shall evaluate the surcharge capacity on a per location basis.
 - 2. Pumping and Bypassing
 - a. When pumping/bypassing is required, the Design-Builder shall supply the pumps, conduits and other equipment to divert the flow of sewage or combined sewage flow around the missing section of the system where other work is being performed. The

Design-Builder shall be responsible for furnishing the labor and supervision to set up, operate and maintain the temporary pumping and bypassing system.

- b. Bypass pumping shall normally be operated 24 hours per day (or installed and available to be put into service) until the bypass is no longer required and work requiring the bypass has been completed. The bypass pumping system shall be attended by qualified worker(s) whenever in operation and until flows recede and pumping is not required.
- c. When pumping systems are not in service, the Design-Builder shall monitor flow conditions at each bypass location and, based on actual flow conditions and compliance with these specifications, activate and operate the pumping equipment already installed by the Design-Builder and available at each site. Conditions shall normally be monitored by visiting each bypass site on a 6-hour frequency unless otherwise allowed by the MBTA.
- d. No leaking bypass piping shall be allowed. Any leaking or damaged pumps and piping shall be immediately repaired or replaced. All work shall be stopped until the leaking or damaged pumps and piping is repaired or replaced.
- e. At no time shall flow from the CSO system or sanitary sewer be discharged into a storm drain system, either by pumping or by gravity flow. If such an incident were to occur, whether intentional or unintentional, the Design-Builder shall be responsible for all costs associated with cleanup of the site and impacted water courses and water bodies, whether within the Project site or not, to the complete satisfaction of the MBTA and at no additional cost to the MBTA.
- f. Prior to activation of the pumping system(s), the Design-Builder shall conduct field tests to demonstrate the adequacy of each temporary pumping system as required by the MBTA. The MBTA shall be notified two (2) days in advance of field testing.

- B. The Design-Builder shall conduct his work so as to not cause excessive surcharging of the sewerage system as defined in this Section and shall not cause damage to the sewerage system, its connections and/or apparatus. Any damage caused by the Design-Builder's operations shall be repaired to the complete satisfaction of the MBTA and at no additional cost to the MBTA.
- C. Flow bypassing and control may be required at multiple locations at the same time. The Design-Builder shall have adequate equipment available to meet the project demands.
- D. At no time shall flow be discharged onto the ground, the tracks or private property. Bypass systems shall not foul the track.
- E. Measures shall be taken to protect water resources, wetlands and other natural resources.

3.2 CLEAN-UP

- A. The Design-Builder shall be responsible for the legal disposal of excess material and general clean-up of the work area which will be subject to the approval of the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02650

EXISTING SITE UTILITIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the maintenance, support, protection, relocation, reconstruction and adjustment-to-grade, restoration, and abandonment of existing utilities affected by the construction work.
- B. For the purpose of this Section, utility means any public or private service, such as electric light and power systems; gas distribution systems; telephone, telegraph, cable television and other communication services; water distribution; storm drain and sanitary sewer services; police and fire communication systems; street lighting and traffic signs and signals; parking meters; and steam distribution systems.
- C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 01020 – ALLOWANCES
 - 2. Section 02100 – SITE PREPARATION
 - 3. Section 02221 – DEMOLITION
 - 4. Section 02240 – DEWATERING
 - 5. Section 02283 – HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
 - 6. Section 02300 – EARTHWORK
 - 7. Section 02369 – DRILLED MINI-PILES
 - 8. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 9. Section 02713 – EXTERIOR WATER DISTRIBUTION SYSTEMS
 - 10. Section 02800 – EXTERIOR CONDUIT SYSTEMS

1.2 GENERAL

- A. The location of existing underground pipes, cables, conduits, and structures as shown have been collected from the best available sources and the Authority together with its agents does not imply or guarantee the data and information in connection with the underground pipes, cables, conduits, structures and other parts as to their completeness nor their locations indicated. The Design-Builder shall contact utility owners and request marking location of all their lines in the work areas. The Design-Builder shall assume there are existing water, gas, electric and other utility connections to every building and structure, whether they appear on the Drawings or not. Any expense and/or damage to these shall be the responsibility of the Design-Builder.
- B. Foundations and lines for services, police and fire alarm boxes, street and pedestrian lights, and traffic signals may not be shown on the Drawings. The appropriate utility companies and/or agencies shall be contacted and consulted for locations of the above.

- C. All utility companies, public and private, shall be notified, including those in control of utilities not shown on the Drawings (see Chapter 370, Acts of 1963, Massachusetts) prior to designing, excavating, blasting, installing, backfilling, grading, or restoring pavement. The Design-Builder shall
 Premark the area of excavation or work and notify the Dig Safe Center (1-888-DIG-SAFE) at least three business days prior to any excavation or work. In addition, notification shall be given to all affected private and/or public utilities to permit street marking of their lines.
- D. Some unknown utilities may exist in the areas to be excavated. The Design-Builder shall take the necessary precautions when excavating in areas of potential utility conflict. Precautions may include, but are not limited to, soil vacuum excavation, hand digging, or other non-destructive means. The Design-Builder shall further be prepared to pre-excavate or pre-trench to locate potential utility conflicts prior to performing such activities as, but not limited to, jacking, tunneling, installing temporary excavation support, etc.
- E. Interruptions of utilities shall not be permitted without written consent of the utility owner. The Design-Builder shall coordinate with all utilities and provide all temporary utilities and connections to avoid interruptions.

1.3 SUBMITTALS

- A. Submit working drawings and, if applicable, shop drawings showing the details, procedures, and scheduling for performance of the existing utility work. Show actual location of existing utility facilities; interferences which these facilities present to the new work; location of settlement markers; method proposed to proceed with the construction; details of proposed support systems; and, if applicable, method of testing and procedure for restoration.
- B. Submit written evidence of affected utility owners' approval of the details, procedure, and scheduling.
- C. Provide as much written notice as possible, well in advance of the intended date to commence operations, to affected utility owners and parties having surface, subsurface or overhead structures in the construction area. Design-Builder to verify the notice procedures of each affected utility owner and party and shall properly notify them based on their requirements. Furnish the Owner copies of all notices.
- D. If a settlement or movement monitoring system is required, submit copies of readings to the Owner and affected utility owner within 24 hours of the reading.
- E. Submit to the Owner, certifications from the respective suppliers that the products to be incorporated in the work are in conformance with applicable requirements.

1.4 NOTIFICATION

- A. Notify the appropriate utility agencies and the Owner at least 72 hours prior to starting any work involving or adjacent to utility service facilities. The Design-Builder is responsible for providing sufficient notice to the utility companies. The Design-Builder is responsible for any delays due to insufficient advance notice to the utility companies.
- B. Where an existing utility facility is encountered that is not indicated or that is determined to be a different utility facility than that indicated, promptly notify the Owner. The Design-Builder is

responsible for determining the owner of the facility and the disposition of the facility.

- C. For proposed waterline and stormwater upgrades located with the City of Boston, Design-Builder to coordinate installation schedule with Boston Water and Sewer Commission (BWSC) inspectors.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Products and materials shall conform to the specifications of the affected utility owners.

2.2 SALVAGE MATERIAL

- A. Reuse materials designated to be salvaged, provided they are inspected and approved by the respective utility owner and the Owner. Salvaged material not designated for reuse or returned to the owner shall become the property of the Design-Builder and removed from the site.
- B. Maintain and have available for inspection by the Owner a detailed record, including signed vouchers and receipts, of new and salvaged materials received from, used, or returned to the various utility owners.

PART 3 - EXECUTION

3.1 GENERAL

- A. Conform to the specifications and standard practices of the affected utility owners. Coordinate with utility owners which work shall be done by the Design-Builder and which work shall be done by utility owner. Ensure continuity of all existing utility services to all users except when the utility owner determines that temporary interruption is required.
- B. Unless otherwise indicated or authorized in writing by the Owner, maintain all utility facilities complete in place.
- C. Abandoned Facilities
 - 1. Demolish and remove abandoned utility facilities in conflict with work.
 - 2. Do not undertake demolition or removal of the service until written approval for such work has been obtained from the utility owner.
 - 3. When abandoned facilities are indicated to be left in place, plug, or cap or bulkhead the ends of
 - 4. conduits and pipes, as indicated. Bulkheads for pipes greater than 15-in in diameter shall be constructed of solid concrete masonry bricks or solid concrete masonry blocks with full mortar joints. The bulkhead shall be watertight. Recess the bulkhead 1/2-in and seal with non-shrink grout.
- D. Provide, install, and maintain all temporary facilities required providing interim utility service when a utility facility is to be relocated and when a utility facility to be replaced is abandoned prior to replacement.

- E. Where an existing utility facility is encountered which is not indicated, or which is determined to be a different utility service than that indicated, promptly notify the Owner. The Design-Builder shall determine the owner of the facility and the disposition of the facility.
- F. If, upon exposure, the condition or location of a facility to be supported complete-in-place is found by the Owner to be unsafe for support or for maintenance of service, replace or reconstruct the facility as required, with prior approval of the Owner and the utility owner.

3.2 SETTLEMENT OR MOVEMENT

- A. Provide suitable settlement or movement monitoring systems where indicated or required by the affected utility owner.
- B. In case of settlement or other movement which might cause damage, take immediate remedial measures to correct the conditions and damages caused by the settlement.

3.3 RECONSTRUCTION AND ADJUSTMENT-TO-GRADE

- A. Relay, reset, or otherwise reconstruct miscellaneous structures and facilities as indicated.
- B. Adjust-to-grade manholes and inlets as indicated, by raising or lowering the upper portion thereof. As necessary, adjust-to-grade all manhole and inlet castings, valve boxes, electric and communication boxes, and all other similar existing structures.
- C. Backfill under utilities supported or exposed using controlled density fill to allow for the proper support and compaction under the utility. Design-Builder shall coordinate with the utility owner to determine the acceptability of the use and type of controlled density fill and shall work with the Owner to develop alternate means to ensure the proper backfill and compaction under the utility.

3.4 AS-BUILT UTILITY LOCATION AND CONDITION SURVEY

- A. For each new or relocated utility installed, including those installed or relocated by others in the Project Area, perform an as-built location survey by coordinates prior to backfilling the excavation.
- B. The survey data shall be obtained by Global Positioning Survey (GPS) and certified by a Professional Land Surveyor registered in Massachusetts.
- C. A complete digital base plan shall be provided in AutoCAD DWG format Release 2012 or later on a Compact Disk (CD), properly referenced to the coordinate system established in the contract. The following standards shall be applicable:
 - 1. Text: Text shall be drawn using a STYLE of "L100-XX" (where XX refers to the plotted scale) and a font file of "ARIAL" as defined in the AutoCAD survey template provided by the Owner. The style shall be defined as a "fixed height" style, and have a height of 0.125 and width factor of 0.85 times the drawing plotted annotated text scale (i.e. 4.0 for 40 scale plan, 2.0 for 20 scale etc.).
 - 2. Precision and Accuracy:

- a. Horizontal Survey:
 - 1. Precision: Horizontal control and surveyed points shall maintain a minimum precision of 1:10,000.
 - 2. Accuracy: No more than 10% of the survey points shall be in error by more than 1/100 inch or 0.25 mm when viewed at the requested scale.
- b. Vertical Survey:
 - 1. Precision: Vertical Control shall have a maximum error of closure no greater than .075 feet or .02 meters.
 - 2. Accuracy: No more than 10% of elevations when interpolated from a Surface shall be in error of more than 1/2 a contour interval.
- 3. Surface Data: The data format shall conform to AutoCAD Civil 3D 2012 files. If the Design-Builder uses a different software product to create a surface, then the surface must be represented as a TIN (Triangulated Irregular Network) of 3D lines on a separate, distinct layer within the AutoCAD drawing file. 3D faces or 2 dimensional lines are NOT acceptable.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02713

EXTERIOR WATER DISTRIBUTION SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing, installing, testing, and disinfecting permanent water supply and fire protection mains and distribution piping.
- B. Related Work:
 - 1. Section 02300 - EARTHWORK
 - 2. Section 02240 - DEWATERING
 - 3. Section 02283 - HANDLING AND DISPOSAL OF CONTAMINATED GROUNDWATER
 - 4. Section 02650 - EXISTING SITE UTILITIES
 - 5. Section 03300 - CAST-IN-PLACE CONCRETE

1.2 SUBMITTALS

- A. Submit to the MBTA shop drawings showing the details, procedures, and scheduling for water utility installation. Coordinate with the water utility Owner when the MBTA's main is ready for connection to utility Owner's meter or piping. Shop drawings shall include the maximum anticipated working pressure in each main and branch, the proposed pressure test pressure, and the fittings material class.
- B. Submit to both the MBTA and the water utility Owner detailed hydrostatic test and disinfection plans, including all proposed materials, concentrations, equipment, temporary piping, valving, connections, flow rates, equipment, methods of metering and measuring, and method of flushing and disposal.
- C. Submit to both the MBTA and the water utility Owner for acceptance all manufacturer's and independent laboratory certified test reports as specified above and in cited standards.
- D. Certifications that all wetted surface metals in contact with potable water comply with the 2014 Safe Drinking Water Act Lead Reduction law and comply with NSF 372.
- E. Submit to the MBTA shop drawings, catalogue cuts and other product literature for all pipe, fittings, joints and accessories, valves, hydrants, couplings, specials, insulation, and service materials.

1.3 QUALITY ASSURANCE

- A. Lining Toxicity Test
 - 1. Procedure: FDA Method of Testing for Toxicity of Coating Material Intended for Use in Transporting or Holding Food or Potable Water.

2. Requirements: Certified test results by pipe manufacturer; no more than 18 mg. per square inch exposed surface and no more than 50 ppm by weight of the water capacity of the test container, of chloroform-soluble extractives, corrected for zinc extractives such as zinc oleate.
- B. Field Pressure and Leakage Tests
1. Ductile Iron: AWWA C 600
 2. Steel: AWWA C 600
- C. Chlorine Residual Test
1. Test Method
 - a. During Disinfection: AWWA Manual M12, APHA/AWWA Standard methods drop dilution, Method E.
 - b. At End of Retention Period: APHA/AWWA Standard methods OTA or Amperometric Titration, Method D or F.
 - c. After Post-Disinfection Flush: APHA/AWWA Standard Methods Amperometric Titration, Method F.
 2. Requirements
 - a. Test to be performed by approved independent testing laboratory. Certified test results to meet requirements of AWWA C 651 and water utility Owner.
 - b. In lieu of independent testing laboratory, Design-Builder may subcontract for water utility Owner to conduct residual chlorine testing at Design-Builder's expense.
- D. Bacteriologic Tests
1. Procedure: AWWA C 651 and APHA/AWWA Standard Methods.
 2. Requirements: Zero coliform organisms, and meet requirements of water utility Owner and public health authority. Certified tests by approved independent testing laboratory or by public health authority at Design-Builder's expense.

1.4 JOB CONDITIONS

- A. Relations with Utility Owner
1. Establish through the MBTA a direct and continuous contact with the water utility Owner to which the MBTA's new distribution piping will be connected.
 2. In all cases, verify from the utility Owner the maximum working pressure than can be encountered at point of interface with utility Owner's piping, and indicate this pressure on the shop drawings.
 3. Do not cut into utility Owner mains or piping. The utility Owner will schedule and conduct interruption of utility services, perform cutting-in, and provide service meter at each point where new Authority piping is to be connected to the utility Owner mains and piping, at the expense of the Design-Builder.

4. Do not connect to utility Owner meter or piping without written authorization from the utility Owner. Connection shall be made by the Design-Builder or utility Owner as indicated.
 5. If agreed to by the utility Owner, the Design-Builder may, at his own expense, elect to have all or any part of the disinfection work performed by the utility Owner.
 6. Design-Builder to coordinate installation service with the utility owner to ensure proper inspection by representatives of the utility owner.
- B. Cross-Connections: Do not connect or cross-connect MBTA fire water distribution piping with other MBTA water piping. Fire distribution piping to be disinfected separately from metered water distribution piping to eliminate need for cross connections.
- C. Disinfection: Disinfect both domestic and service water piping and fire water piping.

PART 2 - PRODUCTS

2.1 PIPE

- A. Ductile Iron Pipe: AWWA C 151 thickness class as indicated; double-thickness cement-mortar lined; with push-on or mechanical joints except where flanges are indicated.
- B. Steel Pipe: AWWA C 200, type, grade, and thickness as indicated, lined, coated, wrapped and jacketed in accordance with AWWA C 203 with Type A primer, Type 2 enamel, standard wrap and kraft jacket, plain ends for mechanical couplings, 8 inch band each end free of external coating and wrap.

2.2 FITTINGS

- A. For Ductile Iron Pipe, and all Transitions: AWWA C 110; ductile iron; 150 psi minimum rating (350 psi minimum rating within the City of Boston); cement-mortar lined; with mechanical joints except where flanges are indicated.
- B. For Steel Pipe: ANSI B16.5; class as indicated; lined, coated, and wrapped as specified for steel pipe.
- C. Couplings for Steel Pipe: Flexible mechanical couplings, primed with AWWA C 203 Type A Primer; with steel bolts bituminous coated.

2.3 FLANGES

- A. For Ductile Iron Pipe: AWWA C 115, coated and lined as specified for iron pipe.
- B. For Steel Pipe: Welded slip-on type flanges, ASTM A 181 or ANSI B16.5 150-pound standard flanged mechanical coupling adaptor, bituminous lined inside and AWWA Type A bituminous primed outside in accordance with AWWA C 203 requirements, flange to mate with AWWA C207, ANSI B16.1, or ANSI B16.5 flange as required; bituminous coated steel bolts.
- C. Flange Gaskets: ANSI B16.21 neoprene, 1/8 inch thick.

2.4 VALVES

- A. For Fire Service and Domestic Water: Type and size as indicated, conforming to the following:
 - 1. Yard Faucets and Miscellaneous through 2-1/2 inches: Approved MSS Standard globe and angle valves, malleable iron or cast bronze.
 - 2. Gate, three inch and larger: AWWA C 509; AWWA C515 also acceptable within the City of Boston.
 - 3. Butterfly, three inch and larger; AWWA C 504.
 - 4. Check: AWWA C 510 double or approved commercial single.
- B. For Fire Water: Type and size as indicated, Class as required, U.L. listed.
- C. Valve Boxes: ASTM A48, 30B minimum, screw type adjustable length, stay-put type removable cover with the word WATER or FIRE as applicable.
- D. Precast Vaults: ASTM C 858, air-entrained, and Section 03300 - CAST-IN-PLACE CONCRETE.
- E. Cast-In-Place Vaults: Section 03300 - CAST-IN-PLACE CONCRETE, Class 4000-3/4.
- F. Iron Castings: ASTM A48, 30B minimum, with lettering as indicated.

2.5 FIRE HYDRANTS

- A. Hydrants shall conform to the "standard for Dry-Barrel Fire Hydrants" ANSI/AWWA C 502-85. Hydrants shall be designed for 150 psi service and for installation in a trench with 5 foot cover (5-1/2 feet bury hydrant). Hydrant barrel extensions shall be furnished and installed as necessary to achieve correct bury depth. The length of the hydrant barrel shall be such that when installed with the proper depth of cover on the branch pipeline, the hydrant will be set with the normal ground line of the barrel within 3-inches of the actual ground grade surface elevation.
- B. Hydrants shall be fabricated to manufacturer's standard pattern and size and shall have one 4-1/2 inch pumper nozzle and two 2-1/2 inch hose nozzles all with National Standard Thread (NST). Hydrant inlet opening on shoe shall have mechanical joints for accepting 6-inch ductile or cast iron pipe.
- C. Hydrants shall open clockwise and shall be marked with an arrow and word "OPEN" to indicate the direction of turn of the stem to open the hydrant.
- D. Hydrants shall have a compression type main valve, opening against and closing with water pressure. The main valve opening at the base of the hydrant shall have a minimum area of 39 square inches (5-inch minimum diameter circle). Each hydrant shall have "traffic" type ground line construction (breakaway bolts not acceptable) and permit 360-degree movement of the upper barrel to allow for any alignment without shutting down service and/or removing flange bolts and nuts. Hydrant operating nut shall be 1-1/2 inches, flat to point, pentagonal. Connecting pipe and pipe nipples between the main line tee and hydrant shall be 6-inch ductile iron conforming to the requirements for ductile iron pipe.
- E. Hydrants shall be hydrostatically tested as specified in AWWA C 502.

- F. Hydrant tees shall be anchor type. The branch shall have a plain end with an integral gland and rotating mechanical joint restraints. Every hydrant shall be equipped with a 6-inch shut-off valve, bolted or anchored to the hydrant tee.

2.6 SERVICE CONNECTIONS

- A. As required by the municipality involved or as specified in the Construction Specifications.

2.7 COUPLINGS

- A. Pressure rating at least equal to that of related pipeline with a minimum rating of 150 psi.
- B. Couplings shall meet the standard requirements of the municipality and MWRA. Couplings shall be provided with plain, Grade 27, rubber gaskets and with black steel, track-head bolts with nuts. Couplings shall be manufactured in the United States of America.

2.8 JOINTS

- A. Provide mechanical joint or push-on joint pipe with necessary accessories, conforming to AWWA A21.11.
 - 1. Provide gasket composition suitable for exposure to liquid within pipe.
 - 2. Provide gasket composition suitable for exposure to potable water.
 - 3. Provide mechanical joint gaskets with copper tips to provide electrical continuity.
 - 4. Provide serrated brass wedges for push-on joints to provide electrical continuity; two per joint for pipe 12-in. and smaller and four per joint for larger pipe.
- B. Restrained joints shall be furnished for installation on all fittings, sleeves, hydrants and valves. Restraints for mechanical and push on joints shall meet the standard requirements of the municipality and MWRA.
- C. Restraint systems for push-on pipe utilizing steel-wedge gaskets will be acceptable.

2.9 INSULATION

- A. Insulation shall meet the standard requirements of the municipality and MWRA. Insulation shall be factory formed-in-place polyurethane foam insulation having nominal thickness of 3", with an in-place density of 2.5 pcf, and a "K" factor of 0.14 BUT/in./hr/deg. F/sq. ft. Straight joints between insulated pipe lengths, and the end section of non-insulated pipe shall be 20-gauge corrugated aluminum performed to be fastened with stainless steel screws and bands. Jackets shall have expansion joints at 25-foot intervals. Sections of jacket shall have 2-inch minimum at all seams.
- B. Jacket shall have one layer of one mil polyethylene film with a protective coat of 40-lb. virgin draft paper to act as a moisture and galvanic corrosion barrier.

2.10 SERVICES

- A. All services shall be Type K Copper Tubing.

2.11 CORPORATIONS, CURB STOPS, AND SADDLES

- A. The corporation stops shall meet the most recent revision of the AWWA standard "Threads for Underground Service Line Fittings" (AWWA C 800). Corporation stops shall be designed for 175 psi pressure and have full keyway and rigid liners.
- B. Curb stops shall include a drain suitable for use with polyethylene. Stops shall have integral checks, O-ring seal and shall be furnished with rigid liners.
- C. Curb stop boxes shall be cast iron Buffalo type with recessed lid with pentagon bolt, adjustable sliding type.
- D. Surface saddles for 2 inch taps shall be double strap with bodies of ductile iron. The straps shall be electrogalvanized carbon steel. Units shall be complete with Buna N gaskets.

2.12 TAPPING SLEEVES AND VALVES

- A. Tapping sleeves shall be mechanical joint type.
- B. Tapping valves shall meet the requirements of AWWA C 500. The valves shall be flanged by mechanical joint outlet with non-rising stem and designed for vertical burial. Tapping valves shall be rated at 200 psi working pressure and shop tested at 300 psi. Bolts on bonnet and stuffing box shall be stainless steel (316 stainless steel); stuffing boxes shall be "O" ring type. The operating nut shall be 2-inches square. The valve shall be provided with oversized seat to permit use of full size cutters. Gaskets shall cover the entire flange surface. Valves shall open right (clockwise).
- C. Valves shall be Mueller H-667 or approved equal.
- D. Valve boxes shall be provided for each gate valve and tapping sleeve and valve.

PART 3 - EXECUTION

3.1 EXCAVATIONS

- A. Conform to the requirements of Section 02300 - EARTHWORK and the AWWA Standards and Manual cited herein.
- B. Dewater as required and disinfect excavation in accordance with AWWA C 651 where required.

3.2 INSTALLATION

- A. Vaults: Install vaults as indicated. Provide six inches of backfill sand bedding for precast vaults. Construct cast-in-place vaults generally as specified for manholes, Section 02400 - DRAINAGE AND SEWER SYSTEMS. Provide pervious backfill subdrains and drainage as indicated or required for proper drainage.

B. Pipe Laying:

1. Install ductile iron pipe, fittings, and valves in accordance with AWWA C 600. Install steel pipe, fittings, and valves in accordance with AWWA C 200 and AWWA Manual M11.
2. Inspect all pipe, fittings and valves for soundness and for imperfections of coatings, wrappings and linings prior to installation.
3. Deflection at joints shall not exceed the maximum recommended by the pipe or coupling manufacturer for each type of coupling and each size of pipe.
4. Blocking will be permitted only where indicated.
5. Field welding will be permitted only where specifically authorized. Pipe may be cut in the field by approved means. After welding or cutting, repair damage to linings and coatings and prime and inspect the cut surface as specified in AWWA C 203, Section 2.14. Repair damaged cement linings in accordance with AWWA C 602 Section 16, or discard the pipe.
6. Prime steel pipe couplings and exposed pipe ends before installation, but do not enamel or wrap until after hydrostatic leak test.
7. Install all temporary piping, valving, meters, gages, and equipment required for hydrostatic testing and disinfection in accordance with approved shop drawings.
8. For installations within the City of Boston, minimum pipe cover for water mains shall be 5-ft 6-inch.

C. Anchorages and Buttresses

1. Construct concrete anchorages and buttresses where indicated. The soil bearing area shall not be less than indicated.
2. Harness all valves and fittings not provided with an anchor, buttress or restrained joint with steel rods and rod socket pipe clamps or by steel rods and rod connectors connected to mechanical joint bolts as indicated.

D. Fittings and valves shall be restrained for the minimum lengths listed on the following table:

MINIMUM RESTRAINED LENGTHS	
FITTING	RESTRAINT LENGTH
12" – 45° Bend	13-feet in each Direction
8" – 45° Bend	9-feet in each Direction
6" - 45° Bend	7-feet in each Direction
12" – 22-1/2° Bend	6-feet in each Direction
10" - 45° Bend	11-feet in each Direction
8" - 90° Bend	23-feet in each Direction
8" – 22-1/2° Bend	4-feet in each Direction
8" – 11-1/4° Bend	2-feet in each Direction
6" – 22-1/2° Bend	3-feet in each Direction
6" – 11-1/4° Bend	2-feet in each Direction
12" – 11-1/4° Bend	3-feet in each Direction
12" Vertical Offset	
Upper 45° Bend	27-feet in each Direction
Lower 45° Bend	12-feet in each Direction
8" Vertical Offset	
Upper 45° Bend	19-feet in each Direction

MINIMUM RESTRAINED LENGTHS	
FITTING	RESTRAINT LENGTH
Lower 45° Bend	8-feet in each Direction
6" Vertical Offset	
Upper 45° Bend	14-feet in each Direction
Lower 45° Bend	6-feet in each Direction
12" x 12" x 12" Tee	42-feet in Branch
12" x 12" x 10" Tee	29-feet in Branch
12" x 12" x 8" Tee	16-feet in Branch
12" x 12" x 6" Tee	1-foot in Branch
8" x 8" x 8" Tee	25-feet in Branch
8" x 8" x 6" Tee	10-feet in Branch
8" x 8" x 4" Tee	1-foot in Branch
6" x 6" x 6" Tee	15-feet in Branch
6" x 6" x 4" Tee	1-foot in Branch
16" x 12" Reducer	32-feet Larger Direction only
12" x 10" Reducer	28-feet Larger Direction only
12" x 8" Reducer	31-feet Larger Direction only
12" x 6" Reducer	42-feet Larger Direction only
8" x 6" Reducer	17-feet Larger Direction only
8" x 4" Reducer	29-feet Larger Direction only
6" x 4" Reducer	16-feet Larger Direction only
12" Valve or Dead-end	58-feet in each Direction
10" Valve or Dead-end	49-feet in each Direction
8" Valve or Dead-end	41-feet in each Direction
6" Valve or Dead end	31-feet in each Direction
4" Valve or Dead-end	22-feet in each Direction
2" Valve or Dead-end	18-feet in each Direction

- Lengths shown are based on 150 psi test pressure, 4-1/2-foot bury, soil type GP, trench Type 3, and 2:1 safety factor. Changes in conditions will require revision in lengths.

3.3 TESTING AND DISINFECTING

A. Hydrostatic Tests

1. Conduct both pressure test and leakage test by the open trench method as specified in AWWA C 600. Conduct leakage test as soon as practicable after completion of the pressure test.
 2. Conduct all hydrostatic tests in the presence of the Owner, and prior to coating joints and disinfecting. Do not conduct any hydrostatic tests until after all associated concrete work has cured for a minimum of 7 days for standard concrete and at least 36 hours for high early strength concrete.
 3. As soon as practicable after completion of hydrostatic tests, drain lines in an approved manner, and disconnect and remove temporary test piping and equipment which will no longer be required.
- B. Field Coating. After completion of hydrostatic tests and before disinfecting, prime or reprime as required and coat all uncoated metal components of the piping system, including joints, harnesses and tie rods, generally as specified in AWWA C 201 for mechanical couplings, except that exposed ends of steel pipe up to the coupling shall be wrapped with hot applied coal tar tape. Inspect field-applied bituminous coatings for holidays as specified in AWWA C 203.
- C. Disinfection. Disinfect and test all lines in accordance with the requirements of AWWA C 651 and as specified herein. Disinfect before final backfill around hydrants and valves. Remove disinfection equipment and temporary piping after approval of the disinfection tests.
- D. Operating Tests. Following approval of the disinfection, conduct operating tests in the presence of the Owner to verify that each valve and hydrant is in proper working condition. Whenever practicable, conduct operating tests during flushing of chlorine from the line.

3.4 BACKFILLING

- A. Conform to the requirements of Section 02300 - EARTHWORK and the AWWA standards and Manuals cited herein.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02714

RELOCATED MWRA WATER MAIN

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing, installing, testing, and disinfecting permanent Massachusetts Water Resources Authority (MWRA) relocated water supply piping. All construction for MWRA system waterworks and appurtenant facilities shall at a minimum comply with the MWRA published procedures, material and installation requirements, issued permit conditions, and as specified in this Section. For other waterworks requirements not covered by this Section, Section 02713 EXTERIOR WATER DISTRIBUTION SYSTEMS, shall be applicable.

The work of this Section specifically pertains to the relocation a section of MWRA 24-inch water main in Medford, between the Winchester St. / Newbern Ave. intersection and just north of the Boston Ave. / Broadway intersection.

- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
1. Section 01010 - SUMMARY OF THE WORK
 2. Section 01300 - SUBMITTALS
 3. Section 02300 - EARTHWORK
 4. Section 02650 - EXISTING SITE UTILITIES
 5. Section 02713 - EXTERIOR WATER DISTRIBUTION SYSTEMS
 6. Section 03300 - CAST-IN-PLACE CONCRETE

1.2 SUMMARY

- A. Ductile Iron Pipe
1. Section Includes:
 - a. Furnishing and installing ductile iron pipe, fittings, jointing material, restrained joints, and piping accessories.
 - b. Preparing QA/QC Plan
- B. Valves and Appurtenances
1. Section Includes:
 - a. Furnishing and installing AWWA butterfly and gate valves for water service.
 - b. Furnishing and installing valves for blow off gate valves and line valves.
 - c. Removing existing and furnishing and installing new air release valves.

- d. Furnishing and installing corporation stops.
- e. Furnishing and installing miscellaneous fittings and appurtenances.
- f. Furnishing and installing insertion valves.

C. Precast Structures

1. Section Includes:

- a. Furnishing and installing pre-cast meter vaults, manholes, air valve chambers, blowoff chambers, and adjusting rings.

D. Pipeline Pressure Testing and Testing

1. Section Includes:

- a. Field hydrostatic pressure and leakage testing of new permanent and temporary pipes.

E. Disinfection of Water Mains

1. Section Includes:

- a. Flushing and disinfection of all new and existing pipelines indicated on the Drawings.

1.3 REFERENCES

A. General

- 1. All materials, methods, procedures, details, and workmanship shall comply with:
 - a. MWRA's Standard Operating Procedures for Performing Construction Work on Pipelines
 - b. MWRA's Policy and Procedures for Chlorination / Disinfection of Pipelines

B. Ductile Iron Pipe

- 1. ANSI/AWWA C151/A21.51 Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids.
- 2. ANSI/AWWA C153/A21.53 Ductile-Iron Compact Fittings 3 Inch through 24 Inch.
- 3. ANSI/AWWA C110/A21.10 Ductile-Iron and Gray-Iron Fittings, 30 Inch through 48 Inch, for Water and Other Liquids.
- 4. ANSI/AWWA C111/A21.11 Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings.
- 5. ANSI/AWWA C115/A21.15 Flanged Ductile-Iron and Gray-Iron Pipe with Threaded Flanges.
- 6. ANSI/AWWA C104/A21.4 Cement-Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water.
- 7. ANSI/AWWA C105/A21.5 Polyethylene Encasement for Ductile-Iron Piping for Water and Other Liquids.
- 8. ANSI/AWWA C219 Bolted, Sleeve-Type Couplings for Plain End Pipe.
- 9. ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, and 250.

10. ANSI B18.22.1 Plain Washers.
11. ANSI/ASME B1.20.1 Pipe Threads, General Purpose (one inch).
12. ASTM D1248 Standard Specification for Polyethylene Plastics Molding and Extrusion Materials.

C. Valves and Appurtenances

1. ANSI/AWWA C111/A21.11 Rubber Gasket Joints for Ductile Iron and Gray Iron Pressure Pipe and Fittings.
2. ANSI/AWWA C115/A21.15 Flanged Ductile-Iron and Gray-Iron Pipe with Threaded Flanges.
3. ANSI/AWWA C207 Steel Pipe Flanges for Waterworks Service - Sizes 4 In. Through 144 In.
4. ANSI/AWWA C508 Swing-Check Valves for Waterworks Service, 2 inches through 24 inches.
5. AWWA C219 Standard for Fusion -Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines.
6. AWWA C504 Rubber-Seated Butterfly Valves.
7. AWWA C509 Resilient Seated Gate Valves.
8. AWWA C515 Reduced Wall, Resilient Seated Gate Valves for Water Supply Service.
9. AWWA C550 Protective Epoxy Interior Coatings for Valves and Hydrants.
10. AWWA C800 Underground Service Line Valves and Fittings.
11. ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, and 250.
12. ANSI B16.5 Pipe Flanges and Flanged Fittings.
13. ANSI/NFPA 1963 Standard Specifications for National (American) Fire Hose Coupling Screw Threads.
14. ASTM A48 Standard Specification for Gray Iron Castings.
15. ASTM A564 Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes.
16. Federal Specification TT C 494 Asphalt Varnish.
17. Federal Specification TT-P-86 Paint, Red-Lead-Base, Ready-Mix.
18. Federal Specification TT-P-636 Primer Coating, Alkyd, Wood and Ferrous Metal.

D. Precast Structures

1. ASTM A48 Specification for Gray Iron Castings.
2. ASTM A536 Specification for Ductile Iron Castings.
3. ASTM A615 Specification for Deformed and Plain Billet - Steel Bars for Concrete Reinforcement.
4. ASTM B221 Aluminum Extruded Bars and Shapes.
5. ASTM C150 Specification for Portland Cement.
6. ASTM C260 Specification for Air-Entraining Admixtures for Concrete.
7. ASTM C478 Specification for Pre-cast Reinforced Concrete Manhole Sections.

8. ASTM C881 Specification for Epoxy-Resin-Base Bonding systems for Concrete
 9. ASTM C923 Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures and Pipes.
 10. ASTM D2240 Test Method for Rubber Property Durometer Hardness.
 11. ASTM D3034 Specification for Type PSM Polyvinyl Chloride (PVC) Sewer Pipe and Fittings.
 12. Federal Specification SS S 210 Sealing Compound, Preformed Plastic for Expansion Joints and Pipe Joints.
 13. Commonwealth of Massachusetts Department of Public Works Standard Specifications for Highways and Bridges.
 14. AASHTO Standard Specification for Highway Bridges.
 15. Federal Specification TT C-494 Asphalt Varnish.
- E. Pipeline Pressure And Leakage Testing
1. AWWA C600
- F. Disinfection of Water Mains
1. American Water Works Association (AWWA)
 - a. AWWA B300 Standard for Hypochlorites.
 - b. AWWA B301 Standard for Liquid Chlorine.
 - c. AWWA C651 Disinfecting Water Mains.
 2. MWRA:
 - a. Standard Operating Procedures for Performing Construction Work on Pipelines
 - b. Policy and Procedures for the Chlorination / Disinfection of Pipelines

1.4 SUBMITTALS

- A. Ductile Iron Pipe
1. Product Data:
 - a. Specifications for all ductile iron pipe, fittings, jointing material, thrust anchors, and piping accessories.
 2. Shop Drawings:
 - a. Complete layout drawings and details for ductile iron pipe.
 - b. Tabulated layout schedule as follows:
 1. Order of installation and closures.
 2. Pipe invert station and elevation at each change of grade and alignment.
 3. Elements of curves and bends, both in horizontal and vertical alignment, including elements of the resultant true angular deflections in cases of combined curvature.
 4. Limits of each reach of pipe thickness class and of restrained joints.

5. Limits of each reach of concrete encasement.
 6. Locations of closures for length adjustment.
 7. Locations of valves and other mechanical equipment.
 8. Methods and locations of supports.
- c. Details of fittings.
3. Quality Control Submittals:
 - a. QA/QC Plan.
 4. All physical and chemical test results along with the identification number for each mechanical joint restraint device.
- B. Valves and Appurtenances
1. Product Data:
 - a. Complete specifications, data, and catalog cuts.
 2. Quality Control Submittals:
 - a. Test Reports:
 1. Manufacturer certified copies of valve test results, in conformance with AWWA C504, AWWA C509, and AWWA C515 before valves are shipped.
 - b. Certificates:
 1. An affidavit of compliance with AWWA C504, AWWA C509, and/or AWWA C515 from manufacturer before valves are shipped.
 2. Valve Installation Checklist
 - a. Do not install valves until Checklist included in MWRA's Standard Operating Procedures for Performing Construction Work on Pipelines has been submitted.
 3. Qualifications:
 - a. Evidence of qualifications specified in Paragraph 1.6.A.1.a.
- C. Precast Structures
1. Product Data for pre-cast concrete chambers, manholes, concrete sections, castings, frames and covers.
 2. Shop Drawings:
 - a. Complete drawings and details of all pre-cast concrete chambers, manholes, concrete sections, castings, frames and covers.
 3. Precast concrete meter vault:
 - a. Sectional plan(s) and elevations shall be signed by a Licensed Professional Engineer registered in the Commonwealth of Massachusetts showing dimensions and reinforcing steel placement.

- b. Structural calculations including all engineering assumptions signed by a Licensed Professional Engineer registered in the Commonwealth of Massachusetts.
- c. Concrete design mix.
- d. Concrete test cylinder reports from independent testing laboratory certifying conformance with Contract Documents.
- e. Pipe-to-structure connectors.
- f. Concrete meter vault fixed ladder and ladder safety post.

D. Pipeline Pressure and Leakage Testing

1. Shop Drawings:

a. Leakage and Pressure Testing Plan:

- 1. Testing schedule and test procedure shall be submitted concurrently with the disinfection plan 90 days prior to the scheduled start date of testing.
- 2. Indicate proposed time and sequence of testing on schedule.
- 3. Test procedure requirements as follows:
 - a. Limits of each pipeline tested.
 - b. Position of all valves during testing.
 - c. Location of temporary bulkheads.

2. Quality Control Submittals:

- a. Certified copy of all pipeline pressure testing results not more than 14 days after completion of testing on each section of pipeline.

3. Evidence of qualifications of persons performing the work as specified in Paragraph 1.6.B.1 within 30 days after the Notice to Proceed

E. Disinfection of Water Mains

1. Disinfection Plan complying with the MWRA's Policy and Procedures for Chlorination / Disinfection of Pipelines and the MWRA's Standard Operating Procedures for Performing Construction Work on Pipelines and including:

- a. A description supplemented with sketches and accompanied by supporting calculations, of proposed methods for disinfection, dechlorination and pH adjustment, and for measuring chlorine concentrations.
- b. Proposed schedule and sequence for disinfection, including monitoring of chlorine residual.
- c. A list of equipment that will be used for disinfection, dechlorination and pH adjustment and for measuring chlorine residual concentrations.
- d. A procedure for testing chlorine residuals greater than 8 mg/l.
- e. Proposed method of filling the pipelines and written calculations to show that the rate at which each pipeline is filled with water does not exceed venting capacity of installed air vent valves and devices.
- f. A plan showing the location of chlorine monitoring equipment and chlorine sample sites.

- g. Proposed methods for storing and handling all chemicals.
 - h. Proposed method for dechlorination and pH adjustment of the discharged water.
 - i. All dimensions, temporary pipe connections, temporary electrical connections, itemized list of pumps and motors, horsepower pump capacities and horsepower requirements.
 - j. Checklist of valves indicating whether valves shall be open or closed during each phase of testing.
2. Disposal Plan: A detailed plan for disposal of flushing, testing and disinfection water, including explanation of dechlorination and neutralization and how those measures will be assessed and documented. Include in that plan the following:
- a. Detection limits of the chlorine residual and pH monitoring devices proposed for use. Verify the monitoring instrumentation has detection limits for chlorine residual less than 0.019 mg/1 and pH range between 5.0 and 10.0.
 - b. Calculations for the dosage of dechlorination agent (such as sodium bisulfite) expected based on the discharge rates anticipated to remove the residual chlorine to below 0.01 mg/1.
 - c. Size and location of dechlorination agent and neutralization agent storage tank(s) to be on site for dechlorination and neutralization of flushing, testing, and disinfection water. Identify the spill containment requirements to be implemented in accordance with the SWPPP.
 - d. Information on the metering and sample pumps proposed for use (pumping capacity, catalog information).
 - e. Information on the pH and chlorine chart recorders proposed for use (locations of the recorders, recording range, catalog information).
 - f. Contingencies should the discharge water not meet the discharge limitations stipulated.
3. Evidence of qualifications of supervisor as specified in Paragraph 1.6.C.1. and including:
- a. Project name and location
 - b. Project owner, name of the owner's representative, and representative's telephone number
 - c. Description of the project including length, diameter and type of pipe
 - d. Method of disinfection
 - e. Name of operator, license number and a copy of the license
4. Evidence of qualifications of individual who will be obtaining and analyzing water samples as specified in Paragraph 1.6.C.2.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Ductile Iron Pipe

1. Packing and Shipping:
- a. Ship pipe to site with wood lagging between pipes to prevent contact of pipe surfaces and coating.
 - b. Pack fittings, jointing materials and piping accessories in containers.

- c. Prevent entry of foreign matter into pipe and fittings during shipping.
 - d. Pack and ship coated pipe and fittings in accordance with recommendations of coating manufacturer and applicator.
 2. Acceptance at Site:
 - a. Examine pipe and related materials delivered to site for defects and compliance with Contract Documents.
 - b. Reject all pipe, fittings, and materials not in compliance with Contract Documents, remove from the site and replace at no additional cost to the Contract.
 3. Storage and Protection:
 - a. Unload and store pipe, fittings, and accessories to prevent damage and weathering before installation.
 - b. Do not handle pipe and fittings by hooks inserted in ends.
 - c. Replace pipe and fittings in which lining has been damaged at no additional cost to the Contract.
 - d. Repair damaged exterior coatings before installation of pipe, fitting, special or appurtenance at no additional cost to the Contract.
 - e. Store joint lubricant in closed containers and keep clean.
- B. Valves and Appurtenances
 1. Protect threads and seats from corrosion and damage. Rising stems and exposed stem valves shall be coated with a protective oil film which shall be maintained until time of installation.
 2. Furnish covers for all openings.
 - a. All valves shall be shipped and stored until time of use with wood or plywood covers on each valve end.
 3. Store equipment in a manner that provides access for inspection and identification. Inspect valves on delivery, and if valves do not meet Contract Documents remove from the site and replace at no additional cost to the Contract.
 4. At delivery, all debris and foreign material is to be cleaned out of valve openings. All nuts and bolts on each valve shall be checked for tightness, all operating mechanisms on each valve shall be operated to verify functioning, and valves shall be checked for defects in workmanship or materials.
 5. Store all equipment in covered storage off the ground.
- C. Precast Structures
 1. Packing and Shipping:
 - a. Check each unit for compliance with tolerances specified in Paragraph 2.3.C.1.a before shipment to site and repair.
 - b. Where surface repairs are required, repaired surfaces shall match adjacent surfaces. Precast manholes which require surface repairs to more than 25 percent of interior or exterior surfaces shall not be delivered to site.

- c. Pre-cast structures with any crack which is greater than 1/16 inch wide and 12 inches in length shall not be delivered to the site.
 - 2. Acceptance at Site:
 - a. Inspect pre-cast concrete sections when delivered.
 - 1. Reject structures which do not meet the requirements of the Contract Documents and repair or remove from site and replace at the sole option of the Owner and at no additional cost to the Contract.
 - 3. Storage and Protection:
 - a. Do not damage pre-cast concrete sections when handling.
 - b. Do not bump or drop.
 - c. Do not allow hooks to come in contact with joint surfaces.
- D. Disinfection of Water Mains
 - 1. Hypochlorite:
 - a. Store and handle in accordance with AWWA B300.

1.6 QUALITY ASSURANCE

A. Valves and Appurtenances

- 1. Manufacturer's Qualifications:
 - a. Valves and appurtenances provided under this Section shall be the standard product in regular production by manufacturers whose products have been used in similar service for at least the last five years as verified in the product data submittal.
 - b. All units of the same type shall be product of one manufacturer.
- 2. Criteria
 - a. All valves and appurtenances shall be new and in working condition. Valves shall be designed for continuous use without exceeding the manufacturer's rated limits for stress, strain or vibration.
- 3. Source Quality Control
 - a. A hydrostatic test shall be performed on valves at the factory prior to shipment. The valve shall be tested to two (2) times the working pressure. The valve performance and hydrostatic tests may be witnessed by the Owner and/or the MWRA.

B. Pipeline Pressure and Leakage Testing

- 1. Testing shall be conducted by an independent testing agency in accordance with AWWA C600 Sec. 5.2 and the MWRA's Standard Operating Procedures for Performing Construction Work on Pipelines.

- a. Persons performing testing of water mains shall have a Grade D4 Water Distribution Operator's License or Grade 4 Water Treatment Operators License.
 - 2. Leakage is defined as total amount of make-up water (gallons per hour) introduced into pipeline during test to maintain test pressure within 5 psi.
- C. Disinfection of Water Mains
- 1. The Supervisor for all disinfection operations shall:
 - a. Have successfully completed disinfection of potable water pipelines or systems, 24-inches in diameter or larger, using the methods described in AWWA 651, on 2 projects within the last 5 years.
 - b. Shall be a licensed Water Supply Grade 4 Distribution Operator or Grade 4 Water Treatment Operators.
 - 2. The individuals who will be obtaining and analyzing water samples shall:
 - a. Have successfully obtained and analyzed water samples of potable water pipelines or systems, 24-inches in diameter or larger, using the methods described in AWWA 651, on 2 projects within the last 5 years.
 - 3. Pipeline disinfection shall be performed in conjunction with dewatering, testing, flushing and discharge of water with chlorine, prior to placing new water main in service:
 - a. Prepare a plan for pipe disinfection and dechlorination including method(s) of filling, chlorine introduction, discharge location(s), testing/monitoring locations and method(s) of dechlorination (both free and combined chlorine) including pH adjustments for chloramines.

1.7 MISCELLANEOUS SYSTEM REQUIREMENTS

- A. Precast Structures
 - 1. All pre-cast structures shall be designed for AASHTO HS-25 load conditions.
- B. Pipeline Pressure and Leakage Testing
 - 1. Perform pressure and leakage tests for pipe that has been installed under this contract.
 - 2. Perform bidirectional pressure testing on all valves installed.
- C. Disinfection of Water Mains
 - 1. Disinfection limits are as indicated on the Contract Drawings.
 - 2. The location of the existing water main line, new water mains, air release and blow-off valves are shown on the Contract Drawings.
 - 3. Pipes that were not dewatered but were out of service for more than 5 days shall be flushed as specified in Paragraph 3.4.B.2.
 - 4. Pipe that was not dewatered but was out of service for 3 weeks or more shall be disinfected.

5. All flushing water shall be discharged in accordance with local, state, and federal regulations and the MWRA's Standard Operating Procedures for Performing Construction Work on Pipelines.

1.8 SEQUENCING AND SCHEDULING

A. Precast Structures

1. Do not deliver pre-cast concrete sections until representative concrete control cylinders have attained a strength of at least 80 percent of minimum specified herein.

B. Pipeline Pressure and Leakage Testing

1. Complete pressure and leakage testing of water main pipes prior to final cleaning, disinfection and connecting to existing water mains. The MWRA shall be present during all testing.
 - a. At each connection to existing water main, install temporary mechanical joint pipe with a restrained cap, for use during pressure testing of all new piping installed. After completion of pressure testing, temporary pipe and restrained cap shall be removed and the closure piece and coupling shall be installed, and all joints shall be visually inspected for leaks at normal working pressure prior to backfilling.
 - b. Notify the Owner and the MWRA of time and place of testing at least 3 working days prior to commencement of work.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Ductile Iron Pipe

1. Pipe, fittings, and accessories:
 - a. American Cast Iron Pipe Company
Birmingham, Alabama
 - b. U.S. Pipe and Foundry Company
Birmingham, Alabama
 - c. Griffin Pipe Products Company
Florence, New Jersey
 - d. Or equal
2. Mechanical couplings:
 - a. Smith-Blair
 - b. Dresser
 - c. Romac
 - d. Or equal

3. Prestressed Concrete Cylinder Pipe (PCCP) to DI Adapters:
 - a. Hanson Pressure Pipe
 - b. Vianini Pipe, Inc.
 - c. Ameron International
 - d. Or equal

- B. Valves and Appurtenances
 1. Butterfly Valves:
 - a. American-Darling
 - b. DeZurik
 - c. Mueller
 - d. Pratt
 - e. Or equal

 2. Resilient Seat Gate Valves:
 - a. American - Darling
 - b. Mueller
 - c. U.S. Pipe
 - d. Or equal

 3. Corporation Stops:
 - a. The Ford Meter Box Co., Inc. Model F 400
 - b. Mueller Company Figure H-10003 except for 1½" air valves, use Mueller Company Figure H-9968
 - c. Powell Figure 4224T
 - d. Or equal

 4. Air Release Valves:
 - a. Cla-Val
 - b. Crispin Multiplex Mfg. Co.
 - c. Valve & Primer Corp.
 - d. Or equal

 5. Valve Box Covers:
 - a. Clay & Bailey "No. 2193"
 - b. Tyler "Series 6890 A"
 - c. Opelika Foundry "No. 6017"
 - d. Or equal

6. Overtorque Protector:
 - a. Aunspach, St. Louis, MO.
 1. This is a proprietary item. Substitution of products from other manufacturers will not be permitted.
 7. Insertion Valves
 - a. Hydro-Stop, Inc.
 - b. Romac Industries, Inc.
 - c. Advanced Valve Technologies, L.L.C.
 - d. Or equal
 8. Pressure Reducing Valves:
 - a. Cla-Val
 - b. Flomatic Valves
 - c. Tyco
 - d. Or equal
- C. Precast Structures
1. Pre-cast Concrete:
 - a. Rotondo & Sons, Inc., Rehoboth, MA
 - b. Chase Pre-cast Corporation, North Brookfield, MA
 - c. Ray Pre-cast Company, Marshfield, MA
 - d. Or equal
 2. Standard MWRA Manhole Frames and Covers:
 - a. East Jordan Iron Works, East Jordan, MI
 - b. Neenah Foundry, Neenah, WI
 - c. Ethridge Foundry, Portland, ME
 - d. Quality Water Products, Inc., South Barre, MA
 - e. Or equal
 3. Standard MWRA Watertight and Locking Manhole Frames and Covers:
 - a. East Jordan Iron Works, East Jordan, MI
 - b. Syracuse Castings, Cicero, NY
 - c. Olympic Foundry, Burlington, IA
 - d. Or equal
 4. Municipal Manhole Frames and Covers
 - a. East Jordan Iron Works, East Jordan, MI

- b. Neenah Foundry, Neenah, WI
 - c. Ethridge Foundry, Portland, ME
 - d. Or equal
5. Non-shrinking Grout:
- a. L&M Concrete Forms, Inc., Omaha, NE - "Crystex"
 - b. Sauereisen Cements Co., Pittsburgh, PA - "F-IDO Level Fill Grout"
 - c. U.S. Grout Corporation, Fairfield, CT - "Five Star Grout"
 - d. Or equal
6. Coal Tar Coating:
- a. Koppers - "Bitumastic Super Service Black"
 - b. Tnemec - "46-465 Heavy Duty Black"
 - c. Valspar Corp. - "35-J-10"
 - d. Or equal
7. Insulation:
- a. Pittsburgh Corning - "Foam Glass"
 - b. Upjohn Manufacturing - "Urethane"
 - c. Dow Chemical - "Styrofoam"
 - d. Or equal
8. Entrance Safety Device:
- a. Bilco Co. Ladder Up Safety Post
 - b. North Safety Products Saf-T-Notch Removable Ladder Extension
 - c. McMaster-Carr Ladder Safety Extension Post
 - d. Or equal

2.2 MATERIALS

A. Ductile Iron Pipe

- 1. Pipe:
 - a. Ductile iron conforming to ANSI/AWWA C151/A21.51.
 - b. Minimum pipe thickness class:
 - 1. For new water main with diameter less than or equal to 48 inches:
 - a. Thickness Class 52 for push-on, flanged or mechanical joint pipe.
 - c. Supply pipe in lengths not exceeding 20 feet.
 - d. Buried pipe:

1. Restrained Rubber-ring type push-on or mechanical joints with mechanical restraint joint devices unless otherwise indicated on Drawings.
2. Insulating flanges with wax tape coating.
- e. Provide restrained joints where indicated on the Drawings.
- f. Exposed pipe:
 1. Flanged joints.
2. Fittings:
 - a. Ductile iron conforming to ANSI/AWWA C110/A21.10.
 - b. Minimum pressure rating:
 1. Push-on and mechanical joint:
 - a. 350 psi for 24 inch and smaller
 - b. 250 psi for 30 inch and larger
 2. Flanged joint:
 - a. 250 psi
 - c. All fittings shall be manufactured and fabricated in the United States.
3. Shop coating and lining for pipe and fittings:
 - a. Cement mortar lining for water mains: ANSI/AWWA C104/A21.4.
 - b. Exterior primer for exposed pipe with diameter less than 48 inches: Cook "391-N-167 Barrier Coat", Koppers" No. 10 Inhibitive Primer", Tnemec "77 Chem-Prime", Valspar "13-R-28 Chromox Primer", or equal.
 - c. Asphaltic coating for buried pipe with diameter less than 48 inches: Manufacturer's standard.
 - d. Rust-preventive compound for flange faces: Houghton "Rust Veto 344", Rust-Oleum "R-9", Devoe Paint "Devrin 201", or equal.
4. Field coating:
 - a. Coal tar coating for buried steel anchors: Thixotropic coal tar, MIL-C-18480; Koppers "Bitumastic No. 50", Tnemec "46-450 Heavy Tnemecol", Devoe Paint "Devtar 5A", or equal.
 - b. Polyethylene tube for buried ductile iron water main: ANSI/AWWA C105/A21.5, seamless.
 1. Remove lumps of clay, mud and cinders from outside surface of pipe prior to installation.
5. Joints:
 - a. Push-on and mechanical joints: ANSI/AWWA C111/A21.11.
 1. Gaskets: Oil-resistant synthetic rubber.
 2. Natural rubber gaskets are not acceptable.

- b. Restrained push-on joints: American "Flex-Ring", "Lok-Fast", or "Lok-Ring"; Clow "Super-Lock"; U.S. Pipe "TR Flex"; Griffin "Snap-Lok"; or equal.
 - c. Flanged joints: ANSI/AWWA C115/A21.15
 - 1. Flanges: Ductile iron, flat faced
 - 2. Bolts: ASTM A307, chamfered or rounded ends projecting 1/4 to 1/2 inch beyond outer face of nut.
 - 3. Nuts: ASTM A307, hexagonal, ANSI B18.2.2, heavy semifinished pattern.
 - 4. Gaskets: ASTM D1330, Grade I rubber, full face type, 1/8 inch thick, except that gaskets for buried flanges other than insulating flanges shall be oil-resistant synthetic rubber.
 - d. Mechanical joints with tie rods:
 - 1. Tie rods: ASTM A307.
 - 2. Steel pipe: ASTM A53, Schedule 40.
 - 3. Washers: ANSI B18.22.1, plain steel.
 - e. Threaded connections for tapping of pipe wall: ANSI/ASME B1.20.1, NPT.
 - 1. Threaded connections shall only be permitted where wall thickness minus foundry tolerance is equal to or greater than that required for 4-thread engagement as set forth in ANSI/AWWA C151/A21.51. Otherwise, provide boss or tapping saddle.
 - f. Mechanical Joint Restraint Device:
 - 1. The device shall impart multiple wedging action against the pipe increasing its resistance as the pressure increases.
 - 2. Ductile iron heat treated to a minimum hardness of 370 BHN.
 - 3. Working pressure of at least 250 psi with a minimum safety factor of 2:1.
 - 4. Flexibility of the joint shall be maintained after burial.
 - 5. Retainer Glands: Ductile iron conforming to ASTM A536-80. Dimensions which permit use with mechanical joint bell and tee head bolts conforming to ANSI/AWWA A21.11 and ANSI/AWWA C153/A21.53 latest revision.
 - 6. Twist off nuts shall be installed and result in actuating of the restraining device.
6. Mechanical Couplings:
- a. Insulating Type
 - b. Gaskets: Oil-resistant synthetic rubber
 - c. ANSI/AWWA C219
 - d. Minimum pressure rating: 250 psi
7. Flanged coupling adapters:
- a. Smith-Blair "Type 913", Dresser "Style 128", Baker "Series 604", or equal.
8. Tapping saddles:
- a. Ductile iron with steel straps and rubber sealing gasket.

- b. Minimum pressure rating: 250 psi

B. Valves and Appurtenances

1. Butterfly Valves:

a. Valve shafts:

- 1. Valve shafts from high tensile stainless steel ASTM 564, Type 630.

b. Valve seats:

- 1. ANSI Type 304 stainless steel, monel, or plasma applied nickel chrome overlay for all seating surfaces mating with rubber.

c. Valve discs:

- 1. ASTM A48 cast iron.

d. Shaft seals:

- 1. Chevron or O ring type shaft seals.

e. Valve body:

- 1. Ductile iron.

2. Gate Valves:

- a. Rubber Seats: shall be new, natural or synthetic, acceptable for water service application per ASTM D429.

b. Valve Body:

- 1. Gate Valves up to and including 12": cast iron
- 2. 24" Gate Valves: ductile iron

c. Stem:

- 1. Bronze

d. Wedge:

- 1. Gate Valves up to and including 12": cast iron
- 2. 24" Gate Valves: ductile iron

3. Extension stems:

- a. As indicated on the Drawings.

4. Extension guides:

- a. Guides from steel.

5. Valve boxes:

- a. Boxes, bases, covers, and shafts from cast iron.

6. Asphalt Varnish:

- a. Federal Specification TT C-494.

7. Corporation Stops:

- a. Corporation stops shall conform to AWWA C800, not less than 1-inch in diameter and shall be installed where indicated on the Contract Drawings.
 - b. All corporation stops shall be certified to be NSF 61 compliant in accordance with the "Safe Drinking Water Act" requirements for low lead in potable (human consumption - drinking and cooking) and non-potable water applications (non-human consumption).
8. Push on and mechanical joints: ANSI/AWWA C111/A21.11.
9. Shop painting:
- a. Coating for unfinished surfaces:
 1. Interior surfaces:
 - a. Fusion bonded epoxy coating meeting requirements of AWWA C550.
 2. Exterior surfaces of valves below ground line.
 - a. Asphalt varnish conforming to Federal Specification TT C-494.
 - b. Coal tar: Koppers "Bitumastic Super Service Black", Tnemec "46 465 Heavy Duty Black", Valspar "35 J 10 Hi Build Bituminous Coating", or equal.

C. Precast Structures

1. Concrete sections:
 - a. Pre-cast concrete vaults, manholes and chambers:
 1. General:
 - a. Sections and reinforcement shall conform to ASTM C478 for circular sections and ASTM C858 for rectangular sections.
 - b. Minimum wall thickness: 1/12 of inside diameter, plus one inch.
 2. Riser and base sections:
 - a. Circular Sections shall have uniform outside diameter.
 - b. Rectangular sections shall have square corners and true sides.
 3. Minimum compressive strength shall be 5,000 psi at 28 days.
 4. Top slabs shall support their own weight, weight of soil at 130 pcf and a live load equal to AASHTO HS-25 psf applied to top slab.
 5. Cast base slab and walls together to form a monolithic base section.
 6. Structure walls shall withstand a water pressure of 90 psf. Originate pressure diagram at finished ground surface. Include lateral pressure from vehicles in accordance with AASHTO.
 7. Provide additional reinforcing around openings to prevent cracking. Frame openings to carry full design loads to support walls.
 8. Prevent flotation, with ground water level at finished ground surface, by dead weight of structure and soil load above structure. Do not account for skin friction,

- soil friction, or weight of equipment in structure. Factor of safety for resisting flotation shall be 1.10.
9. Provide wall castings to the precast concrete manufacturer for inclusion in the manufacture of the structure.
2. Precast Structure Joint Gaskets:
 - a. Butyl Rubber Sealant
 1. AASHTO Specification M-198, Type B.
 2. Use cross sectional area as recommended by structure manufacturer.
 3. Castings:
 - a. General:
 1. Cast Iron - ASTM A48, Class 30B or better.
 2. Ductile Iron - ASTM 536-77
 - a. Frames and covers shall be for heavy duty use and able to withstand HS-25 loads.
 - b. MWRA Manhole frames and covers:
 1. Cast Iron:
 - a. 24 inch MH frame and cover as indicated on the drawings.
 2. Ductile Iron:
 - a. Watertight and locking manhole frame and covers shall be made of ductile iron and include one polyethylene ring for load transmission and one rubber gasket for air and water tightness. The watertight and locking frame and covers shall be airtight and watertight up to 15 psi external pressure.
 - b. Watertight and locking manhole frame and covers shall be secured with iron cams and stainless steel bolts equally spaced around the cover. Internal threads for bolts shall be located entirely in blind holes of frame to prevent sticking or corrosion.
 - c. Cover shall weigh no more than 150 pounds.
 - d. Furnish one (1) set of spare parts for each watertight and locking manhole frame and cover. Furnish two (2) sets of tools suitable for locking/unlocking ductile iron covers.
 4. Miscellaneous materials:
 - a. Pre-cast concrete adjusting rings.
 - b. Circular rings with shear keys.
 - c. Non-shrinking grout.
 - d. Mastic fill:
 1. Butyl rubber compatible with resilient connector material.
 - e. Insulation:

1. Exterior 2- inch thick insulation.
 2. "R value" shall be at least 17.0.
 3. Insulation adhesive and coating as recommended by insulation manufacturer.
 4. DO not damage coating and insulation during placement and compaction of back-fill.
- f. Asphalt Varnish: Federal Specification TT C-494.
- g. Expandable plugs: rubber, air tight to 8 psi with wing nut type expansion mechanism.
- h. Connector between sewer manhole and pipe: rubber seal system meeting the requirements of ASTM C923 and recommended by the manhole manufacturer for the type of connection.
- i. Protective Epoxy Coating: shall be an epoxy-resin-based product providing high bond strength to concrete and steel surfaces conforming to ASTM C881.
- j. Sump Cover Grating:
1. Cover shall be removable fiberglass reinforced plastic grating, thermal cured with smooth mold surface.
 2. Grate shall match outside diameter of sump and be mounted flush with chamber floor.
 3. Grate shall have a maximum mesh opening of 1½"x 1½" with a minimum thickness of 1".
 4. Grate shall be high impact, slip and fire resistant.
 5. Grate shall be electrically non-conductive.
- k. Water-Based Masonry Sealer:
1. Apply DRYLOK Masonry waterproofer by United Gilsonite Laboratories, Thompson's Water Seal Concrete Care Sealer by the Thompson's Company, Memphis, TN; Conspec Weather Seal WB, Dayton Superior, Kansas City, KS; Crete-Trete 350 Water Repellent, Cresset Chemical Co., Weston, OH; or equal to all interior and exterior surfaces of meter vaults.
- l. Hydraulic Cement:
1. Seal all vault penetrations, except penetrations for water piping, both inside and outside structure with quick-setting Portland cement, Type 2, conforming with ASTM C150.
 2. Use concrete bonding adhesives or acrylic fortifiers as recommended by manufacturer for preparing surfaces to be sealed.
- m. Mechanical Penetration Seal and Wall Sleeve:
1. Seals around water pipe penetrations through precast concrete meter vaults.
 2. Penetration Seal shall be a modular, mechanical seal consisting of rubber links shaped to continuously fill the annular space between the pipe and wall opening. Hardware shall be steel with a 60,000 psi minimum tensile strength.
 3. Wall sleeve shall be a molded sleeve with an integral hollow, molded water-stop ring and in accordance with manufacturer's recommendations.
 4. Nuts and bolts shall be ANSI type 316 stainless steel.

- n. Ladder Extension Post:
 - 1. Extension post shall be fabricated from high strength steel with black enamel finish.
 - 2. Extension post shall be completely assembled and adjustable for installation with structure fixed ladder.
- o. Fixed Ladder:
 - 1. Ladder shall be high strength steel with black enamel coating.
 - 2. Rung diameter shall be 1-inch minimum with 12 inches between rungs and minimum 18 inches between side bars.
 - 3. Fixed ladder shall be compatible for use with ladder extension post specified in Paragraph 2.2.C.4.n.
 - 4. Attach to structure at three (3) attachment points with Type 316 stainless steel bolts and anchors.

D. Disinfection of Water Mains

- 1. Calcium hypochlorite shall conform to AWWA B300.
 - a. Granules with 70 percent available chlorine.
- 2. Liquid sodium hypochlorite shall conform to AWWA B300.
- 3. Dechlorination and pH adjustment agents shall conform to the MWRA's Policy and Procedures for Chlorination / Disinfection of Pipelines.

2.3 FABRICATION

A. Ductile Iron Pipe

- 1. Flange by mechanical joint pieces:
 - a. Mark top for horizontal pieces and side for vertical pieces at foundry.
- 2. Push-on joint pipe:
 - a. Bevel each spigot end.
- 3. Flanged joint pipe:
 - a. Extend pipe completely through screwed-on flanges.
 - b. Machine finish the pipe end and flange face in a single operation.
 - c. Fabricate flange faces flat and perpendicular to the pipe center line.
- 4. Mechanical Joint Restraint Device:
 - a. An identification number consisting of year, day, plant and shift (YYDDD)(plant designation)(Shift number), shall be cast into each gland body.
 - 1. All physical and chemical test results shall be recorded with the identification number on the casting.

2. Production pieces that are too small to accommodate individual numbering, such as fasteners and wedges, shall be controlled in segregated inventory until such time as all quality control tests are passed. These component parts may then be released to a general inventory for final assembly and packaging.
 - b. The coating system shall consist of two coats of liquid fluoropolymer coating with heat curing to follow each coating.
 1. All wedge assemblies and related parts shall be processed through a phosphate wash, rinse and drying operation prior to coating application.
 2. All casting bodies shall be surface pretreated with a phosphate wash, rinse and sealer before drying.
 3. The coating shall be electrostatically applied and heat cured.
 4. The coating shall be a polyester based powder and provide corrosion, impact and UV resistance.
5. Flanged coupling adapters and mechanical couplings:
 - a. Prepare inner and exterior surfaces of couplings for painting in accordance with the recommendations of paint manufacturer.
 - b. Paint with liquid epoxy in accordance with AWWA C210.
 - c. Clean and shop prime other surfaces with the standard rust-inhibitive primer of the manufacturer.
 - d. Do not paint flange mating surfaces on flanged coupling adapters.
 - e. Flanged coupling adapters shall have anchor studs.
6. Outlets:
 - a. Furnish factory welded-on boss under following conditions:
 1. Branch outlet is 12 inch or smaller.
 2. Diameter of pipe is at least twice diameter of branch.
 3. Either tee or tapping saddle are not used.
 4. Working pressure 250 psi.
7. Reducers:
 - a. Furnish concentric pattern reducers.
8. Gaskets:
 - a. Gasket for portable water service shall be certified as suitable for chlorinated potable water (NSF 61), compatible with joint specified herein and the specified field test pressure service conditions and provided by pipe manufacturer.

B. Valves and Appurtenances

1. Butterfly Valves:
 - a. General:
 1. All butterfly valves, including operators, shall conform to AWWA C504.

b. Valves:

1. Fabricate valves in accordance with the following schedule:

Size, (inches)	Service	Type of Installation	AWWA Class ⁽¹⁾	Type of Operator	Min. Operator Torque Capability ^(2,3) , (inch-pounds)	Minimum Turn Count
36	Water	Buried	250B-MJ	Wrench Nut	90,000	108
48	Water	Buried	250B-FL	Wrench Nut	190,000	144
54	Water	Buried	250B-FL	Wrench Nut	190,000	168

- (1) Suffix letter defines valve ends as follows: FL – Flanged Joint; MJ – Mechanical Joint
- (2) Manufacturer's rated torque capacity for each butterfly valve operator shall be at least equal to minimum specified operator torque capability.
- (3) Valve operators (actuators) shall withstand an input torque of 450 ft-pounds.

c. Valve bodies:

1. The valve body shall contain an adjustable stop, fastened to the valve body at a location 90 degrees from the valve shaft orientation, to prevent the valve disc from moving past its closing point. The stop and all fastening materials shall be Type 316 Stainless Steel.
2. Flanged Joints:
 - a. AWWA C115.
3. Short-body type.

d. Valve discs:

1. Secure discs to shafts by means of solid, smooth sided, stainless steel or monel taper pins or dowel pins having circular cross section.
2. Each taper pin or dowel pin shall extend through the shaft and shall be mechanically secured in place.
3. Do not use bolts, setscrews, knurled or fluted dowel pins, expansion pins, roll pins, tension pins, spring pins, or other devices in lieu of specified pins.

e. Valve seats:

1. Do not use valve seat configurations which rely on mating pipe flange to hold seat in position.

f. Valve coating:

1. All interior and exterior ferrous metal surfaces, except bearing surfaces and stainless steel components, shall be shop coated with a fusion-bonded epoxy coating in accordance with AWWA C550. Machined surfaces shall have a protective coating of rust inhibitive compound: Houghton "Rust Veto 344", Rust-Oleum "R-9", Devco Paint "Devrin 201", or equal.

g. Thrust bearings:

1. Provide each valve with one or more bronze thrust bearings.

2. Do not use thrust bearings which are directly exposed to line liquid and which consist of metal bearing surface in rubbing contact with opposing metal bearing surface.
 - h. Overtorque Protectors (This is a proprietary item, see Paragraph 2.1.B.6):
 1. Provide an overtorque protector on each butterfly valve.
 2. Overtorque protectors will be factory set to slip at 350 ft.-lbs.
 3. Overtorque protectors will be designed to fit over 1-3/4" by 1-3/4" nut and will be equipped with 1-3/4" by 1-3/4" top nut.
 - i. Position Indicators:
 1. Provide each butterfly valve operator with a position indicator to display position of disc in range from fully open to fully closed.
2. Gate Valves:
- a. Sizes up to and including 12-inch gate valves:
 1. Gate valves, including operators, shall conform to AWWA C509.
 2. Valve Construction:
 - a. Resilient-seated gate valves shall be rated 250 working pressure, iron body, nonrising stem, and shall conform to AWWA C509.
 3. Flanges:
 - a. Finish flanges to true plane surfaces within tolerance limit of 0.005 inch.
 - b. Flanges shall be flat faced. Finished face shall be normal to longitudinal valve axis within a maximum angular variation tolerance of 0.002 inch per foot of flange diameter.
 - c. Flange diameter and drilling shall conform to ANSI B16.1 Class 125 or ANSI B16.5 Class 150.
 4. Bonnet Thrust Plate:
 - a. The bonnet shall have a removable thrust plate which permits the removal and replacement of the valve stem and O-ring seal while the valve is in service.
 5. The gate shall have resilient rubber, urethane rubber, Buna N or SBR rubber, minimum thickness 3/8 inch, bonded to or mechanically attached to one side or both sides of the wedge type gate, with no sliding or shear, on the resilient seat, when compressed to a driptight shutoff.
 - b. Sizes equal to or greater than 24-inch:
 1. Gate valves, including operators, shall conform to AWWA C515.
 2. Valves shall be rated 250 working pressure, ductile iron body.
 3. Valves shall be specifically designed for horizontal installation and equipped with beveled gearing.
 4. Wedge type gate shall be ductile iron, encapsulated with EPDM or SBR rubber.
 5. Vertical and horizontal resilient seated valves shall be equipped with rollers and scrapers.

- c. Valve Coating:
 - 1. All interior and exterior ferrous metal surfaces, except bearing surfaces and stainless steel components, shall be shop coated with a fusion-bonded epoxy coating in accordance with AWWA C550. Machine surfaces shall have a protective coating of rust inhibitive compound: Houghton "Rust Veto 344", Rust-Oleum "R-9", Devoe Paint "Devrin 201", or equal.
- d. Mechanical Joints:
 - 1. AWWA C111.
- e. Stem Seals:
 - 1. All valves shall be provided with stem seals of the O ring inserted above the thrust collar.
- f. Stainless Steel Bolts and Nuts:
 - 1. The bolts and nuts that fasten the bonnet to the valve body and bonnet thrust plate to the bonnet shall be ANSI Type 316 stainless steel.
- g. In accordance with following schedule:

Size (inches)	Location	Max. Pressure Differential Across Valve (psi)	Ends	Type of Stem	Operator	Minimum Turn Count
8	Buried	250	MJ	NRS	WN	24
8	Vault	250	FL	NRS	WN	24
12	Buried	250	MJ	NRS	WN	36
12	Vault	250	FL	NRS	WN	36
24	Buried	250	MJ	NRS	WN	60

Abbreviations in gate valve schedule as follows:

- FL - Flanged ends
- MJ - Mechanical joint ends
- NRS - Nonrising stem
- WN - Wrench nut

- 1. Number plate shall include number of turns to operate valve from fully closed to fully open position.
- 3. Wrench nuts:
 - a. Provide wrench nuts on all buried valves and on all valves enclosed in vaults as indicated on drawings.
 - b. All wrench nuts shall be 1-3/4" by 1-3/4".
 - c. Design valve and operator so that shaft leakage cannot enter operator housing.
 - d. Direction of rotation of wrench nut to open valve shall be to the right (clockwise).
 - 1. Cast word "Open" and an arrow indicating direction to open on each valve body or operator.
- 4. Extension stems:

- a. As indicated on the Drawings.
5. Extension stem guides:
- a. Stem guides shall be cast iron, bronze bushed, and adjustable in two directions.
 - b. Stem guide spacing shall not exceed 100 times the stem diameter or 10 feet, whichever is smaller.
 - c. The extension stem shall have a collar; the collar shall be pinned to the stem and shall bear against the stem thrust guide.
 - d. At least two stem guides shall be furnished with each valve.
 - e. The top stem guide shall be designed to carry the weight of the extension stem.
6. Insertion Valves:
- a. General
 - 1. Insertion Valves shall conform to the requirements specified in this Section for Gate Valves, except as specified below:
 - a. Valves shall be constructed of a two (2) piece ductile iron casting, pieces to be bolted together using ductile iron bolts with zinc alloy anodes manufactured to comply with ASTM A536 65-45-12.
 - b. Ductile Iron Gate shall have a resilient rubber seal 360 degrees around the gate which is expandable to the inside diameter of the pipe.
 - c. The valve assembly design shall enable the valve assembly to be rotated 120 degrees, perpendicular across the top of the pipe, while riding on two SBR rubber gaskets construed of SBR, by using a perpendicular rotary feed mechanism, driven by a chain.
7. Valve boxes:
- a. General:
 - 1. Shop coat all parts of valve boxes, bases, and covers by dipping in asphalt varnish.
 - b. Boxes for valves buried or enclosed to a depth of 4 feet or less:
 - 1. Shall be slide type.
 - 2. Shall be cast iron, extension sleeve type and shall be built to withstand depth of cover indicated by Drawings.
 - 3. Do not use more than one extension for each slide type valve box.
 - 4. Shall not be less than 5 inch inside diameter nor less than 3/16 inch thick at any point.
 - 5. Shall have cast iron bases and covers.
 - c. Boxes for valves buried or enclosed to a depth greater than 4 feet:
 - 1. Shall have cast iron cover and 6 inch cast iron pipe section.
 - 2. Pipe shaft to extend from valve to 5 inches within valve box cover.
8. Air Release Valves:
- a. Automatic

1. Air release valves shall be equipped with cast iron body and cover, Buna-N seat bronze linkage and stainless steel float.
 2. Valves shall be suitable for average working water pressure at 300 psi.
- b. Manual Air Release Valves
1. Shall be assembled as shown in the Drawings.

C. Precast Structures

1. Concrete sections:

- a. Cast and finish to following tolerances:
 1. Overall length - $\pm 1/4$ inch
 2. Overall height - $\pm 1/4$ inch
 3. Overall width - $\pm 1/4$ inch
 4. Wall, floor, and roof thickness - $+1/4$ inch, - $1/8$ inch
 5. Position of handling devices - $\pm 1/2$ inch
 6. Squareness of ends (vertical and horizontal alignment) - $\pm 1/4$ inch
 7. Face width of joint - $\pm 3/16$ inch
 8. Anchors and inserts - $\pm 1/4$ inch
- b. If boxouts for grouting are used, groove or roughen surfaces.
- c. Provide lifting notches on inside faces of pre-cast section walls for handling.
 1. Do not make notches more than 3 inches deep.
 2. Do not extend hole through wall.
- d. Dampproof pre-cast units in shop.
 1. Apply one coat of coal tar coating to outside surfaces of each section.

2. Castings:

- a. Standard dimensions for manhole frames and covers as indicated on the Drawings.
- b. The bearing surfaces of frames and covers and frames and grates against each other shall be machined to give continuous contact throughout their entire perimeter.
- c. All iron castings shall be cleaned at foundry.
- d. The castings shall be free from all defects including scale, lumps, blisters, sandholes.

2.4 EQUIPMENT

A. Pipeline Pressure and Leakage Testing

1. Provide test equipment as follows:
 - a. Piping connections between pipeline tested and water source.
 - b. Pumping equipment
 - c. Water meter

- d. Pressure gauges
- e. Sectionalizing devices:
 - 1. Flanges
 - 2. Valves
 - 3. Bulkheads
 - 4. Bracing
 - 5. Blocking

2.5 SOURCE QUALITY CONTROL

A. Valves and Appurtenances

- 1. Tests:
 - a. Test all butterfly valves in accordance with AWWA C504.
 - b. Test all gate valves in accordance with AWWA C509 or C515, as applicable.
- 2. Inspection:
 - a. The protective fusion-bonded epoxy coating on interior surfaces of each valve shall be holiday tested in accordance with AWWA C550 and shall be electrically void free.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Ductile Iron Pipe

- 1. Alignment:
 - a. Lay piping to lines and grades indicated on the Drawings. Transfer all lines and grades from basic survey control points.
 - b. Deflections from straight line or grade shall not exceed values stipulated in Table 4 or Table 5 of AWWA C600.
 - c. Install either shorter pipe sections or fittings to conform to alignment or grade indicated on the Drawings.
- 2. Laying pipe:
 - a. Protect pipe from lateral displacement by placing granular embedment material.
 - b. Lay pipe with bell ends facing direction of laying.
- 3. Cutting pipe:
 - a. Cut pipe without damage to pipe or lining.
 - b. Provide smooth, straight cuts at right angles to pipe axis.
 - c. Remove all roughness and sharp edges from cut end of pipe.

- d. Bevel cut ends of push-on joint pipe.
 - e. Do not cut pipe with hydraulic squeeze type cutters, portable guillotine saw, or oxyacetylene torch.
 - f. Do not cut tapping holes with an oxyacetylene torch.
4. Cleaning:
- a. Clean all foreign material from interior of pipe and fittings before installation.
 - b. Wipe clean all joint contact surfaces before jointing pipe and fittings.
 - c. Prevent all material from entering pipe or joints during installation.
 - d. Seal open end of pipe with watertight plug when pipe laying is stopped.
 - e. Keep interior of installed pipe clean until the pipeline is placed into service.
5. Inspection:
- a. Examine pipe and fittings for cracks and other defects immediately before installation.
 - b. Examine the spigot ends of pipe.
 - c. Remove and replace all cracked or defective pipe and fittings at no additional cost to the Contract.
6. Field Joints:
- a. Use flanged joints in all other locations unless otherwise indicated on the Drawings.
 - b. Assemble field joints in accordance with the recommendations of the manufacturer.
 - c. Mechanical Joints:
 - 1. If mechanical joint fails to seal, disassemble, clean, and reassemble joint at no additional cost to the Contract.
 - 2. Tighten bolts to torque values listed in ANSI/AWWA C111/A21.11.
 - 3. Do not over tighten bolts.
 - 4. Align holes in harnessed mechanical joints with tie rods to permit installation of tie rods.
 - 5. When installing flange and mechanical joint pieces, align holes in mechanical joint bell and flange to straddle top center line for horizontal piping and side centerline for vertical piping.
 - d. Push-On Joints:
 - 1. Lubricate all joint surfaces before joint is made with lubricant certified to meet NSF 61 for potable water service.
 - 2. Install restrained joint pipe in accordance with recommendations of pipe manufacturer.
 - e. Flanged Joints:
 - 1. Do not restrain opposite end of pipe or fitting in any direction when tightening flange bolts.
 - 2. Tighten bolts gradually and at uniform rate to provide uniform compression of gasket.

3. Do not over stress flanges.
 4. Allow one flange to move in any direction while tightening flange bolts.
 5. Insulate flanges shown on Drawings.
- f. Flanged Coupling Adapters:
1. Determine location of holes for anchor studs after the pipe is in place and adapter is bolted tight.
 2. Field drill pipe for anchor studs.
 3. Drill holes for anchor studs completely through pipe wall.
 4. Use hole diameter not more than 1/8 inch larger than diameter of stud projection.
- g. Couplings:
1. Provide space of 1/4 inch to one inch between pipe ends.
 2. Clean and remove foreign material from pipe and coupling surfaces which contact gaskets during assembly.
 3. Install coupling with all parts square and symmetrical with the pipe.
 4. Uniformly tighten assembly bolts so coupling is free from leaks.
 5. Couplings shall be installed with heat shrinkable sleeve for corrosion protection.
7. Polyethylene Tube Protection:
- a. Provide all buried ductile iron pipe and fittings used for water mains with a diameter of 48 inches or less with polyethylene tube protection.
 1. Install tube in accordance with AWWA C105, Method A.
8. Field Repair of Protective Coatings and Linings:
- a. Entry into pipe for application of interior linings to unlined ends shall be from open ends or through access manholes.
 - b. Field Repair of Shop-Applied Coatings and Linings:
 1. For Flanged Joints: Extend cement mortar lining to ends of pipe.
 2. For Push-On and Restrained Joints:
 - a. Cement Mortar: Line to end of pipe on spigot end. Hold back lining in bells one inch beyond the point of nominal full joint engagement. Field repair in accordance with AWWA C104.
 3. For Coupled Joints:
 - a. Interior Linings: Cement Mortar Lining shall extend to end of pipe.
 - b. Exterior Coatings: Repair damaged areas of shop coatings on pipe and coupling after installation at no additional cost to the Contract.
9. Reducers:
- a. All reducers shall be concentric pattern, unless indicated on the Drawings.
10. Concrete Encasement:

- a. Install concrete encasement as indicated on the Drawings.
 - b. Provide concrete and reinforcing steel as specified in Section 03300.
 - c. Support, block, and anchor all pipe to be encased to prevent flotation.
11. Reaction Anchorage:
- a. Anchor all pipe, fittings, and valves subject to internal pressure to prevent separation of joints.
 - b. Provide joint anchors on all push-on and mechanical joint tees, Wye branches, bends, plugs, and valves.
 - c. Provide restrained joints on pipes as indicated on Drawings.
 - d. Provide mechanical joints with tie rods for joint anchorage, as indicated on Drawings.
12. PCCP to DI Adapters:
- a. Install in accordance with AWWA C301 and as indicated on the drawings.
 - b. Welding: AWS D1.1.
- B. Valves and Appurtenances
1. Valves:
 - a. Install butterfly valve in accordance with recommendations set forth in AWWA C504 and recommendations of manufacturer.
 - b. Install gate valves in accordance with recommendations set forth in AWWA C509 or C515, as applicable, and recommendations of manufacturer.
 - c. Repair damaged coatings in accordance with manufacturer's recommended procedure at no additional cost to the Contract.
 - d. Gate valves in chambers shall have flanged ends. Buried gate valves shall have mechanical joint ends unless otherwise indicated on the drawings.
 2. Extension stems:
 - a. Install extension stems for buried valves and for valves enclosed in vaults as indicated on drawings.
 - b. Install stems with extension guides as indicated on drawings.
 3. Valve boxes:
 - a. Set valves and valve boxes plumb.
 - b. Place valve box directly over valve and bring top of box flush with finished grade.
 - c. After box is in final position, place earth fill or bituminous pavement around valve box and tamp on each side of box.
 4. Air release valves:
 - a. Install each valve assembly complete with appurtenant piping and valves as indicated on drawings.
 - b. Install a shutoff valve in bypass piping of each valve assembly as indicated on the drawings.

5. Valve Actuators:
 - a. Valve actuators shall be provided, installed, and adjusted by the valve manufacturer. Actuator mounting arrangements shall be as indicated on the drawings.
 6. Number Plates:
 - a. Install on valve body.
- C. Precast Structures
1. Bases:
 - a. Construct structures with pre-cast concrete bases.
 1. Excavate subgrade materials to undisturbed earth and uniform elevation allowing installation and dynamic compaction of at least 12 inches of structural fill.
 - b. Grade surface of granular material and set base section so connecting pipes will be on line and grade.
 - c. Adjust elevation of granular material until grade and alignment of base section is attained.
 - d. Do not wedge or block under pre-cast concrete bases.
 2. Riser Sections for Manholes:
 - a. Provide circular pre-cast sections with mastic gasket to seal joints between sections.
 1. Only use mastic gaskets at temperature recommended by manufacturer.
 - b. Fill lifting notches in manhole walls with non-shrinking grout.
 3. Connecting Piping for Manholes:
 - a. Drains: fill space between connecting pipes and wall of pre-cast sections with non-shrinking grout.
 - b. Sewer and Water: use rubber seal system in accordance with ASTM C923.
 4. Dampproofing:
 - a. Field applied:
 1. If shop applied dampproofing has been damaged, paint outside surface of structure with one coat of coal tar paint before backfilling.
 5. Waterproofing:
 - a. Field apply masonry sealer to all exterior surfaces of meter vault in accordance with manufacturer's instructions.
 6. Castings:
 - a. Frames shall be set in full mortar beds. All voids beneath the bottom flange shall be completely filled and result in a watertight fit.
 7. Core Drilling:
 - a. When core drilling is completed, clean the exposed concrete surface and ends of reinforcing steel and apply two (2) coats of protective epoxy coating for a total dry film thickness

of 10-15 mils. Allow first coat to cure before applying second coat. Allow second coat to cure before installing component requiring the concrete penetration.

8. Painting:
 - a. Castings shall be furnished unpainted.
9. Sealing:
 - a. Seal concrete manhole, chamber and vault penetrations, except penetrations for water pipe, on both inside/outside surfaces with hydraulic cement in accordance with manufacturer's instructions.
 - b. Seal water pipe concrete vault penetrations with mechanical penetration seal and wall sleeve in accordance with manufacturer's instructions.

3.2 GPS SURVEY

- A. Collect and provide the Owner and the MWRA as-built global positioning survey (GPS) points for the pipelines installed under this contract. GPS survey points shall be performed by a Licensed Professional Land Surveyor registered in the Commonwealth of Massachusetts.
 1. GPS locations shall be collected at the following locations:
 - a. Every 100 feet along straight segments and at every joint with a deflection of 2 degrees or higher.
 - b. All Fittings
 - c. All couplings and flange adapters
 - d. At all changes in direction
 - e. All valves
 2. The GPS locations shall be surveyed prior to backfilling the pipe, fittings and valves.

3.3 PIPELINE PRESSURE AND LEAKAGE TESTING

- A. Preparation:
 1. Protection:
 - a. Provide and install blocks, anchors, and supports for pipeline before test pressure is applied.
- B. Installation:
 1. Water:
 - a. Furnish water for testing.
 - b. Do not allow water to enter other parts of pipeline.
 - c. Dispose of test water in accordance with prepared disposal plan and regulatory requirements.
 2. Venting:

- a. Air release valves and other venting devices shall be installed as specified in Paragraph 3.1.B and shall be placed in open position when filling pipeline with water.
 - b. Provide vents in test bulkheads to expel air from pipeline.
 - c. Do not close hand operated vent valves until water flows in an uninterrupted stream from each valve.
3. Gauge Connections:
- a. Do not drill and tap pipe.
 - b. Use the existing pipe access points including:
 - 1. Air release valve openings.
 - 2. 1-inch corporations at butterfly valve chambers.
 - 3. 1-inch corporations at blow offs.
 - c. Provide adapter fittings for use at the specified access points.
- C. Field Quality Control:
1. Tests:
- a. Pressure Testing:
 - 1. Calibrate water meter and pressure gauges prior to pressure testing.
 - 2. Apply and maintain test pressure by force pump, without interruption, for a minimum of 2 hours after tested pipeline has been filled with water.
 - 3. Test pressure:
 - a. Subject new water mains to hydrostatic test pressure of at least 1.5 times the design working pressure of the main, but not less than 150 psi.
 - b. Leakage Testing:
 - 1. For at least 2 hours.
 - 2. Joints in piping shall be watertight and free from visible leaks during leakage test. Repair any visible leakage at no additional cost to the Contract.
 - 3. Leakage Test Pressure:
 - a. Maintain hydrostatic pressure within plus or minus 5 percent during entire time of leakage measurements.
 - 4. Leakage Measurement:
 - a. Do not measure leakage until trapped air has been vented and constant test pressure has been established.
 - b. Measure leakage with a water meter installed in the pressure supply piping on the pipeline side of the force pump.
 - 5. Allowable Leakage:
 - a. Leakage rate for each pipeline reach tested shall not exceed:
 - 1. For pipe with welded or mechanically coupled joints, Allowable leakage as defined in AWWA C219 shall be zero.

2. Calculate allowable leakage with following formula for pipes with other types of joints:

$Q = 0.0075 DLN$, where:

Q = allowable leakage in gallons per hour

D = nominal diameter of pipe in inches

L = length of section tested in thousands of feet

N = square root of average test pressure in psi

3. Calculate allowable leakage separately for each diameter and add resulting allowable leakage rates to obtain total allowable leakage for entire pipeline.

2. Inspection:
 - a. Locate leaking joints and pipe materials during pressure testing.
 - b. If test indicates pipeline leakage rate exceeding allowable leakage rate, repair leaking joints to reduce pipeline leakage to allowable rate specified at no additional cost.

3.4 DISINFECTION OF WATER MAINS

A. General:

1. Furnish the chlorine product for disinfection at rate and dose required in AWWA standards.
2. Furnish and install pipeline taps for dosing and testing of chlorinated water.
3. Install and remove bulkheads for testing.
4. Dispense the dose chlorine at points and rates in accordance with AWWA standards.
5. Operate new mainline valves, air release valves, and blowoff valves.
6. Dechlorinate and pH adjust water prior to discharge.

B. Preparation:

1. Disinfection:
 - a. Perform disinfection in accordance with the latest version in effect at bid of AWWA C651 and MWRA's Policy and Procedures for the Chlorination / Disinfection of Pipelines.
 - b. Disinfection shall be performed under the direct supervision of MWRA personnel and in accordance with the plan and regulatory requirements.
 - c. Monitor all valves within the isolation limits indicated on the Drawings to verify they are in the position indicated on the prepared disinfection plan, and for any discharges or leakage at the valves. The MWRA will monitor valves outside the isolation limits.
 - d. MWRA Operation Support personnel will perform water quality tests to verify that disinfection has been accomplished according to MWRA Water Quality Assurance Standards that include:

1. Coliform = 0
 2. Iron < 0.3 mg/L
 3. HPC <500 CFU/ml.
 4. A pH ranging from 8.7 to 9.3.
 5. Total Chlorine Residual between 1.7 ppm and 2.0 ppm
 6. Turbidity < 1.0 NTU
 7. Color <20 Color Units
2. Flushing:
- a. Perform flushing in accordance with the latest at bid version in effect at bid of AWWA C651 and MWRA's Policy and Procedures for the Chlorination / Disinfection of Pipelines.
 - b. Flush pipelines immediately prior to disinfection.
 - c. The minimum flushing velocity shall be greater than 2.5 feet per second.
 - d. Flushing shall be performed in accordance with regulatory requirements.
3. Discharge:
- a. Following disinfection, water with chlorine shall be dechlorinated prior to being discharged.
 - b. Water with chlorine to be discharged as in a legal manner.
- C. Installation:
1. Calcium Hypochlorite:
 - a. Use only as a solution.
 - b. Pump into pipeline with a chemical feed pump that is compatible with the chemical nature of the disinfectant.
- D. Application:
1. Special Techniques:
 - a. Disinfect pipelines by continuous feed method as follows:
 1. At a point not more than 10 feet downstream from the beginning of the new pipes, water entering the new pipe shall receive a dose of hypochlorite solution fed at a constant rate such that the water in the pipes will have not less than 25 mg/l free available chlorine. To assure that this concentration is achieved, measure chlorine concentration at regular intervals along the pipes, using chlorine test kits, or as otherwise described in the current edition of AWWA M12 - Simplified Procedures for Water Examination.
 2. Apply chlorine continuously until entire pipeline is filled with chlorine solution.
 3. Retain treated water in pipeline for at least 24 hours.
 4. Free chlorine residual at end of test shall be at least 10 mg/l.
 - b. Blow-offs, air release valves and gate valves shall be fully disinfected.

E. Field Quality Control:

1. Tests:

a. Bacteriological Tests

1. Notify the Owner and the MWRA 48 hours prior to flushing pipeline. The MWRA will collect samples and test for bacteriological quality after chlorine solution has been flushed out of pipeline.
2. Repeat disinfection at no additional cost to the Contract if bacteriological tests indicate that pipeline is not disinfected in accordance with Contract Documents.

b. Measure the chlorine concentration and pH every 60 minutes at the monitoring and flushing discharge locations. The monitoring shall start prior to the anticipated time the chlorine will reach the monitoring point and shall continue through the entire disinfection process until the measured chlorine concentration is less than 2.75 mg/L.

1. Measurements of chlorine concentration shall be obtained using the DPD Drop Dilution Method as described in AWWA C651. The use of test strips for measuring chlorine concentration will not be allowed.
2. Provide graphs showing time versus chlorine residual and pH value at each sampling, monitoring, and discharge location.

F. Protection:

1. The following equipment shall be on site within the isolation limits at all times during disinfection and flushing operations:

- a. Means of communication
- b. Operating tools
- c. Maintenance tools
- d. Chemicals required for chlorine neutralization

3.5 FIELD QUALITY CONTROL

A. Castings:

1. Install a new gasket for each watertight and locking manhole frame and cover within seven (7) days prior to Substantial Completion.

B. Clean and dewater all manholes prior to final walkthrough.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02756

STORM DRAIN LINING

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Work Included: Provide all equipment necessary for the lining of existing storm drain piping by the cured-in-place-pipe (CIPP) method. Provide all equipment necessary for the lining of storm drain structures by the cured-in-place manhole (CIPM) liner method. The extent of this lining work is described in Section 02400, Paragraph 2.1 A. and as shown on the Contract Plans. If the Design Builder intends to use existing drainage it also includes the track corridor drain piping and associated structures from Cross Street to Washington Street, including the 42 inch main collector drain and its lateral pipe connections and their structures, and the 20-inch double-barrel siphon crossing Washington Street.

Work Included: Furnish all necessary labor, materials, supervision and equipment to satisfactorily inspect existing gravity siphon storm drains and structures that are to be lined, as required by the Contract Documents by means of a closed circuit television system (CCTV). The work shall include a combination of pre-drain pipe lining CCTV and post- drain pipe lining CCTV inspections of each of the pipes to be lined. CCTV work shall be completed and delivered per the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP) standards.

- B. Related Work:
1. Section 02400 – Drainage and Sewer Systems
 2. Section 02632 - Stormwater Bypass Pumping Systems

1.2 QUALITY ASSURANCE

- A. Standards:
1. Cured-in-place-pipe (CIPP) shall meet all the requirements of ASTM F1216 and ASTM F1743.
 2. Cured-in-place liners for drain structures shall comply with the applicable system provisions of the Performance Specification Guideline for Manhole Rehabilitation, December, 2013, by the National Association of Sewer Service Companies (NASSCO). Other systems may be considered by the Owner, however the Design-Builder shall furnish all documentation required to prove the alternate system provides all the performance requirements specified and is compatible for use with the existing system. Alternate systems are subject to the review and approval of the Project LSP.
- B. Acceptable Contractor:

1. The Design-Builder or his subcontractor shall have a minimum of 5 years experience in sewer or storm pipe lining.

1.3 SUBMITTALS

- A. The Design-Builder shall submit to the MBTA complete design calculations for the pipe liner that meet the requirements of ASTM F1216. Calculations shall be approved and stamped by a Massachusetts licensed Professional Engineer. The design shall be based on the following physical conditions of the existing pipe to be rehabilitated:
 1. All pipes shall be considered fully deteriorated.
 2. All pipes are subjected to a soil load of 120 lbs/cf with capacity to support the greater of HS-20 live traffic load or a Cooper E-80 train loading with a 1.5 impact factor.
 3. The water table is assumed to be 3 feet below the ground surface.
 4. Pipe lengths and depths are as shown on the Contact Plans.
 5. The maximum pipe ovality is 2%.
 6. The minimum wall thickness for CIPP liner is 6 mm.
- B. Design-Builder to submit materials and installation procedures for review by the MBTA.
 1. Product data submittals required for all liner system shall include:
 2. Liner material type and manufacturer to be used, including: catalog data sheets, ASTM references, material composition, manufacturers recommended specifications, component physical properties and chemical resistance.
 3. Manufacturer's detailed description of the recommended procedures for handling and storing materials including a proposed method for monitoring temperatures of the storage location, if applicable to the specific liner material.
 4. Manufacturers detailed description of the recommended material installation/application process including mixing, additives, set time, cure time (return to service) and all equipment required for quality product delivery.
 5. Technical data sheet describing each rehabilitation component to be applied/installed, stating the expected longevity of the component in a stormwater environment. Data shall be based on independent third party tests.
 6. Manufacturer's detailed description of all required field testing processes and procedures.
- C. A detailed description of the Design-Builder's proposed procedures for cleaning and preparing the manhole structure, prior to applying/installing the liner shall be submitted.
- D. Design-Builder to submit video recording of CCTV inspections, pre-lining and post-lining, as required.

- E. Design-Builder to submit documentation relative to the qualifications, training and experience of the installers.

2.1 PIPE LINER

- A. The liner shall be fabricated from a vinyl ester resin material that is chemically resistant to exposure to chlorinated volatile organic compounds (CVOC).
- B. The liner shall be continuous, seamless, and jointless from manhole to manhole.
- C. Liner shall be sized to provide a tight fit to the host pipe.
- D. Liner material shall meet the requirements of ASTM F1216 and ASTM F1743.

2.2 STRUCTURE LINER

- A. The liner shall be fabricated from a vinyl ester resin material that is chemically resistant to exposure to chlorinated volatile organic compounds (CVOC).
- B. The liner shall be a pre-made system custom fabricated for each manhole shape and size.
- C. Liner shall be sized to provide a tight fit to the host structure.
- D. At a minimum, the manhole liner system shall be composed of a multiple layered composite consisting of felt, an impervious membrane, and fiberglass as required. The fibrous layer will be impregnated with a polymer resin. Add fiberglass and resin, for additional liner thickness.

2.2 CCTV

- A. The cameras shall be designed and constructed for storm drain piping inspection work. The mechanical design of the lens shall allow it to turn and rotate 360 degrees to provide a close up view of pipe walls. The camera shall be designed to maintain proper orientation of the picture while the lens is turning and rotating.
- B. The cameras shall be operative in 100% humidity conditions.
- C. The lighting for the cameras shall be suitable to allow a clear picture of the entire periphery of the drain pipe, such that joints, root intrusions, cracks, offset joints, deposits, etc. can be seen and identified by the Owner.
- D. The lens focus and rotational capabilities and the light intensity will be remotely controlled from an above ground television "studio".
- E. The cameras shall produce a continuous, full color picture with a quality acceptable to the Owner.

3.1 INSTALLATION

- A. All work shall be done in compliance with all current OSHA safety regulations. The Design-Builder shall conform to all work safety requirements of pertinent regulatory agencies, and shall

secure the site for working conditions in compliance with the same. The Design-Builder shall erect such signs and other devices as are necessary for the safety of the work site.

- B. Prior to lining the storm drains, the piping shall be cleaned and inspected with CCTV equipment. Design-Builder shall verify that the conditions of the drain pipes are acceptable for the method of liner installation specified.
- C. Prior to lining the drain structures, clean interior surfaces of manhole of debris, dirt, oil, grease, remains of old coating materials, and any other extraneous materials. Pressure wash manhole walls to remove loose mortar, concrete and debris. Pressure washing levels, used for cleaning, shall be as recommended by the manufacturer. Properly dispose of debris and residue from cleaning and other construction operations in a manner satisfactory to Owner and regulatory authorities.
- D. Design-Builder to control existing flow and bypass pump as required.
- E. The Design-Builder shall install the pipe liner per the method recommended by the liner manufacturer and as submitted in the shop drawing.
- F. Steam curing shall only be allowed for pipe sizes of 18-inch diameter and smaller, unless written permission from the MBTA is granted.
- G. Water used for installation shall be provided by the Design-Builder. The water shall be disposed of in a legal manner, as required by regulatory agencies.
 - 1. If the residents complain about the potential odors from the curing process, the MBTA may require the following actions to minimize the impacts of the odors:
 - a. The length of pipe that can be lined at one time may be limited, and/or
 - b. The curing water may only be able to be released during certain times of the day.
- H. Leakage testing shall be performed on the liner according to the requirements of ASTM F1216.
- I. Provide a watertight seal at the insertion and termination points in the manholes. Seal any space between the liner and host pipe in the manholes and provide for smooth merging of flows from other pipelines entering the manhole. Sealing material shall be chemically resistant to exposure to CVOC compounds.
- J. After completion of the work, perform CCTV inspection of the completed liner.
- K. The Design-Builder shall furnish all materials, equipment, tools, and labor as required for the CIPM lining of the manholes designated.
 - 1. The installation of the selected liner system shall be in strict accordance with the manufacturer's instructions. This shall include the preparation, installation, inflation, curing, and finishing, required for the complete installation of the CIPM liner. Custom fabricate liner to individual manhole dimensions.
 - 2. Line bench area with material placed in the bottom of the manhole and extending a minimum of 6 inches up the manhole wall.

3. Saturate liner with resin, place into manhole, pressurize with air or water and cure with hot water, steam or hot air following manufacturer's recommendations.
 4. When finished, liner shall form a monolithic structure from the manhole frame to the bench.
 5. The Design-Builder shall observe all safety rules, regulations, applicable laws and insurance requirements for storing, handling, use and application of the liner materials, resins and any solvents.
- L. During the Design-Builder's one-year warranty period, any defects which will affect the integrity or the strength of the liner shall be repaired at the expense of the Design-Builder.

3.2 CCTV INSPECTIONS AND DOCUMENTATION

A. Flow Control:

1. A minimum of 75% of the periphery of the storm drain shall be visible at all times.
2. CCTV inspections shall be conducted during dry weather when there are no storm flows in the piping. The MBTA may require that the piping be plugged and existing flows bypassed so that the entire periphery can be inspected.

B. Operation:

1. Perform inspection of storm drains after piping has been suitably cleaned. The Design-Builder shall clean piping just prior to CCTV inspections. The Design-Builder shall legally transport and dispose of all materials.
2. Drains shall be suitably isolated from the remainder of the storm piping as required.
3. Move the cameras through the piping in either direction at a uniform rate as directed by the MBTA.
4. The MBTA may require Design-Builder to pull cameras back to get a second view of a section of the pipe.
5. Use manual winches, power winches, television cable reel powered rewinds, high-pressure hose and reels on jet-cleaning trucks, or a flexible pole, to move the camera through the storm drains.
6. The screen monitor and winch operators shall be in full communication at all times.
7. Remove all wires, screens, sand bags, etc. used in the television inspection process from the piping at the completion of inspection of each drain section.

C. Measurement:

1. Measurement for location of defects, etc., shall be accurate to two tenths (0.2) of a foot over the length of the section being inspected.

D. Records:

1. Printed records shall be provided reflecting location of defects, etc., and shall be recorded per PACP standards and stored to a NASSCO-certified digital reporting software:
 - a. Keep records and supply to the MBTA when the work has been completed.
 - b. Show the exact location in relation to adjacent manholes, of each defect and infiltration point observed by the television camera.
 - c. Show locations of unusual conditions, roots, lateral storm drain connections, collapsed sections, presence of scale and corrosion, and other discernible features.
2. Video / Photographs:

Two copies of each set of videos shall be provided to the MBTA in DVD format, downloaded or output from a NASSCO certified software.

The video shall be digitally recorded, indexed by pipe section (labeled by manhole number or other means acceptable to MBTA) and allow for printing of still photographs.

Photographs shall be printed at MBTA's request and shall be identified on the back as follows:

Date of Photograph _____

Section, MH# _____ to MH# _____

Diameter of Pipe _____

Distance from MH# _____ is _____

Description of item photographed _____

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02800

EXTERIOR CONDUIT SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies exterior electrical distribution and communications facilities including concrete-encased underground duct banks, conduits, exposed conduits on bridges and other structures and associated manholes, handboxes, vaults, covers, and appurtenances.
- B. Exterior conduits and duct banks include, but not limited to, telephone, electric, fire alarm, police signal, traffic signal, cable, communications and lighting.
- C. Related Work:
 - 1. Volume 2 Technical Provisions Exhibit 21 "Additional Project Requirements".
 - 2. Section 02260 – EXCAVATION SUPPORT AND PROTECTION
 - 3. Section 02300 – EARTHWORK
 - 4. Section 02650 – EXISTING SITE UTILITIES
 - 5. Section 03300 – CAST-IN-PLACE CONCRETE
 - 6. Section 05420 – TEMPORARY STEEL UTILITY BRIDGES

1.2 SUBMITTALS

- A. Submit to both the MBTA and affected utility company for approval, detailed plan and schedule for proceeding with the work. Submit to the MBTA written evidence of utility company's approval of proposed procedure, schedules, and materials.
- B. Certificates of compliance for conduits and appurtenances.
- C. Brochures and catalog cuts.
- D. Conduit location working drawings.
- E. Samples of all units along with certified engineering data. Upon approval of samples and test data, delivery of the units shall be made. No changes or modifications, with the exception of minor changes not affecting operation or appearance, will be allowed.
- F. Detail working drawings and design documentation for support spacing (maximum $\frac{5}{8}$ -inch mid-span deflection) and expansion / deflection systems for conduit installed on bridges and other structures.

1.3 JOB CONDITIONS

- A. Establish through the MBTA direct and continuous liaison with utility companies who are involved in the indicated work. Verify or determine interface with utility company, and work to be performed and materials to be furnished by utility company.
- B. The Design-Builder shall be responsible for necessary coordination and project engineering with the private utility companies and public agencies.

1.4 QUALITY ASSURANCE

- A. Inspection of the work will be made by the respective utility company involved and the Design-Builder.
- B. Notification Point – In the event that the supplier makes a modification or change to the specified unit, or development of a new unit to replace the specified unit, written notification shall be provided to the MBTA. It shall be the MBTA's option to accept delivery of the modified or new unit, or to request the specified unit. In no case shall the delivery of any new or modified unit result in any additional increase in cost to the MBTA.

1.5 GUARANTEES/WARRANTIES

- A. All manufacturers' guarantees against defects in the materials and workmanship shall be transferable to any authorized agency of the local authority or private utility company who shall be responsible for maintenance. Structural defects in the unit shall be cause for complete replacement of the unit. Defects in any component part of the unit, which is covered by the guarantee, may be replaced on an individual basis at the discretion of the MBTA. The cost of such replacement shall be borne by the Design-Builder. Any defective unit or compound thereof, returned within the guarantee period, shall be replaced by the Design-Builder who shall make arrangements to return any unit or components thereof, to the manufacturer at the Design-Builder's expense.
- B. The warranties that the Design-Builder receives from each manufacturer of equipment and materials pertinent to the complete and satisfactory operation of each unit included in the Section shall be turned over to the MBTA at the time of acceptance of the project, at no cost to the MBTA. Each warranty so furnished shall indicate its expiration date and be in effect for a minimum period of one (1) year from the date the units were placed in continuous operation. Warranties shall be transferable to any agency designated by the MBTA.
- C. If, within one (1) year from the date the units are placed in continuous operation, the equipment and materials do not meet the warrants specified above and the MBTA notifies the Design-Builder or his authorized representative promptly, the Design-Builder or his authorized representative thereupon, shall correct any defects either by repairing or replacing any defective part or parts, at no expense to the MBTA.

PART 2 - PRODUCTS

2.1 HANDHOLE AND/OR PULLBOXES

- A. Handhole and pullboxes influenced by the track live load shall meet Cooper E-80 load conditions.

- B. All handhole and pullboxes shall meet the requirements of the governing agency relative to installation location (MBTA, MassDOT, private utility company, etc.)

2.2 CONDUIT AND FITTINGS

- A. PTS 77 (C Plastic) or Schedule 40: with the following specific requirements

Nominal Size, Inches	4.0
Minimum Sweep	3 feet – 90 degrees radius
Maximum No. 90 degree Bends	2
3/8” Minimum polypropylene pull line or equivalent strength Polyester Woven Mule Tape must be installed in terminated conduit end to end	
Leave a minimum of 3’ of secured rope in box	

- B. 4” Hot Dip Galvanized Rigid Steel (0.25” wall): ANSI C80.1
- C. Reinforced thermosetting resin conduit (RTRC) or fiberglass reinforced epoxy (FRE), iron pipe size (IPS) of the sizes shown or noted on the Plans for conduit installed on bridges and other structures. The conduit shall be filament wound fiberglass reinforced epoxy as manufactured to comply with specifications outlined in NEMA TC-14. Conduit shall be free from defects including, but not limited to, delaminations and foreign inclusions. Conduit shall be uniform in color, density and physical properties. It shall be straight with ends cut square to inside diameter. Conduit shall be pigmented black and be supplied with an ultraviolet inhibitor. Conduit shall be supplied with all fittings, expansion joints, adapters and bends (sweeps) manufactured from the same materials as the conduit. All required underbridge anchors, hangers and support elements shall be supplied by the manufacturer of the fiberglass conduit. Hangers shall be comprised of fiberglass reinforced plastic tube and plate components and galvanized steel hanger rods, washers, bolts and related attachment accessories. Conduit jointing method shall be as approved by the respective utility.
- D. Conduit influenced by the track live load shall meet Cooper E-80 load conditions.

PART 3 - EXECUTION

3.1 EXCAVATING AND BACKFILLING

- A. Section 02300 - EARTHWORK.

3.2 PLACING DUCTS

- A. Completely encase underground duct banks in concrete where indicated. Do not use earth forms. Comply with the requirements of ANSI C2, Sections 31 and 32, NFPA 70, and Section 03300 - CAST-IN-PLACE CONCRETE.
- B. Lay the bottom tier of ducts, using the type of chairs and spacers recommended by the utility company.

- C. Make tight joints in the duct lines complying with the recommendations of the manufacturer of the jointing compound or coupling. Install rigid metal stub-ups, as indicated, adapted by suitable fittings to individual ducts for stub-up from duct bank to connection to equipment and lighting above grade. Cap stub-up to prevent water, dirt, or debris from entering stub-ups.
- D. Hold Point - Obtain the MBTA's approval of the installed duct prior to placing the concrete encasement.

3.3 PLACING CONDUIT

- A. Place conduit for direct burial without encasement only where so indicated. Provide four inch minimum clean sand bedding under conduit and 12 inch minimum sand cover over the conduit.
- B. Prove the conduit clear by:
 - 1. Rodding and pulling an approved test mandrel from structure to structure; or
 - 2. Blowing an approved device from structure to structure with compressed air.
- C. Leave a nylon or polyester pull-line in each conduit and cap open ends.
- D. For fiberglass conduit on bridges and other structures, expansion / deflection fittings shall be installed as recommended by the manufacturer.

3.4 CONSTRUCTION OF MANHOLES, HANDBOXES, AND VAULTS

- A. Comply with all requirements of NEC and NESC.
- B. Communication manholes/vaults shall conform to the respective utility company's requirements, or approved equal.
- C. Structures influenced by the track live load shall meet Cooper E-80 load conditions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith shall be included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02852

TRACKWAY DEMOLITION AND SALVAGE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work specified under this Section includes demolition work and track removal and disposition, as identified on the Contract Documents and identified as follows:
 - 1. Salvaging items for reuse by the MBTA.
 - 2. Removal of track material and its disposition.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 - 2. Section 02856 – COMMUTER RAIL TRACK CONSTRUCTION.
 - 3. Section 02300 – EARTHWORK.

1.2 DEFINITIONS

- A. Demolish: Completely remove and legally dispose of off-site.
- B. Salvage: Carefully detach from existing construction, in a manner to prevent damage, and deliver to MBTA ready for reuse. Include fasteners or brackets needed for reattachment elsewhere.
- C. Hazardous Material: included but is not limited to asbestos and materials regulated under TSCA, RCRA (310CMR 30.00) and the Massachusetts Contingency Plan (MCP) (310 CMR 40.00) and building construction material defined by OSHA. Where applicable, consideration shall be given to MSDS in determining if a material could be potentially hazardous.

1.3 MATERIALS MBTASHIP

- A. Unless otherwise indicated, demolition waste becomes property of Design-Builder.
- B. All turnouts, crossovers, rail and other track materials shall be designated as salvage material and delivered to the MBTA as specified in Article 3.10 of this Section.
- C. All timber ties and switch timber removed shall be removed from the MBTA's property and disposed as specified in Article 3.10 of this Section.
- D. Historic items, relics, antiques, and similar objects including, but not limited to, cornerstones and their contents, commemorative plaques and tablets, and other items of interest or value to MBTA that may be uncovered during demolition remain the property of MBTA.

1. Carefully salvage in a manner to prevent damage and promptly return to MBTA.

1.4 SUBMITTALS

- A. Proposed Protection Measures: Submit informational report in accordance with OSHA Part 1926 procedures, including drawings, that indicates the measures proposed for protecting individuals and property, for environmental protection, for dust control and for noise control. Indicate proposed locations and construction of barriers.
- B. Indicate the following:
 1. Adjacent trackwork and systems equipment: Detail special measures proposed to protect adjacent trackwork and systems equipment to remain.
 2. Detailed sequence of demolition work, with starting and ending dates for each activity.
 3. Temporary interruption of utility services.
 4. Inventory: Submit a list of items to be removed and salvaged and delivered to MBTA prior to start of demolition.
 5. Pre-demolition Photographs or Video: Show existing conditions of adjoining construction and site improvements, including finish surfaces that might be misconstrued as damage caused by building demolition operations. Comply with Volumes 1 and 2. Submit before the Work begins.
 6. Hazardous material remediation plan. Included in the plan are landfill records indicating receipt and acceptance of hazardous wastes by a landfill facility licensed to accept hazardous wastes.
- C. All submissions shall be approved before work may proceed

1.5 QUALITY ASSURANCE

- A. Regulatory Requirements: Comply with governing EPA notification regulations before beginning demolition. Comply with hauling and disposal regulations of authorities having jurisdiction.
- B. Standards: Comply with ANSI A10.6 and NFPA 241.
- C. Prepare a hazardous material remediation plan and submit to MBTA for approval.

1.6 PROJECT CONDITIONS

- A. Buildings immediately adjacent to demolition area may be occupied. Conduct demolition so operations of occupied buildings will not be disrupted.
 1. Provide not less than 72 hours notice of activities that will affect operations of adjacent occupied buildings.
 2. Maintain access to existing walkways, exits, and other facilities used by occupants of adjacent buildings.

- a. Do not close or obstruct walkways, exits, or other facilities used by occupants of adjacent buildings without written permission from authorities having jurisdiction.
- B. The MBTA assumes no responsibility for trackwork and systems equipment to be demolished.
 - 1. Conditions existing at time of inspection for bidding purpose will be maintained by MBTA as far as practical.
- C. Hazardous Materials: Hazardous materials may be present in signal instrument houses to be demolished. A report on the presence of hazardous materials is on file at the MBTA for review and use. Examine report to become aware of locations where asbestos, lead paint or other hazardous materials are present. Do not disturb hazardous materials or items suspected of containing hazardous materials except under procedures specified or required by a licensed professional and/or agency having jurisdiction.
- D. On-site storage or sale of removed items or materials is not permitted.
- E. Construction Access and Staging
 - 1. Special attention shall be given to sequence demolition staging work so the MBTA Commuter Rail operations are not affected with respect to safety, operation and schedule.
 - 2. All materials removed as part of this demolition shall become the property of the Design-Builder and are to be disposed of properly according to applicable local, State and Federal regulations, unless otherwise specified by the MBTA.

1.7 COORDINATION

- A. Arrange demolition schedule so as not to interfere with MBTA's operations and operations of adjacent occupied buildings.
- B. Demolition shall proceed in sections. The demolition work shall be performed in conjunction with the approved sequence of construction plans.
- C. A minimum of one track shall be in operation at all times. This track will be active during all demolition activities. Design-Builder shall take steps to ensure that his operations will not impact rail service.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that utilities have been disconnected and capped before starting demolition operations.
- B. Review Project Record Documents of existing construction provided by MBTA. MBTA does not guarantee that existing conditions are same as those indicated in Project Record Documents.

- C. Inventory and record the condition of items to be removed and salvaged. Provide photographs or video of conditions that might be misconstrued as damage caused by salvage operations.
- D. Verify that hazardous materials have been remediated before proceeding with trackwork or systems equipment demolition operations.

3.2 PREPARATION

- A. Existing Utilities: Refer to Section 02650 – EXISTING SITE UTILITIES for shutting off, disconnecting, removing, and sealing or capping utilities. Do not start demolition work until utility disconnecting and sealing have been completed and verified in writing.
- B. Salvaged Items: Comply with the following:
 - 1. Clean salvaged items of dirt and demolition debris.
 - 2. Pack or crate items after cleaning. Identify contents of containers.
 - 3. Store items in a secure area until delivery to MBTA.
 - 4. Transport items to storage area designated by MBTA.
 - 5. Protect items from damage during transport and storage.

3.3 PROTECTION

- A. Existing Facilities: Protect adjacent active tracks and walkways during demolition operations.
- B. Existing Utilities: Maintain utility services to remain and protect from damage during demolition operations.
 - 1. Do not interrupt existing utilities serving adjacent occupied or operating facilities unless authorized in writing by MBTA and authorities having jurisdiction.
 - 2. Provide temporary services during interruptions to existing utilities, as acceptable to MBTA and authorities having jurisdiction.
 - a. Provide at least 72 hours notice to occupants of affected businesses or buildings if shutdown of service is required during changeover.
- C. Temporary Protection: Erect temporary protection, such as walks, fences, railings, canopies, and covered passageways, where required by authorities having jurisdiction and as indicated. Comply with requirements in Volumes 1 and 2.
 - 1. Protect existing site improvements, appurtenances, and landscaping to remain.
 - 2. Provide protection to ensure safe passage of people around demolition areas and to and from occupied portions of adjacent businesses and structures.
- D. Remove temporary barriers and protections where hazards no longer exist. Where open excavations or other hazardous conditions remain, leave temporary barriers and protections in place.

3.4 DEMOLITION, GENERAL

- A. General: Demolish indicated existing signal systems equipment and site improvements completely.
Use methods required to complete the Work within limitations of governing regulations and as follows:
 - 1. Do not use cutting torches until work area is cleared of flammable materials. Maintain portable fire-suppression devices during flame-cutting operations.
 - 2. Maintain fire watch during and for at least four hours after flame cutting operations.
 - 3. Maintain adequate ventilation when using cutting torches.
- B. Engineering Surveys: During demolition, perform surveys to detect hazards that may result from signal systems equipment demolition activities.
- C. Site Access and Temporary Controls: Conduct signal systems equipment demolition and debris-removal operations to ensure minimum interference with roads, streets, walks, walkways, and other adjacent occupied and used facilities.
 - 1. Do not close or obstruct streets, walks, walkways, or other adjacent occupied or used facilities without permission from MBTA and authorities having jurisdiction. Provide alternate routes around closed or obstructed traffic ways if required by authorities having jurisdiction.
 - 2. Use water mist and other suitable methods to limit spread of dust and dirt. Comply with governing environmental-protection regulations. Do not use water when it may damage adjacent construction or create hazardous or objectionable conditions, such as ice, flooding, and pollution.
- D. Explosives: Use of explosives is not permitted.

3.5 SALVAGE

- A. Salvage indicated material or material determined by the MBTA to be suitable for reuse, including: turnouts, rail, joint bars, and tie plates shall be delivered to the MBTA.
- B. Protect metallic coatings on salvaged items. Remove adhering concrete from salvaged items where required for disposal or directed by the MBTA.
- C. Repair, or replace with new material, salvaged material damaged or destroyed due to the Design-Builder's negligence.
- D. All items designated as "remove" and not relocated as part of this project, and determined to be in salvageable condition by the MBTA, shall be delivered to the MBTA Railroad Operations material yard in Charlestown, MA, unless otherwise directed by the MBTA. No delivery will be greater than 50 miles, one way. Such delivery of materials shall be coordinated with the MBTA prior to delivery.

3.6 SITE RESTORATION

- A. Below-Grade Areas: Rough grade below-grade areas ready for further excavation or new construction.
- B. Site Grading: Uniformly rough grade area of demolished construction to a smooth surface, free from irregular surface changes. Provide a smooth transition between adjacent existing grades and new grades.

3.7 REPAIRS

- A. Promptly repair damage to adjacent buildings, utilities, fences, or track caused by demolition operations.

3.8 DISPOSAL OF DEMOLISHED MATERIALS

- A. Remove demolition waste materials from Project site and legally dispose of them in an EPA-approved landfill acceptable to authorities having jurisdiction.
 - 1. Do not allow demolished materials to accumulate on-site.
 - 2. Remove and transport debris in a manner that will prevent spillage on adjacent surfaces and areas.
- B. Do not burn demolished materials on site.

3.9 CLEANING

- A. Clean adjacent structures and improvements of dust, dirt, and debris caused by trackwork or systems equipment demolition operations.

3.10 TRACK AND TURNOUT REMOVAL AND DISPOSITION OF MATERIALS

- A. Prior to track construction the existing track and turnouts shall be dismantled and removed to the limits shown on the approved drawings.
- B. Rail, joint bars and tie plates shall be salvaged and returned to the MBTA as specified in paragraph G.
- D. Track bolts, nuts, washers, spikes, anchors and lags shall become the property of the Design-Builder and shall be disposed of off of the MBTA's property.
- E. Track and turnout dismantling shall be done using equipment and procedures that will not damage salvaged material or make it unfit for future use. If a torch is used to remove bolts from joints care shall be taken so as not to damage joint bar.
- F. All salvaged turnout material shall be packaged as a unit and delivered to designated MBTA material yard(s) in Somerville or elsewhere within 50 miles of the Project, and shall be unloaded and stockpiled as directed by yard personnel.
- G. All salvaged rail and other track materials shall be delivered to designated MBTA material yard(s) in Somerville or elsewhere within 50 miles of the Project. Materials shall be separated, not mixed together, by class, type and weight and stockpiled as directed by yard personnel.

- H. Crossties and Switch Timber - All existing crossties and switch timber removed shall become the property of the Design-Builder, removed from the ROW and disposed of as indicated in paragraphs I through M below.
- I. Disposal shall be accomplished through incineration of ties, tie butts and switch timbers and bridge timbers at an approved facility.
- J. The processing and disposal facility/facilities shall be fully licensed and permitted for handling, processing, storage and incineration of treated wood waste.
- K. Bottom ash, fly ash, and other by-product residues from the combustion process shall be disposed of at a fully licensed land fill.
- L. Identified combustion facilities shall be approved by the MBTA's Project Manager prior to the commencement of burning of disposed ties and timbers.
- M. Design-Builder shall provide the MBTA with a copy of a certified weight slip for each quantity shipped, unloaded, and properly disposed of at the licensed facility.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith shall be included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02866

DIRECT FIXATION TRACK CONSTRUCTION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies direct fixation track construction for Light Rail Track.
1. Requirements for installation of direct fixation track containing continuous welded rail (CWR) on aerial structure deck, at-grade slabs, and transition between aerial and at-grade track.
 2. The requirements of this Section supplement the requirements of Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 3. The Work includes all ancillary activities as may be required to complete a direct fixation track system.
- B. Section Includes:
1. Site Examination
 2. Preparation
 3. Demonstration Section
 4. Track Alignment, Profile, and Geometry
 5. Concrete Plinth Construction
 6. Direct Fixation Rail Fastener Installation
 7. Distributing Continuous Welded Rail
 8. Rail Gap
 9. Rail Temperature
 10. Rail Installation
 11. Bonded Insulated Joints
 12. Traction Electrification and Signal Bonding
 13. Tolerances
 14. Field Quality Control
- C. Related Work Specified Elsewhere:
1. Section 02850 – LIGHT RAIL TRACK CONSTRUCTION
 2. Section 02851 – RAILROAD RUNNING RAIL

3. Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION
4. Section 02854 – TRACK SURFACING AND ALIGNMENT
5. Section 02865 – TRACK APPURTENANCES
6. Section 02868 – DIRECT FIXATION FASTENERS
7. Section 02877 – THERMITE WELDING
8. Section 03300 – CAST-IN-PLACE CONCRETE
9. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE
10. Section 16060 – GROUNDING AND BONDING
11. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION

1.2 APPLICABLE STANDARDS

- A. The following Codes, Regulations, Reference Standards and Specifications apply to work included in this Section:
1. MBTA Track Maintenance Standards.
 2. MBTA Book of Standard Trackwork Drawings
 3. American Railway Engineering and Maintenance of Way Association, (AREMA):
 - a. Manual for Railway Engineering
 - b. Portfolio of Trackwork Plans
 4. ASTM International (ASTM):
 - a. ASTM A775/A775M Specification for Epoxy-Coated Reinforcing Steel Bars
 - b. ASTM C881 Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.

1.3 SUBMITTALS

- A. General: Submittal procedures for all submittals, including but not limited to Shop Drawings, Product Data, Samples, shall comply with Section 01300 – SUBMITTALS.
1. Relevant submittals as indicated in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 2. Work plan in accordance with Article 3.2A herein.

3. Survey of existing bridge decks and track slabs upon which direct fixation tracks will be constructed indicating as-built conditions and deviations from requirements.
4. Product Data:
 - a. Concrete
 - b. Concrete Reinforcement
 - c. Epoxy grout
5. Shop Drawings:
 - a. Concrete reinforcement details.
 - b. Concrete plinths. Provide drawings indicating the layout of all direct fixation plinths detailing their relationship to the as-built concrete surfaces upon which they will be constructed. Show gaps between plinths as necessary to avoid joints, promote drainage, facilitate the work of other trades who shall position cables beneath the rails, and other physical conditions. Show locations of inserts for individual direct fixation rail fasteners and other attachments.
 - c. Details showing interfaces with the work of other trades.
 - d. HDPE pads.
6. Working Drawings: Configuration and formwork for concrete plinths.
7. Procedures:
 - a. Procedure for resetting removed anchor bolt inserts in concrete plinths in accordance with Article 3.5.C.3 herein.
8. Test Results: Insert tests in accordance with Article 3.14 herein.
9. Miscellaneous: Submit product data and shop drawings for any materials provided as part of the Work of this Section that do not have requirements for such submittals specified in other Sections.

1.4 QUALITY ASSURANCE

- A. General: Comply with the requirements of Section 01400 – QUALITY ASSURANCE.
- B. Quality Plan:
 1. Comply with the requirements of Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 2. Incorporate the following:
 - a. Surface preparation measurements.

- b. Environmental measurements such as temperature, dew point, relative humidity, rainfall, and similar items.
 - c. Mixing, applying, and curing measurements such as component materials viscosity and density, mixing ratios, and material hardness at various cure times.
 - d. Provisions addressing test failure and retesting procedures.
- C. Demonstration Section: Construct a demonstration section of direct fixation track as indicated in Article 3.3 herein. Do not employ construction methods that have not been proven and accepted based on the demonstration section.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Handle all trackwork materials in accordance with Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.

PART 2-PRODUCTS

2.1 TRACK MATERIALS

- A. Furnish all materials required to construct the direct fixation trackwork, including but not limited to the following:
- B. Concrete:
 - 1. Provide concrete meeting the requirements of Section 03300 – CAST-IN-PLACE CONCRETE
 - 2. Concrete strength: 4,000 psi minimum
- C. Concrete Reinforcement: Provide coated steel reinforcement bars in accordance with Section 03300 – CAST-IN-PLACE CONCRETE, the approved drawings, and ASTM A775.
 - 1. Epoxy Coating: Submit catalog cuts on epoxy coating used to repair damage to epoxy coated rebar. Use coating to touch up “chipped or cut” existing stirrups or new rebar to provide a complete insulating cover.
 - 2. All reinforcement shall be securely fastened to the underside of the attaching members as shown on the approved drawings.
 - 3. Special Hook Tie Bars: In superelevated track sections provide a series of reinforcing hook tie bars to generate the stepped-up installation shown on the approved drawings with spacer thimbles at low rail plinths.
 - 4. Tie Wires: For reinforcement bar, connection shall be an insulating material.
- D. Direct Fixation Fastener Insulating Shims:
 - 1. Place a minimum of one High-Density Polyethylene (HDPE) insulating shim directly beneath each direct fixation rail fastener to provide an additional electrical isolation barrier between

the rails and ground. All direct fixation fasteners shall have at least one HDPE shim directly beneath the fastener body.

2. HDPE Vertical Adjustment Shims:

- a. One 3/16-inch shim is provided per fastener under Section 02868 – DIRECT FIXATION FASTENERS. Provide additional shims as specified herein and as needed to correct track profile and cross-level to within specified tolerances.
- b. Conform to the requirements for insulating pads in Section 02868 – DIRECT FIXATION FASTENERS.
- c. Provide shims in graduated thicknesses so that no more than two shims will be required for all increments of 1/16-inch thickness from 1/16 inch to 3/8 inch.

E. Epoxy Grout:

1. Provide epoxy grout for securing replacement embedded fastener anchor inserts that require repositioning due to alignment errors.
2. Grout material: Provide material that complies to ASTM C881, Type 4.

F. Temporary Rail Clips: Furnish temporary threaded rail hold down clips for direct fixation fasteners, to be used during the installation/construction phase as described in Article 3.6 herein. The temporary clips shall be painted yellow for recognition.

H. Provide all other materials incidental to the construction of direct fixation trackwork that are necessary to provide a complete and acceptable track installation providing the function, appearance, and electrical isolation, as specified and necessary.

2.2 EQUIPMENT

A. Comply with the equipment requirements specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.

PART 3 -EXECUTION

3.1 SITE EXAMINATION

- A. Perform an as-built survey of the concrete surfaces upon which the direct fixation track will be constructed. Thoroughly inspect the existing stirrups, inserts and other attachment devices that are in place on at-grade slabs and determine if they are a suitable anchorage points for the direct fixation trackwork.
- B. Determine if existing work conforms to the requirements of the specifications to which it was built including but not limited to Section 03300 – CAST-IN-PLACE CONCRETE.
- C. Note all defects, including out of tolerance locations, and prepare a comprehensive survey and report. Arrange to have deficiencies corrected by the responsible party prior to commencing direct fixation track installation.

3.2 PREPARATION

- A. Work Plan: Prior to beginning the Work specified in this Section, submit a detailed work plan describing the installation procedures required for the Work, including but not limited to the following:
1. All applicable requirements as stipulated in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 2. Specific preparation and installation procedures for transporting and placing CWR in direct fixation track. Include listing of transporting and working equipment required.
 3. Describe the methods proposed for construction/installation of plinths, direct fixation rail fasteners and rails. Two methods are generally expected as detailed below. The Design-Builder may employ either method or, if appropriate, utilize both methods at different locations on the work site:
 - a. Top-down construction: This method uses track gauge jigs for supporting skeleton track (rails and direct fixation rail fasteners) in proper horizontal and vertical alignment. Temporary steel shims are employed in lieu of the permanent HDPE shims so as to avoid damage to the latter. Concrete forms and reinforcing steel are installed in the conventional manner. Concrete is then poured beneath the suspended direct fixation rail fasteners.
 - b. Bottom-up construction: Concrete forms and reinforcing steel are installed in the conventional manner. Jigs are positioned to hold the embedded female anchor inserts in proper position. After concrete curing, the direct fixation rail fasteners and rails are installed.
 4. Include details and shop drawings pertaining to the components to be used, methods, templates, fixtures, temporary clips, and method to protect concrete plinths from thermal expansion during the concrete plinth curing period.
- B. Roughen the structure floor by waterblasting, a light jack hammer process or other acceptable means of providing a good surface for bond between the floor concrete and the plinth concrete. Remove all loose laitance and debris from the floor surface that will be in contact with the concrete plinth.

3.3 DEMONSTRATION SECTION

- A. To confirm the proposed procedure for the construction of direct fixation track, construct a demonstration section not less than 100 track feet in length. Demonstration section shall be a continuous segment of track.
- B. Demonstration section shall become a segment of the final track subject to final acceptance. Propose the specific track segment where it is planned to construct the demonstration section and how that particular segment will illustrate the construction methods proposed.

- C. If the demonstration section (or portion thereof) is unsatisfactory, it shall be demolished, a revised construction procedure proposed, and a new demonstration section constructed.
- D. Production construction of direct fixation track will not be permitted until the designated demonstration section has been accepted.
- E. Once the demonstration section has been accepted, construction methods other than those used to build the accepted section shall not be employed unless verified through construction of a new demonstration section.

3.4 TRACK ALIGNMENT, PROFILE, AND GEOMETRY

- A. Provide track alignment, profile, and geometry in accordance with the requirements specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
- B. Construct track conforming to the alignment and profile data shown on the approved drawings.

3.5 CONCRETE PLINTH CONSTRUCTION

- A. Construct concrete plinths in conformance with the requirements of Section 03300 – CAST-IN-PLACE CONCRETE, and with the following:
 - 1. Use non-conductive plastic tie bands to secure epoxy coated reinforcing bar cage assembly.
 - 2. Inspect all reinforcing bar installation for cut ends, chipped, or uncoated conditions and repair with an approved epoxy coating material similar to and compatible with the factory-applied coating on the reinforcing bars.
 - 3. Inspect plinth stirrups and reinforcing bar cage for tight contact with slab or deck stirrups. Cage shall be securely fastened down with no upward movement possible.
- B. Construct the concrete plinth in the direct fixation fastener bearing seat area, which includes the concrete surface area covered by the direct fixation fastener insulating shim, with a uniform steel-trowel cement mortar finish to provide a smooth and uniform bearing surface capable of providing full contact with the HDPE insulating shim. Comply with criteria cited in Article 3.14 herein.
- C. Cast anchor bolt inserts into the concrete plinths for the direct fixation fasteners as shown on the approved drawings, the accepted work plan and associated working drawings, and in accordance with the following:
 - 1. Furnish and install anchor inserts that are free of loose scale, grease, or other foreign matter.
 - 2. Use either top-down skeleton track with suspended direct fixation fasteners or bottom-up installation with gages to accurately locate anchor inserts, and positively secure the inserts against displacement during concrete placement.
 - a. In both installation methods, do not use final installation direct fixation fastener clips during the procedure. Use a temporary threaded clip to not disturb inserts embedded

in green concrete at the time of release of rail or gages during concrete curing and finishing.

- b. Install inserts flush with top of the concrete to plus 0 inches above or minus 1/8 inch below.
3. Carefully remove displaced or misaligned inserts in a manner that will prevent spalling or compromising the structural integrity of surrounding plinth concrete by core drilling or other approved means.
 - a. Submit a procedure for resetting removed anchor bolt inserts in concrete plinths for the direct fixation fasteners, including epoxy grout materials for setting the insert and the alignment method.
 - b. Reset all displaced or misaligned inserts at no additional cost to the MBTA.

D. Repairs to Concrete Plinth Surface:

1. Repair voids in top surface of concrete plinth by troweling in cementitious mortar to smooth the surface. Prepare surface in compliance with rail fastener manufacturer's recommendations. An unacceptable number or volume of voids shall be cause for rejection of the concrete pour.
2. Do not use cementitious mortar to correct second pour concrete that is not within the required vertical tolerances. Grinding of second pour concrete surfaces to bring concrete flush with rail anchorage inserts, or to achieve proper elevation or flatness tolerances, is allowable only with the approval of the MBTA. Low concrete may be corrected by using shims beneath the fasteners, subject to the limitations on shimming that are stated elsewhere in this Section.

3.6 DIRECT FIXATION RAIL FASTENER INSTALLATION

- A. Once the plinth concrete has attained its initial set, release the temporary rail clips on fasteners, jigs, or templates used during the concrete pour.
 1. If using the top-down construction method, remove the temporary threaded clips used in the direct fixation rail fasteners so the anchor insert setting is not disturbed.
 2. The intent of releasing the rail installation from the fastener before final concrete cure is to relieve stress in the concrete plinths caused by thermal expansion and contraction in either the rail or concrete plinth, both of which could lead to concrete cracks in the plinths, originating at the anchor insert locations. Development of hairline cracks originating at anchor inserts will be grounds for removal and replacement of concrete plinth.
 3. Permanently connect/anchor the rail and the direct fixation fasteners only after the plinth concrete has attained at least 70% of its specified 28-day strength.
- B. If concrete surface grinding is required to achieve uniform bearing or to correct the vertical plinth height, do not grind the concrete lower than the top of the anchor insert collar unless the procedure and limits of grinding are established in writing, approved by the insert manufacturer and submitted to the MBTA.

- C. Thoroughly blow stone dust and extraneous materials off the surface of each concrete plinth to prevent damage to the direct fixation fastener HDPE insulating shim.
- D. Install one direct fixation fastener insulating shim for each fastener on the concrete plinth.
- E. Install elevation correction shims between the direct fixation fastener-insulating shim and the concrete plinth, as required, to ensure proper rail line and grade.
 - 1. Total number of HDPE shims per fastener: one minimum, three maximum.
- F. Direct fixation rail fasteners include a lateral adjustment feature for moving the fastener relative to the rail. This adjustment capability is primarily for future maintenance so as to adjust for lateral wear on the rail, and shall not be all used by the constructor for aligning the track. Design-Builder's accuracy in positioning anchor inserts shall leave not less than 3/8 inch of residual lateral adjustment in both directions after final aligning and gauging of the track. If this minimum cannot be met, replace as many anchor inserts as may be necessary to make it possible to position rail fasteners with the specified minimum residual adjustment.
- G. Remove misaligned inserts by core drilling or other method that prevents spalling or structural damage to the surrounding concrete. Use power tool, or other device as accepted by the MBTA, to roughen sides of cored hole. Wire brush inside of hole to loosen dust and loose material from hole, and then blow out hole with compressed air. Provide filter on compressed air system to ensure that air jet is free of any oil residue. Set anchor bolt insert with epoxy grout in accordance with manufacturer's instructions. Do not use previously installed anchor inserts that have been damaged during coring operations.

3.7 DISTRIBUTING CONTINUOUSLY WELDED RAIL

- A. Distribute continuously welded rail in accordance with the requirements specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

3.8 RAIL GAP

- A. Determine the allowable rail gap when welding CWR strings together by using the rail gap equation in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

3.9 RAIL TEMPERATURE

- A. The zero thermal stress temperature at final closure and fastening for CWR direct fixation track is as noted in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.

3.10 RAIL INSTALLATION

- A. Lay, clamp, fasten, and weld CWR in direct fixation track according to the procedure specified in Section 02853 – CONTINUOUS WELDED RAIL INSTALLATION.
- B. Install running rail and pre-curved running rail in conformance with Section 02851 – RAILROAD RUNNING RAIL.

- C. Electric welding shall comply with Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
- D. Thermite welding shall comply with Section 02877 – THERMITE WELDING.

3.11 BONDED INSULATED JOINTS

- A. Locate bonded insulated rail joints where shown on the approved drawings.
 - 1. Locate bonded insulated joints by centering between adjacent fasteners.
 - 2. Stagger the location of bonded insulated joints on the opposite rail by the distance of one fastener spacing from the opposite insulated joint position.
- B. Install and test bonded insulated joints in accordance with Section 02865 – TRACK APPURTENANCES.

3.12 TRACTION ELECTRIFICATION AND SIGNAL BONDING

- A. Install traction power and signal bonds as shown on the approved drawings and in conformance with requirements of Section 16060 – GROUNDING AND BONDING.

3.13 TOLERANCES

- A. Conform to the track construction tolerances as specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION. Longitudinal fastener spacing tolerance shall be $\pm 3/8$ inch from specified dimensions.
- B. Fastener spacing:
 - 1. Ordinary installations: Plus 1 inch or minus 3 inches from specified dimension.
- C. Concrete cover over rebar:
 - 1. Minimum concrete cover over all rebar: 1-1/2 inches.
 - 2. Maximum concrete cover between top rebar layer and top surface of plinth: 3 inches.
- D. Rail Anchorage Insert Placement: Perpendicularity of insert to top surface of concrete: maximum deviation 3 degrees.

3.14 FIELD QUALITY CONTROL

- A. Anchor Bolt Insert Tests:
 - 1. During the construction period, intermittently conduct the restrained pull-out test, unrestrained pull-out test, and torsion test as described below:
 - a. Inserts to be tested:

- 1) A minimum of 10 inserts spaced out within each concrete pour. For purposes of this Article, a concrete pour is defined as a series of plinths poured in a continuous operation over a time not to exceed 4 hours.
 - 2) At least 15 inserts per 300 direct fixation fastener inserts cast in place.
 - 3) 100% of inserts that have been reset in epoxy grout.
- b. Randomly select inserts, other than reset inserts, unless otherwise directed by the MBTA.
 - c. Notify the MBTA 24 hours in advance of the location and time of insert testing.
 - d. Submit the test results of insert tests to the MBTA, unless otherwise directed. Retain copies for submission with project record documents.
2. Restrained Pull-Out Test:
 - a. Test Method:
 - 1) Place a 5-inch by 5-inch by 1/2-inch steel plate with a hole in the center 1/4 inch larger in diameter than the insert top collar over the insert and clear of the collar.
 - 2) Install an anchor bolt in the insert and apply an upward vertical load of 20,000 pounds bearing against the steel plate.
 - 3) Hold the load for 1 minute, and then release the load.
 - b. Acceptance Criteria: No evidence of slippage or cracking of concrete or failure of the bond between the insert and plinth concrete or epoxy grout.
 3. Unrestrained Pull-Out Test:
 - a. Test Method:
 - 1) Install an anchor bolt in the insert and apply an upward vertical load of 10,000 pounds to the bolt in such a manner that no vertical load is applied to the plinth concrete within a radius of 6 inches from the centerline of the insert.
 - 2) Hold the load for 1 minute, and then release the load.
 - b. Acceptance Criteria: No evidence of slippage or cracking of concrete or failure of bond between the insert and plinth concrete or epoxy grout.
 4. Torsion Test:
 - a. Test Method: Apply 500-foot-pounds of torque to an anchor bolt installed with at least 1-inch thread engagement in the insert but not threaded to the bottom of the insert.
 - b. Acceptance Criteria: No evidence of failure of the bond between the insert and surrounding plinth concrete or epoxy grout.
 5. Shall inserts fail to pass the specified tests, test four additional inserts from the same concrete pour or 300-insert lot.
 - a. Failure of additional inserts to pass the tests shows that the installation procedure is defective and 100 % of the remaining lot will be rejected.

- b. Perform additional tests as specified above and other tests as required on concrete and other materials associated with insert installation to determine the limits and cause of the defective installation.
- c. Do not proceed with further insert installation until the causes of failure have been determined and a modified procedure ensuring satisfactory installation has been established.
- d. Investigate failure of a reset insert prior to remedial work and do not reset additional inserts without the MBTA's approval.
 - 1) Submit revised procedures and materials for resetting inserts for the MBTA's approval.

B. Plinth Concrete:

- 1. Do not place concrete that is delivered without the required batch documentation in accordance with Section 03300 – CAST-IN-PLACE CONCRETE. Missing or incomplete concrete test data will be construed as noncompliance.
- 2. Remove and replace plinth concrete batches failing to comply with the requirements of both this Section and Section 03300 – CAST-IN-PLACE CONCRETE, at no additional expense to the MBTA.
- 3. Concrete plinth surface finish: Direct fixation continuous bearing surface shall be within a tolerance of plus or minus 3/8 inch in 10 feet of the correct longitudinal slope and plus or minus 1/8 inch in 3 feet in cross slope.
- 4. Rail fastener bearing areas finish:
 - a. Voids: Prior to their being filled with cementitious grout, any surface voids in freshly poured concrete beneath direct fixation fasteners shall not exceed 10 % of concrete surface area under the fastener. Maximum size of any single void: 1/2-inch diameter by 3/8 inch deep.
 - b. Uniformity:
 - 1) Compliance with the requirement for a uniform bearing surface will be determined after rail is installed to final alignment with all welds, rail clips, anchor bolts, and associated components installed and all threaded elements such as anchor bolts fully torqued.
 - 2) Surface bearing acceptance criteria:
 - a) Do not allow gaps more than 1/16 inch, as determined by a 1/16-inch thick by 1-inch wide feeler gage, over 90 % of the projected rail base area immediately under the projected rail base, between the rail base and fastener rail seat, between the fastener bottom and the concrete surface or a shim, between shims, and between the bottom shim and the concrete surface.
 - b) Do not allow gaps more than 1/16 inch, as determined by a 1/16-inch thick by 1-inch wide feeler gage, over 70 % of the area outside the projected rail base area between the fastener, shim, and concrete.
 - c) When additional vertical adjustment shims are present, do not allow the sum of gaps to add up to more than 1/16 inch over the

respective area percentages for the projected rail base in Article 3.14 B.4.b.2) a) herein, and outside the projected rail base in Article 3.14 B.4.b.2).b) herein.

- C. Track Inspection: Perform track inspection in accordance with the requirements specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
- D. Track-to-Earth Resistance Testing:
 - 1. Conduct track-to-earth resistance acceptance tests of each section of track installed, in accordance with Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION.
 - 2. Test tracks in sections between insulated joints, except that test section lengths shall not exceed 2,000 feet in length.
 - 3. Complete resistance testing before field welding adjoining CWR strings, so that rail joints may be disassembled to isolate rail sections testing and to assist in locating areas of low-resistance conditions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith shall be included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02868
DIRECT FIXATION FASTENERS

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This section specifies:
1. Requirements for furnishing, fabricating, and delivering direct fixation (DF) fasteners.
 2. Furnish all labor, materials, and equipment for the manufacture, fabrication, and delivery of “off-the-shelf” DF fasteners, which are defined as currently available fasteners designed to meet or exceed the requirements of these Specifications, for installation on the Contract.
 3. Provide the material fabrication, testing, shipping, delivery, unloading, and storage of DF fasteners.
- B. Section Includes:
1. Materials
 2. Components
 3. Source Quality Control
 4. Static Tests
 5. Electrical Tests
 6. Dynamic Tests
 7. Anchorage Assembly Test

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
1. Section 02866 – DIRECT FIXATION TRACK CONSTRUCTION

1.3 APPLICABLE STANDARDS

- A. American Institute of Steel Construction (AISC):
1. AISC ASD Manual of Steel Construction
- B. ASTM International (ASTM):
1. ASTM A36/A36M Standard Specification for Carbon Structural Steel
 2. ASTM A148/A148M Standard Specification for Steel Castings, High Strength, for Structural Purposes
 3. ASTM A449 Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
 4. ASTM A536 Standard Specifications for Ductile Iron Castings

5. ASTM A668 Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use
6. ASTM B117 Standard Test Method for Salt Spray (Fog) Testing
7. ASTM D256 Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
8. ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials
9. ASTM D395 Standard Test Methods for Rubber Property – Compression Set
10. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
11. ASTM D429 Standard Test Methods for Rubber Property – Adhesion to Rigid Substrates
12. ASTM D471 Standard Test Method for Rubber Property – Effect of Liquids
13. ASTM D570 Standard Test Method for Water Absorption of Plastics
14. ASTM D573 Standard Test Method for Rubber – Deterioration in an Air Oven
15. ASTM D624 Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers
16. ASTM D638 Standard Test Method for Tensile Properties of Plastics
17. ASTM D648 Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
18. ASTM D695 Standard Test Method for Compressive Properties of Rigid Plastics
19. ASTM D746 Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
20. ASTM D785 Standard Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
21. ASTM D1149 Standard Test Methods for Rubber Deterioration-Cracking in an Ozone Controlled Environment
22. ASTM D1248 Standard Specification for Polyethylene Plastics Molding and Extrusion Materials for Wire and Cable
23. ASTM D1505 Standard Test Method for Density of Plastics by the Density-Gradient Technique
24. ASTM D1525 Standard Test Method for Vicat Softening Temperature of Plastics
25. ASTM D1693 Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
26. ASTM D2240 Standard Test Method for Rubber Property – Durometer Hardness
27. ASTM E23 Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

- 28. ASTM G101 Standard Guide for Estimating the Atmospheric Corrosion Resistance of Low Alloy Steels
- C. National Research Council of the National Institute of Standards and Technology (NIST):
 - 1. NIST Publication Calibration Standards
- D. SSPC: The Society for Protective Coatings (formerly Steel Structures Painting Council):
 - 1. SSPC Vis 1 Guide to Pictorial Surface Preparation Standards for Painting Steel Surfaces

1.4 DESIGN REQUIREMENTS

- A. Furnish “off the shelf” DF fasteners designed to meet or exceed the requirements of these Specifications.
- B. Provide fastener of a design in continuous daily service for at least 5 years with a proven record of successful performance.
 - 1. Provide complete and detailed shop drawings.
 - a. Submit existing shop drawings and other data, including existing design calculations, required by these Specifications or that are necessary to adequately perform the Work.
 - b. Provide shop drawings showing the general arrangement and such details as are necessary to provide a comprehensive description of the Work to be performed.
 - c. Furnish shop drawings in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
 - 2. Furnish product data, design calculations, and other required data on standard 8-1/2-by-11-inch sheets, printed on one side only.
 - a. Provide the title block information required by Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”, Product Data, and Samples, on each sheet.
 - 3. Unless otherwise indicated, submit not less than two identical samples of the DF fastener.
 - a. Label each sample in accordance with Section Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
 - b. Enclose a copy of a transmittal letter for each shipment of samples with a block for an approval stamp in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
 - 4. Submit all drawings, data, and schedules in accordance with the time requirements specified in Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- C. Type of Fastener:
 - 1. Furnish fasteners with one-piece body designed for use on the 115 RE (5 1/2-inch base width) rail section.

2. Furnish standard rail fasteners having a longitudinal restraint between 1,600 and 3,000 pounds.
3. Furnish rail fasteners having a spring rate of between 94,000 pounds per inch and 120,000 pounds per inch for vertical loads between 4,500 pounds and 12,000 pounds.
4. Furnish rail fasteners that bond the elastomeric component of the rail fastener on its bottom surface to a base plate not less than 1/4-inch thick and bond the elastomeric component of the rail fastener's top surface to a plate.
 - a. Furnish plates of the same plan dimensions and configurations as the elastomer.
5. Form the rail hold down assembly of the rail fasteners from spring clip type elements (Pandrol "e" clip non-threaded components).
6. Furnish rail fasteners comprised of as few components as is economically and technically feasible for ease of assembly, disassembly, and maintenance.
7. Furnish rail fasteners designed to permit installation and replacement of the entire assembly or its components by one worker using standard, conventional hand tools.

D. Properties in Installed Position:

1. Design the assembled fastener with a tapered shape to provide 40 to 1 inward rail cant when installed on a level plinth or aerial structure deck.
2. Do not furnish fasteners having projections into leveling pads, aerial structure deck, or plinth concrete.
3. Bonding of the rail fastener to the plinth concrete, aerial structure deck or leveling pads will not be permitted.

E. Dampening of Forces:

1. Furnish rail fasteners designed to provide damping of lateral and vertical forces transferred to anchor bolts.
2. Furnish fastener plates having full bearing on the elastomer in all positions of lateral adjustment and having a means of preventing displacement of the elastomer under operating conditions.
3. Furnish rail fasteners with stability in directions not solely dependent upon the strength of bonding of the elastomer to metal.

F. Anchorage Assemblies:

1. Furnish rail fasteners each providing two complete anchorage assemblies for securing the rail fastener to the concrete track bed.
2. Use embedded female threaded anchor inserts with 7/8-inch anchor bolts to anchor or secure the rail fastener to the concrete track bed.
3. Provide high-strength anchorage connections that provide lateral restraint through clamping of the fastener to the plinth or deck. Systems that rely on spring washers of any kind for resisting uplift or maintaining anchor bolt tension will not be acceptable.

G. Restraint Properties and Rail Release:

1. Indicate the restraint properties of the rail fastener in both longitudinal directions and in both lateral directions.
2. Furnish rail fasteners providing a positive means of preventing more than a total of 1/8-inch total lateral movement of the rail base relative to the fastener on each side of the rail base in the event of failure or loosening of one or both rail hold-down spring clip elements.
3. Furnish rail fasteners permitting the release of the rail hold-down spring clip elements so that the rail may be removed by lifting it vertically until it is completely free of the fastener without disturbing the horizontal or vertical alignment of the fastener body.

H. Rail Hold-Down:

1. Include one-piece elastic spring clip type elements in the rail hold-down assembly.
 - a. No lateral adjustment is permitted in the rail hold-down.
2. Neither the rail hold-down assembly nor the means of preventing lateral movement of the rail shall make point contact against the rail.
 - a. If contact is made in the static or dynamic state, it shall not be less than 0.125 inch in any dimension and not less than 0.15 square inch in area.
3. Furnish rail hold-down not dependent upon elastomer components in torsion.
4. Design the rail hold-down elastic spring clips so longitudinal rail movements does not cause denting, carving, scoring, or other damage to the rail base or the rail hold-down assembly.
5. Furnish rail hold-downs that do not incorporate design configurations that permit denting, carving, scoring, or other damage to the rail caused by either the method of installation or the rail hold-down configuration.
6. Install the spring clip into a fixed shaller.
 - a. The fixed shaller shall be an integral part of the fastener top plate.

I. Dimensional and Shape Requirements:

1. Furnish fasteners that are generally rectangular in shape.
 - a. Include keying, peg and socket, or turned up plate edges in the bottom plate and top plate so that loss of elastomer bond does not result in complete loss of the fastener's ability to hold track line and gauge.
2. Height:
 - a. The overall distance between the top surface of the underlying direct fixation concrete track bed (concrete plinths) and the base of the rail with the rail fastener in the installed position shall be between 1-3/4 inches and 2-1/16 inches, inclusive of a 3/16 inch thick HDPE shim beneath the fastener body.
 - b. No part of the rail fastener assembly shall project more than 3 inches above the rail base in the installed position.

3. Length and Width:
 - a. The overall dimensions of the fastener, including the elastomer, shall not be less than 7 inches or more than 8-1/2 inches in length measured parallel to the rail and shall not be less than 14-1/2 inches or more than 16-3/4 inches in width measured perpendicular to the rail centerline.
4. Anchor Bolts:
 - a. Furnish rail fastener anchor bolts complying with Article 2.2A herein, and located 5-1/4 inches from the centerline of rail in the installed position, and 1-3/4 inches from the centerline of the rail fastener taken perpendicular to the rail centerline as detailed in Figure 02868-1 (See Appendix A for figures).
 - b. Symmetrically locate the anchor bolts with respect to the fastener centerline taken perpendicular to the rail.
5. Anchor Inserts (female):
 - a. Furnish rail fastener female anchor inserts complying with Article 2.2B herein.
 - b. Calculate the minimum bolt insertion length into the insert to provide anchorage strength meeting the requirements of this Section.
 - c. Submit drawings, at a minimum scale of 1:1, that demonstrate that the proposed anchor bolt and insert combination will accommodate the full range of vertical adjustment specified in this Section. Illustrate in these drawings the length of anchor bolt insertion into the insert under both the maximum and minimum shim conditions. Decrease bolt insertion length by an additional 1/16 inch under the maximum shimming condition, to allow for cases where the top of insert is recessed 1/16 inch below the top of concrete.
6. Minimum manufacturing tolerances for rail fasteners:
 - a. Length and width: Plus or minus 1/16 inch
 - b. Thickness: Plus or minus 0.030 inch
 - c. Squareness: Plus or minus 1 degree
 - d. Centering of holes: Plus or minus 1/32 inch
 - e. Diameter of holes: Plus or minus 1/32 inch

J. Adjustment Requirements:

1. Lateral Adjustment:
 - a. Furnish rail fasteners providing a minimum of plus or minus 1/2-inch rail lateral adjustment in 1/8-inch increments.
 - 1) All lateral adjustment shall be provided at the anchor bolts mountings.
 - b. Do not use friction as a means for adjustment or for preventing lateral movement.
 - c. If lateral adjustment employs serrations on components, each serrated interface shall have at least three engaged serrations on the assembly.
 - 1) Provide a minimum of 3 linear inches of serration engagement for each fastener.
 - 2) Machine or cast serrations to a minimum depth of 1/16 inch.

- 3) If cap plates are used, they shall cover the opening to any ground potential in every position of adjustment and form a reasonable seal to prevent the intrusion of dirt, metallic particles, and other material.
 - d. Furnish each rail fastener with all components required for all specified increments of lateral adjustment.
 - 1) Do not replace or add components to the basic configuration of the rail fastener in order to laterally adjust the rail.
 2. Vertical Adjustment:
 - a. Vertical rail adjustment capability shall be a maximum of 9/16 inch in 1/16-inch increments, provided by a maximum of two shims per fastener.
- K. Electrical Isolation:
 1. Furnish fasteners providing an electrical surface leakage distance of not less than 1-1/2 inches measured from the grounded portion of the fastener to the charged portion by the most direct path that does not pass through an insulating material, and not less than 1/4 inch when measured passing through an insulation material.
 2. Meet the insulation requirements within the body of the fastener.
 - a. Separate or detachable insulating components such as rail base pads or spring clip insulators are not allowed.
 3. No surface cut-outs, gaps, edge voids, or edge cut-outs are allowed that could permit an accumulation of dirt, metallic particles, or other material, which could eventually provide electrical leakage to ground.
- L. Markings:
 1. Develop and submit a lot and fastener numbering system for marking each fastener. Permanently and clearly mold on the top of each fastener the lot number, a daily production identification number, and the Fabricator's name or trademark so that they are readily visible when the complete assembly is in the installed position. Indentations in the elastomer or metal components will not be allowed.
 2. Mark the field side of the canted fastener body in letters not less than 1/2 inch high.

1.5 SUBMITTALS

- A. General: Refer to Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements", for submittal requirements and procedures.
- B. Submit the following:
 1. Product Data
 2. Shop Drawings
 3. Samples

4. Quality Program: In accordance with Article 1.6A herein
5. Test Results:
 - a. Six hardcopies and a pdf file of a formal report with qualification test results from tests performed within the last 24 months (alternatively, qualification tests run specifically for this contract) for acceptance in accordance with Article 2.3A herein.
 - b. Six hardcopies and a pdf file of the results of all production tests for acceptance in accordance with Article 2.3B herein.
6. Manuals: Compile consolidated manuals incorporating all relevant manufacturers' data for the DF fasteners and their components, including the anchorage and rail hold down assemblies. Include in this manual instructions for installation, maintenance, adjustment and removal of fasteners.

1.6 QUALITY ASSURANCE

- A. Develop and maintain a Quality Assurance Program as required by General Requirements, Volume 1 DB Contract Terms and Conditions Section 4 "Quality Control and Quality Assurance" and Volume 2 Technical Provisions Subsection 2.5 "Quality Management" regulating methods, procedures, and processes to ensure compliance with standards of quality.
 1. Include in the Quality Assurance Program an Inspection and Testing Plan (ITP), subject to review by the MBTA. Submit the detailed ITP within 30 days of Notice of Award and include therein the following information for each identified inspection and test:
 - a. List of inspections and tests to be performed.
 - b. Identify the Specification paragraph containing the inspection or test requirements.
 - c. Identify who is responsible for each test: Design-Builder or sub-supplier.
 - d. Schedule of inspections and tests.
 - e. Identification of independent test laboratories if any are to be used.
 - f. Identify the characteristics to be inspected, examined, and tested at each activity point.
 - g. Specify inspection and test procedures and acceptance criteria to be used.
 - h. Identify inspection checklists and test reports.
 - i. Identify hold points as described herein below.
 2. Do not commence any inspection or test until the ITP has been reviewed and accepted by the MBTA. During the life of the Contract, update the ITP to reflect any changes in the inspection or test requirements.
 3. Implementation of Quality Assurance Program:
 - a. Provide adequate staff and resources to perform all quality activities and to ensure Contract compliance, whether the Work is performed at the Design-Builder's own facility, provided by a sub-supplier, or on location at the project.
 - b. Supplier Control: Perform source inspections and audits at major supplier's facilities to assess compliance with the requirements of the Quality Assurance Plan and the Contract Documents.

- c. Control of Measuring and Testing Equipment:
 - 1) Describe in the Quality Assurance Plan the methods for ensuring that equipment used for measuring and testing is calibrated as applicable to provide accurate test and inspection results. At intervals established to ensure continued validity, verify or calibrated measuring and testing devices against certified national standards that are traceable to National Institute of Standards and Technology (NIST).
 - 2) Establish methods to ensure proper handling, storage, and care of measuring and test equipment to maintain the required accuracy of such equipment. Material and test equipment that is considered out-of-calibration or that has been subjected to possible damage shall be identified as non-conforming and shall be removed from service, replaced, or repaired according to the manufacturer's instructions. Review all inspections or tests accepted by the use of the nonconforming measuring and test equipment since its last valid calibration date, to ensure acceptability.
 - 3) Ensure that all measuring and testing equipment selected for measurements, tests, or calibration is of the proper range, type, and is controlled, adjusted, and maintained at specified intervals identified in the Quality Assurance Plan or before use to assure conformance to the established requirements or predetermined accuracy.
 - 4) Affix labels or tags to measuring and testing equipment that:
 - a) Attest to the current calibration status
 - b) Indicate the name of the individual responsible for the last calibration
 - c) Show the date (or other basis) that inspection or recalibration is next required

d. Preventive Action and Control of Non-Conforming Conditions:

- 1) Include in the Quality Assurance Plan provisions for implementing preventive and corrective actions and identifying, recording, controlling, and correcting non-conforming items.
- 2) Include provisions for reinspecting and retesting of repaired and reworked items to the original requirements.

B. Technical Support: Provide the services of a manufacturer's technical representative for consultation to resolve issues concerning the DF fastener.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Deliver and place material into storage at the Design-Builder's material storage area.
- B. Load, transport, unload, store, and handle DF fasteners and components to prevent damage or loss from handling and the elements, including adverse weather conditions.
 - 1. Pack and ship fasteners to prevent a load on a fastener from exceeding 1,000 pounds.
 - 2. Package fasteners to permit long-term outdoor storage in a secured area.
 - a. Palletize and band fastener bodies.

- b. Package rail hold-down assemblies, spring clips, fastener anchor bolts and inserts, insulating shim, and other loose items by component type in secure shipping kegs, wood boxes, or steel containers and clearly identify each content.

PART 2 – PRODUCTS

2.1 MATERIALS

A. Metal Plate Components:

1. Make metal plate components from rolled, forged cast steel or ductile iron.
 - a. Provide ASTM A36/A36M rolled steel with the addition of not less than 0.20 % copper, or other steel having the equivalent or greater strength and corrosion resistance.
 - b. Provide ASTM A148/A148M cast steel, Grade 80-40 or equal.
 - c. Provide ASTM A668 forged steel, Grade C or equal.
 - d. Provide ASTM A536 ductile iron, Grade 65-45-12 or equal.
2. Calculate a Corrosion Resistance Index for all rolled steel products and other steel with a chemical content within the composition range listed in ASTM G101 and containing less than 1.0 % manganese.
 - a. The minimum Corrosion Resistance Index is 4.0.
3. Perform the following Charpy Impact Test on metal plate components, which shall perform as specified below.
 - a. Test Method: Prepare three Charpy Impact Test specimens in accordance with ASTM E23 from the same metal used for the top and base elements of the fastener body. If different grades of steel or iron are used for the two elements, prepare three specimens of each. Conduct a Charpy Impact Test on each specimen at a temperature of 21°Celsius in accordance with ASTM E23. The test report shall include the information required by ASTM E23.
 - 1) Acceptance Criteria: The fracture energy shall be greater than three foot-pounds for iron and 15 foot-pounds for steel.
 - b. In lieu of the above, submit previous test data demonstrating that the type of material being proposed clearly meets the above criteria. The MBTA may review the data and determine whether additional testing is required.

B. Elastomer:

1. Fabricate the elastomer using a minimum of 51 % natural rubber.
2. Provide a natural rubber design based on a Durometer Shore A measurement of 70 plus or minus 10, as measured in accordance with ASTM D2240 Test Method for Rubber Property – Durometer Hardness.
3. Do not allow the compressive strain of the elastomer to exceed 25 % of its uncompressed thickness for a load of 14,000 pounds applied vertically to the rail for a single fully assembled fastener.
 - a. Include pre-compression of elastomer in fasteners in the installed position in determining the total compressive strain.

4. The elastomer shall perform as specified when tested in accordance with the following test methods:
- a. Tensile Properties: ASTM D412.
 - 1) Tensile Strength (natural rubber): Minimum 2,500 psi.
 - 2) Ultimate Elongation: Minimum 350 %.
 - b. Resistance to Compression Set: ASTM D395.
 - 1) Test Condition (natural rubber): 22 hours at 70 degrees Celsius.
 - 2) Maximum Set (natural rubber): 25 %.
 - c. Resistance to Aging in Air: ASTM D573.
 - 1) Test Condition: 72 hours at 70 degrees Celsius.
 - 2) Retention of Tensile Strength (natural rubber): Minimum 75 %.
 - 3) Retention of Ultimate Elongation: Minimum 75 %.
 - 4) Change in Hardness: Maximum 10 points Durometer Shore A.
 - d. Resistance to Ozone Cracking: ASTM D1149.
 - 1) Test Condition: Test specimens prepared in accordance with ASTM D1149 at a temperature of 40 degrees Celsius and an ozone concentration of 50 ppm.
 - 2) Acceptance Criteria: The elastomer shall not exhibit cracking when examined in accordance with ASTM D1149 at the end of a 100-hour exposure.
 - e. Adhesion to Metal: ASTM D429, Method B.
 - 1) Test Condition: Test specimen shall duplicate actual rail fastener fabrication in respect to type of steel, preparation of steel, bonding agents, and elastomer.
 - 2) Acceptance Criteria: The failure of the elastomer shall be type R failure, i.e., elastomer tears before bond fails.
 - f. Resistance to Oil: ASTM D471.
 - 1) Test Condition: 70 hours at 23 degrees Celsius in ASTM Number 1 oil.
 - 2) Acceptance Criteria: Volume change shall not exceed minus 10 % or plus 20 %.
 - g. Tear Resistance Test: ASTM D624:
 - 1) Test Method: Test using Die C specimens.
 - 2) Acceptance Criteria: Resistance to tearing to be not less than 150 pounds per inch.
 - h. Water Absorption Test: ASTM D570:
 - 1) Test Method: Immerse specimens in distilled water for 24 hours at 23°Celsius.
 - 2) Acceptance Criteria: Elastomer to have a maximum increase in weight of 1 %.
 - i. Electrical Resistivity Test: ASTM D257:
 - 1) Test Condition: Twenty-four hours in a clean, dry environment with ambient conditions of 16 to 27 degrees Celsius and 50 to 70 % relative humidity. Apply 100 volts (minimum) DC for 3 minutes.
 - 2) Acceptance Criteria: Minimum volume resistivity of 10¹² ohm-cm.

C. Assembly:

1. Anchor bolts shall not pre-compress the elastomer in their installed position.

2.2 COMPONENTS

A. Anchor Bolts and Other Threaded Elements:

1. Furnish all threaded elements of high-strength steel conforming to the chemical and mechanical requirements of ASTM A449, SAE Grade 5, and having Class 2A and 2B thread fit.
 - a. Thread length may vary from that specified for structural bolts.
2. Furnish 7/8-inch diameter anchor bolts of sufficient length to provide an acceptable length of insert thread engagement with 9/16 inch of vertical shims under the rail fastener.
3. All threaded elements in the fastener shall include a positive means of preventing the loosening of the element due to in-service vibrations.
4. Threaded element installation data shall include, but not be limited to, the bolt torque range in foot-pounds.
 - a. The torque range shall provide the minimum tension as specified by the AISC ASD Manual of Steel Construction.
5. Coat all bolts with a water-resistant coating as thread protection against rusting prior to installation.

B. Anchor Inserts:

1. Furnish LB Foster epoxy-coated 7/8 inch concrete anchor inserts or approved equal.
2. Furnish inserts with an installed plug of metal or plastic material to preclude the entrapment of moisture, concrete, or other foreign materials.
 - a. Use plugs designed to be removed by using a socket wrench or other common device.
 - b. Furnish plugs capable of reinsertion, and if reinserted, still capable of excluding concrete and other materials from entry.

C. Insulating Pads and Vertical Adjustment Shims:

1. Provide 3/16-inch thick high-density polyethylene (HDPE) pads, matt finish, to provide an additional insulating surface between the base of the fastener and the concrete surface.
 - a. The shape, size, and configuration of the pads shall conform in general to the overall configuration of the DF fastener and consider lateral adjustment.
 - b. Insulating pads shall have circular holes for anchor bolts, no larger than 1 inch in diameter.
 - c. Size the pads so that they project out from under the fastener by 3/8-inch, minimum, on all sides, under all positions of fastener lateral adjustment.

2. Design the pads so that installation requires the removal of the fastener body.
 - a. Incorporate a positive means of preventing the pads from displacement under operating conditions in the design.
3. Furnish pads of high-density polyethylene (HDPE) meeting the requirements of ASTM D1248, Types III or IV, Grades W8 or W9; and conforming to the physical properties listed in Table 02868-1.

Table 02868-1

High Density Polyethylene Tests

Property	Units	Test Methods (ASTM)	Acceptance Criteria
Color			Blue
Density	Grams/cm ³	D1505	0.941 to 0.965
Environmental Stress Cracking		D1693	<1 to >1000
Vicat Softening Temperature	Degrees Fahrenheit	D1525	235 to 260
Brittleness Temperature	Degrees Fahrenheit	D746	<-180 to -100
Impact Strength	Ft.-Lbs Inch Notch	D256	0.8 to 14
Tensile Strength			
20 Inches/Minute	psi	D638	2,600 and 4,800
2 Inches/Minute	psi	D638	3,500 and 4,700
Elongation			
20 Inches/Minute	%	D638	12 to 700
2 Inches/Minute	%	D638	128 to 860
Heat Distortion Temperature at 66 psi	Degrees Fahrenheit	D648	160 to 170
Coefficient of Linear Expansion	Inches/Inch/Degree Celsius	D695	1.3 X 10 ⁻⁴
Hardness	Shore D Scale	D2240	55 to 70
Modulus of Elasticity	psi	D638	60m to 150m
Compressive Stress at 1 % Offset	psi	D695	3,200 to 3,600
Dielectric Constant			
100 kc		D1531	2.32
1 mc			2.32
Dissipation Factor			
100 kc		D1531	<0.0001
1 mc			<0.0001
Dielectric Strength, 1/8-Inch Thick	Volts/mil	D149	500
Volume Resistivity	Ohm-cm	D257	>6 X 10 ¹⁵

D. Rail Fastening System:

1. The rail fastening system shall include the rail fastening spring clips and the shallers by which they are attached to the DF fastener.
 - a. Furnish shallers that are an integral part of the top plate.

2. Furnish rail fastenings that are resilient, threadless, and detachable.
 - a. Use component part shapes that are easily recognizable and are difficult to install incorrectly.
 - b. Furnish fastenings comprised of as few components as economically and technically feasible for ease of assembly, disassembly, and maintenance.
 - c. Construct fastenings so that the rail clips can be installed from the right side or replaced in the field by one man using hand tools.
 - d. Construct fastenings so that when the rail clips are removed, the rail may be lifted vertically until it is completely free of the fastening shaller without disturbing the horizontal or vertical alignment of the shaller or the adjacent restraining rail and fastener.
 - e. On both sides of the rail base, provide fastenings with a positive means of preventing more than 1/8-inch total lateral movement of the rail base relative to the shallers in case of failure or loosening of one or both rail clips.
 - 1) Provide positive means of restraint extending at least 3/8 inch, but not higher than 1-3/4 inches above the base of rail in the installed position.
3. Rail Fastening Spring Clips:
 - a. Furnish rail clips not dependent on elastomeric components in torsion.
 - b. Use one identical clip design on the field and gauge sides of the rail at the railseat.
 - c. Furnish identical clips for concrete crossties, concrete road crossing ties, concrete turnout ties, special trackwork switch and frog plates, and DF fasteners.
 - d. Furnish clips designed to be reusable after repeated removals without effects on the operating performance of the system.
 - e. No part of the clip shall protrude below the plinth surface.
 - f. The clip shall not make point contact.
 - 1) Furnish clips designed so that lateral rail movements within the confines of the shallers will not produce transverse denting, carving, or scoring of the rail base.
 - 2) Furnish clips designed so that longitudinal rail slippage will not produce overstressing, ending, twisting, or other damage to the clips, and will not damage the rail.
 - g. Rail clips used on rail insulated joint bars need not to be identical in design to those used on a standard rail.
 - 1) Furnish special modified clips that clear the joint bar, have similar performance characteristics, are made by the same manufacturer, and are installed into identical shallers as the standard rail clip.

2.3 SOURCE QUALITY CONTROL

A. Qualification Testing:

1. Testing may be performed at any testing facility, including such facilities at the Design-Builder's plant.
 - a. Use only testing equipment in good repair, of adequate capacity, and that is verified or calibrated against certified standards that have a known traceable relationship to the National Research Council of the National Institute of Standards and Technology (NIST).
 - b. Provide notification not less than 14 days in advance of dates scheduled for tests.
2. Perform the following rail fastener testing at no additional cost to the MBTA using the test procedures as prescribed in Articles 2.4, 2.5, and 2.6 herein.
 - a. Static Tests: Perform all tests on a two-fastener assembly.
 - 1) Loads, as described in the tests, are per fastener and shall be doubled during performance of each test.
 - 2) Vertical Load Test: Perform testing in accordance with Article 2.4A herein.
 - 3) Lateral Load Test: Perform testing in accordance with Article 2.4B herein.
 - 4) Longitudinal Restraint Test: Perform testing in accordance with Article 2.4C herein.
 - 5) Lateral Restraint Test: Perform testing in accordance with Article 2.4D herein.
 - 6) Vertical Uplift Test: Perform testing in accordance with Article 2.4E herein.
 - b. Electric Tests: Perform all tests on single fasteners.
 - 1) Voltage Withstand Test: Perform testing in accordance with Article 2.5A herein.
 - 2) Electrical Resistance and Impedance Tests: Perform testing in accordance with Article 2.5B herein.
 - c. Dynamic Tests: Use a separate fastener for each test.
 - 1) Dynamic to Static Stiffness Ration Test: Perform testing in accordance with Article 2.6A herein.
 - 2) Loads, as described in the tests, are per fastener and shall be doubled during performance of each test.
 - 3) Vertical and Lateral Repeated Load Test: Perform testing in accordance with Article 2.6B herein.
 - d. Post Fatigue Tests: Repeat the tests listed above in Articles 2.3A.3.a through 2.3A.3.c, on the fastener that was subjected to the Vertical and Lateral Repeated Load Test.

3. Submit six copies of the results of all qualification tests. Commencement of fastener production before the qualification tests have been approved shall be at the Design-Builder's sole risk.
4. In addition to the rail fastener tests, subject all components of the fasteners to full or partial testing for compliance with these Specifications.
 - a. Perform all such additional testing of components that do not comply with these Specifications or portion thereof at no additional cost to the MBTA.

B. Production Testing:

1. Select two DF fasteners from each 5,000 production fasteners or portion thereof produced thereafter for production testing.
 - a. Shall the fasteners fail to meet the test requirements, test two additional fasteners from the same production lot.
 - b. In the event either of the two additional fasteners fail, either reject or test 100 % of the lot, and only those fasteners successfully passing all tests will be accepted.
2. Not less than 7 days prior to each shipment of fasteners from the Design-Builder's facility, submit certified statements that each lot of fasteners being shipped has passed the production testing specified herein.
 - a. In the event that any batch fails any one of the production tests, provide full test results for that batch to the MBTA and a statement as to whether the batch will be reworked or scrapped.
 - b. Retain all production test results in an organized fashion for a period of 10 years after delivery of the final fastener to the MBTA. During that period, provide the MBTA representatives access to all production test records upon 5 days' notice.
3. Perform the following production testing and certification requirements as prescribed in Articles 2.4, 2.5, and 2.6 herein.
 - a. Static Tests: Perform tests on a two-fastener assembly in compliance with Article 2.3A.3.a herein.
 - 1) Vertical Load Test
 - 2) Lateral Load Test
 - 3) Longitudinal Restraint Test
 - 4) Lateral Restraint Test
 - 5) Vertical Uplift Test
 - b. Electrical Tests: Perform each test on a single fastener assembly.
 - 1) Voltage Withstand Test
 - 2) Electrical Resistance Tests
 - c. Dynamic Tests: Perform each test on a two- fastener test assembly. The loads as specified in the reference articles are test loads for a two-fastener assembly.
 - 1) Dynamic to Static Stiffness Ratio Test

- 2) Vertical and Lateral Repeated Load Test: As specified in Article 2.6.B herein except that test shall extend for only 500,000 cycles.
- d. Elastomer Tests: Provide certification that each elastomer batch used complies with the requirements specified in Article 2.1B herein.

2.4 STATIC TESTS

A. Vertical Load Test:

1. Procedure:

- a. Apply a vertical load downward at the center of the rail head at the centerline of the fastener normal to the rail.
- b. Increase the load in increments of 1,000 pounds to a maximum load of 14,000 pounds at a rate not less than 500 pounds per minute and not more than 2,000 pounds per minute.
- c. For each increment of load, measure the vertical deflection of the rail head to the nearest 0.001 inch.
- d. Remove the load and measure and record the final position of the rail head.
 - 1) Plot the recorded values for vertical loads versus deflection on a graph, as shown in Figure 02868-2. (See Appendix A for figures)
- e. Pre-cycle the fasteners by loading from 0 to 14,000 pounds two times prior to measuring deflections.

2. Acceptance Criteria:

- a. The load versus deflection curve shall lie within the envelope shown in Figure 02868-2 (See Appendix A for figures) for loads in the range from 4,500 pounds to 12,000 pounds.
 - 1) The spring rate of the fastener (slope of the load-deflection curve) shall not be less than 94,000 pounds per inch or more than 200,000 pounds per inch for all loads between 4,500 pounds and 12,000 pounds.
 - 2) Calculate the spring rate by applying the least-squares linear regression method to the recorded data to obtain a straight-line load-deflection relationship.
 - 3) Each recorded deflection shall be within 10 % of the deflection calculated from the straight-line relationship over the loading range, from 4,500 pounds to 12,000 pounds.
 - 4) After removal of the maximum load, the fastener shall return to within 0.005 inch of its original position within one minute.
- b. At no time during the test shall fastener components exhibit signs of failure by slippage, yielding, or fracture.
 - 1) Slippage is defined herein to mean any movement of the fastener components relative to their initial position not attributed to deflection or yielding.
 - 2) Use the deflection measured at 14,000 pounds divided by the design thickness of the elastomer component to establish the fastener's compliance with the requirement for a maximum vertical deflection not to exceed 25 % of the

elastomer thickness. The values obtained when this test is repeated on the same fastener shall be within 20 % of the initial test values.

B. Lateral Load Test:

1. Procedure:

- a. While applying a vertical load of 12,000 pounds downward, offset 3/4 inch from the center of the rail head towards the gauge at the centerline of the fastener normal to the rail, apply a lateral load horizontally to the rail head at a point 0.625 inch below the top of the rail along the centerline of the fastener in a direction normal to the rail.
- b. Increase the lateral load in increments of 1,000 pounds to a maximum load of 8,000 pounds at a rate of not less than 500 pounds per minute and not more than 1,500 pounds per minute.
- c. For each load increment, measure the lateral deflection of the rail head at a point 0.625 inch below the top of the rail to the nearest 0.001 inch and record.
- d. Remove the lateral load and measure and record the final position of the rail head.
- e. Plot the recorded values for lateral loads versus deflection on a graph as shown in Figure 02868-4. (See Appendix A for figures)

2. Acceptance Criteria:

- a. The lateral deflection of the rail head for a lateral load of 4,000 pounds shall not exceed 0.10 inch.
- b. The lateral deflection due to the maximum load shall not exceed 0.37 inch.
- c. The difference between the original and final positions of the rail head shall not exceed 0.03 inch.
- d. At no time during the test shall fastener components exhibit signs of failure by slippage, yielding, or fracture.

C. Longitudinal Restraint Test:

1. Procedure:

- a. During this test, support the rail end on a roller or other low friction support properly elevated to prevent the longitudinal load from binding the rail in the fastener.
- b. Apply a load longitudinally to the rail at its base.
 - 1) Increase the load in increments of 500 pounds at a rate not less than 500 pounds per minute and not more than 1,500 pounds per minute to a maximum load of 8,000 pounds or until the rail moves 2 inches from the initial position.
 - 2) Maintain each load increment until the longitudinal movement of the rail ceases before increasing the load to the next increment.
 - 3) For each load, measure the longitudinal movement of the rail in relation to the top plate of the rail fastener to the nearest 0.01 inch and record.
 - 4) Remove the longitudinal load at slippage and measure and record the final position of the rail in relation to the top plate of the rail fastener.

- 5) Plot the recorded values for longitudinal load versus movement on a graph as shown in Figure 02868-3 (See Appendix A for figures) and identify it as “Initial Test.”
 - c. Without altering test set-up, apply the load then to the opposite end of the test rail and rerun the test in its entirety.
 - 1) Plot the recorded values for longitudinal load versus movement on a graph as shown in Figure 02868-3 and identify it as “Reverse Test.”
 2. Acceptance Criteria:
 - a. The longitudinal load versus deflection curve, when plotted on Figure 02868-3 (See Appendix A for figures), shall lie entirely within the limits defined by limit lines A and B.
 - b. The difference between the original (before initial test) and final (after reverse test) position of the rail shall not exceed the total rail slippage plus 0.24 inch.
 - c. At no time during the test shall fastener components exhibit signs of failure by slippage, yielding, or fracture, except that slippage that may occur between the rail hold-down assembly and the rail.
 - d. The rail hold-down shall maintain a uniform longitudinal restraint that when plotted shall be a constant, uniform, and unbroken curve which falls within the envelope shown in Figure 02868-3. (See Appendix A for figures)
- D. Lateral Restraint Test:
1. Procedure:
 - a. Apply two lateral loads at the base of the rail in the same direction normal to the centerline of the rail and symmetrically on each side of the fastener centerline.
 - b. Increase both loads simultaneously in increments of 500 pounds from zero pounds to 2,500 pounds.
 - c. Measure and record the lateral deflection of the rail at the intersection of the centerline of the fastener and the gage line of the rail to the nearest 0.001 inch after each increment of loading.
 2. Acceptance Criteria:
 - a. At no time during the test shall components show signs of slippage, yielding, or fracture.
 - b. The difference between the original and final positions of the gage line shall not exceed 0.062 inch.
 - c. The lateral deflection of the rail, when fully loaded, shall not exceed 0.125 inch from the original gage line of the rail.
- E. Vertical Uplift Test:
1. Procedure:
 - a. Apply and secure a vertical load to the center of the rail head at the centerline of the fastener in a direction normal to the rail, alternating continually from a vertical downward load to a vertical upward load.

- b. Increase the upper and lower peaks per cycle in increments of 200 pounds to a maximum of 3,600 pounds downward and upward.
 - c. Continually measure the loads and deflections to the nearest 0.001 inch and immediately record on a load-versus-time graph and deflection-versus-time graph, respectively.
 - d. Remove the load and measure and record the final position of the rail head.
 - e. Apply the reaction force to the uplift load by only securing the test block on which the fastener is mounted.
2. Acceptance Criteria:
- a. The vertical deflection of the fastener for lifting load of 2,000 pounds shall be within 105 % to 205 % of the deflection for a 2,000-pound downward vertical load as determined using the format the vertical load test.
 - b. When the vertical load is continuously varied from vertical downward loads to vertical uplift loads, the load-deflection curve shall be continuous; and there shall be no other indication of backlash or free play at times when the load or the deflection changes direction.
 - c. After removal of the maximum load, the rail shall immediately return to within 0.005 inch of its original position within one minute.
 - d. At no time during the test shall fastener components, including the fastener anchorage to the test block, exhibit signs of failure by slippage, yielding, or fracture.

F. Corrosion Test:

- 1. Test Method: The DF rail fastener system, including the fastener body, the rail hold down assemblies, and the anchorage assemblies, with the exception of the female inserts, shall be exposed to a 5 % chloride solution in accordance with ASTM B117 for 1,000 hours. Spring steel elements shall be placed in the test chamber under load to be at their maximum service duty deflection during the test. Solution shall be a 50-50 combination of sodium chloride and calcium chloride.
- 2. Acceptance Criteria: Acceptance shall be based upon visual comparison between actual metal surface condition after completion of the test and the pictorial surface preparation standards presented in SSPC-Vis 1. The condition of the coated, including galvanized, metal surfaces shall match or be superior to Rust Grade B, wherein there is no more than light surface rust, mill scale has only begun to flake and there is no pitting. There shall be no evidence of adhesion loss of adhesive coating. Areas of ductile iron components which only have an adhesive coating are not required to meet the above condition, but when cleaned shall not exhibit section loss of more than 5 % and shall not exhibit pitting depths greater than 1/32 inch.

2.5 ELECTRICAL TESTS

A. Voltage Withstand Test:

- 1. Procedure:
 - a. Place a ground plate below the elastomer of a complete, fully assembled fastener configured as specified.
 - b. Apply a DC potential of 10 kV to the rail head for 1 minute.
 - c. In the event of breakdown, record the breakdown voltage.

2. Acceptance Criteria:
 - a. The elastomer shall not show visible damage such as splits, cracks, pinholes, or fractures at the completion of the test.
 - b. Perform all other electrical tests on the fastener.

B. Electrical Resistance Test:

1. Procedure:
 - a. Test a complete, fully assembled fastener for electrical resistance, using both the wet and dry conditions procedures as specified herein.
 - b. Before assembly, metal parts, anchoring devices, rail clips, elastomer surfaces, and all other ancillary parts associated with the fastener shall be clean and dry.
 - c. Assemble the fastener with a section of 115-pound RE rail, not less than 1 foot in length.
 - d. Mount the test fastener on a 1/4-inch thick metallic ground plate sized to extend 1.2 inches beyond all edges of the fastener.
 - e. Use anchorage assemblies supplied, or similar to those for use in actual field installation, to mount the fastener to the ground plate.
 - f. Use the same number of bolts (or other device) that will be used to anchor the fastener in-service.
 - g. Verify that improper assembly and other causes do not make the parts that are in electrical contact exhibit excessive contact resistance; including, but not necessarily limited to, the following contact points:
 - 1) Rail-to-rail plate interface.
 - 2) Rail hold-down assembly (clip) and rail.
 - 3) Anchor bolts and bottom fastener plate (if present).
 - 4) Anchor bolts and ground plate.
 - h. Dry Conditions Test:
 - 1) Procedure:
 - a) Twenty-four hours prior to testing, store the assembled fastener(s) in a clean, dry environment with ambient conditions of 60 degrees Fahrenheit to 80 degrees Fahrenheit and 50 to 70 % relative humidity.
 - b) Apply 100 volts (minimum) DC between the rail head and the ground plate for 3 minutes.
 - c) Measure the applied voltage and resulting current flow, or directly measure the resistance with an accuracy flow, or directly measure the resistance with an accuracy of plus or minus 2 %.
 - i. Use instrumentation for direct measurement that has a minimum 100-volt output capacity.
 - 2) Acceptance Criteria: The minimum resistance for 100 volts DC is 10 megohms.
 - i. Wet Conditions Test:
 - 1) Procedure:

- a) Perform this test on the same fastener(s) that passed the dry electrical resistance tests specified in Article 2.5B.1.h herein.
- b) Place the assembled fastener in a nonmetallic trough or other suitable container.
 - a. Size the container such that there is a minimum of 2 inches between the sides and bottom of the fastener/ground plate assembly and the sides and bottom of the container.
 - b. In the event more than one fastener is placed in the same container, maintain a 2-inch clearance between the edges of the ground plates on adjacent fasteners and the clearances cited above.
- c) Pour water into the container to a level midway up the rail web covering all surfaces of the fastener.
- d) Maintain this level of immersion for 72 hours.
- e) Ambient temperature of fastener surfaces (prior to immersion), water, and air shall be 60 to 80 degrees Fahrenheit.
- f) Relative humidity shall be 50 to 70 %.
- g) Water resistivity shall be 1,000 to 1,500 ohm-cm (use potable water and adjust resistivity by addition of sodium chloride).
- h) Drain water from trough to a level at least 1/2 inch below the ground plate. Without drying or otherwise disturbing the fastener or creating a condition that causes the fastener surface to dry, apply a 100 volt (DC) potential as described above and record the current flow at the following times:
 - i. Initial measurement at 15 seconds
 - ii. Repeat the resistance measurement every 5 minutes for the first hour and every 10 minutes for the second hour. Record data to establish the wet resistance versus time characteristics of the fastener. Submit all resistance measurements as part of the test report.
- i) Continue tests for at least 2 hours after draining.
- 2) Acceptance Criteria: The minimum resistance for 100 volts DC shall be as follows:
 - j. The average of three consecutive resistance readings taken within 2 hours after draining shall be a minimum of 700,000 ohms.
 - k. The variance among the three readings shall not exceed 10 % of the average of the three readings.

C. Electrical Impedance Test:

- 1. Test method: Test a complete, dry, fully assembled fastener, as specified, for electrical impedance. Apply a potential of 50 V (ac) RMS to the rail head for 3 minutes for each increment of measurement for frequencies from 20 Hz to 10 kHz, in increments of 20 Hz up to 100 Hz, 200 Hz up to 1 kHz, and 2 kHz up to 10 kHz. Measure the impedance after 3 minutes with an accuracy of plus or minus 2 % and record for each frequency. Electrical resistance may be calculated by measuring current flow, and impedance may be calculated from the measurements of resistance and capacitance using the impedance equation that applies to a resistance and capacitance in parallel.

2. Acceptance Criteria: Minimum impedance for any frequency between 20 Hz and 10 kHz with 50 V (ac) RMS: 10 kilohms.

2.6 DYNAMIC TESTS

A. Dynamic to Static Stiffness Ratio Test:

1. Procedure:

- a. Apply a dynamic vertical (compression) load to the rail head over the centerline of the fastener assembly.
- b. Apply a load varying sinusoidally over the range of 5,000 pounds to 10,000 pounds and at a rate of 10 cycles per second.
- c. After a minimum of 1,000 cycles, measure and record the dynamic deflection of the fastener at 5,000 pounds and 10,000 pounds.
- d. Immediately after completing the dynamic deflection measurements, but only after the fastener deflection has stabilized, measure the static deflection at compression loads from 5,000 pounds to 10,000 pounds in 1,000-pound increments at a rate not exceeding 1,000 pounds per minute.
- e. Measure the deflections to an accuracy of within 0.001 inch.

2. Acceptance Criteria:

- a. Calculate the dynamic stiffness by dividing the difference between the recorded maximum and minimum load value (the dynamic load) by the difference between the recorded maximum and minimum deflection (the dynamic deflection).
- b. Calculate the static stiffness by applying the least-squares linear regression method to the recorded data to obtain a straight line and determining the slope of the static load-deflection curve.
- c. The ratio shall not exceed 1.5.

B. Vertical and Lateral Repeated Load Test:

1. Procedure:

- a. Apply loads to the rail head producing a vertical downward load of 12,000 pounds, and lateral loads along the centerline of the fastener normal to the rail of 3,900 pounds to the gauge side of the rail head and 2,700 pounds to the field side of the rail head.
- b. Apply the vertical load to the rail head and apply the lateral loads 0.625 inch below top of rail along the centerline of each fastener normal to the rail.
- c. Alternate the application of the lateral loads, each combined with alternate application and release of the vertical load.
 - I. Application of the field side load and vertical load and then the gauge side load and vertical load constitutes one cycle.
- d. Regulate the frequency to prevent the temperature of the components from exceeding 160 degrees Fahrenheit.
- e. Re-torquing threaded elements is not permitted without written approval.

2. Acceptance Criteria:

- a. The fastener shall withstand 3,000,000 cycles of load application with no evidence of failure for the qualification test and 500,000 cycles of load application with no evidence of failure for the production test.
- b. Disassemble the fastener assembly and upon visual inspection, no component of the fastener shall exhibit evidence of failure by slippage, yielding, abrasion, or fracture during the test.
- c. The rail shall exhibit no evidence of wear or grooving that would contribute to a failure of the rail.
- d. The concrete test block at the anchorage shall exhibit no evidence of failure as a result of the dynamic test.

C. Uplift Repeated Load Test:

1. Test Method:

- a. Apply alternately a vertical downward load of 12,000 pounds and a vertical upward load of 2,400 pounds a load to a fully assembled fastener. Apply the loads at the rail head. Apply the loads alternately for a total of 1,500,000 complete cycles. Regulate the frequency to prevent component temperature reaching 120 degrees Fahrenheit. Do not reposition rail clips or retorque the threaded elements.
 - b. During the final 500,000 cycles, a longitudinal load shall be applied to the rail at its centroid. Increase the load in increments of 100 pounds up to 600 pounds at intervals of at least one increment per 100 cycles of vertical loading. For each load increment, measure and record the longitudinal deflection of the rail to the nearest 0.001 inch. Then remove the longitudinal load and measure and record the longitudinal position of the rail. Plot the recorded values for the longitudinal load versus deflection on a graph.
2. Acceptance Criteria: The fastener shall withstand 1,500,000 cycles of load application with no evidence of failure. Upon visual inspection, no component of the fastener shall exhibit evidence of failure by yielding, abrasion, slippage or fracture. The rail shall indicate no evidence of wear or grooving that could contribute to its failure. The plot of the load versus deflection curve shall indicate the elastic deformation and the residual deflection. The residual deflection shall not exceed 0.005.

2.7 ANCHORAGE ASSEMBLY TESTS

A. Test Preparation:

3. Provide six anchor assemblies identical in design to those specified for supply with the fasteners to perform the following tests. Use two separate anchorage assemblies for each of the three tests. For the acceptance of anchorage design, each anchor assembly shall satisfy the test requirements. Test results shall not be averaged.
4. Embed anchor inserts in a reinforced concrete test block at least 4 feet long and 7-1/2 inches high. The sides shall be vertical and the top and bottom shall be horizontal. Position inserts for three fasteners 16 inches apart measured parallel to the rail. Inserts shall be vertical, with the top face flush with the concrete surface. Set the insert in the concrete before placing the concrete. Post-drilling and placing of inserts with resins or grouts is permitted only if this is the intended method of installing track.
5. Concrete test block: Cast test block using concrete meeting the requirements for concrete specified in Section 02866 – DIRECT FIXATION TRACK CONSTRUCTION. Cast an adequate number of test cylinders to develop a detailed profile of concrete strength gain over time. When one

cylinder test indicates that the concrete strength is within plus or minus 200 psi of the minimum strength required by Section 02866 – DIRECT FIXATION TRACK CONSTRUCTION, test a second cylinder for confirmation. If the second test also falls within the plus or minus 200 psi range, conduct all anchorage assembly tests that day.

6. Thread the anchor bolts into the inserts to the minimum permissible thread engagement, as required in Section 1.4.I.5 herein, plus or minus 1/16 inch, before load application. Place a stack of flat washers under the bolt head so that full torque can be applied for the torsion test with the bolt partially inserted.
7. The test apparatus working drawings shall be submitted to the MBTA.

B. Restrained Pullout Test:

8. Test Method: Place a 3-1/2 inch by 3-1/2 inch by 1/2inch thick steel plate with a 1-1/8 inch diameter hole in its center, over an anchor bolt. Apply an upward vertical load of 40,000 pounds to the anchor bolt with the reaction force bearing against the steel plate. Hold the load for three minutes. Repeat the test on one other anchor bolt.
9. Acceptance Criteria: No evidence of vertical bolt movement or deformation of threads in either the bolt or the insert, in either of the two anchor bolts tested. No slippage, cracking of concrete, or failure of bond between the inserts and concrete.

C. Unrestrained Pullout Test:

10. Test Method: Apply a vertical pullout load on an anchor bolt through a cylindrical loading frame so that no restraining load is applied to the concrete within a radius of 6 inches from the center of the bolt. Apply a load of 20,000 pounds and hold it for at least 3 minutes. Repeat the test on one other anchor bolt.
11. Acceptance Criteria: No evidence of concrete cracking or failure of bond between either of the two bolts or inserts and concrete.

D. Torsion Test:

12. Test Method: Subject an anchor bolt to a torque of 600 foot-pounds. Hold the load for three minutes and release. Repeat test on one other anchor bolt.
13. Acceptance Criteria: No evidence of failure of the bond between inserts and concrete on either of the two anchor bolts.

PART 3 – EXECUTION

NOT USED

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith shall be included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

APPENDIX A – FIGURES

Figure 02868-1

FASTENER DETAILS

BILL OF MATERIALS PER ASSEMBLY		
ITEM	DESCRIPTION	QUANTITY/FASTENER
1	FASTENER BODY	1 EACH
2	7/8" DIA. ANCHOR BOLT AND LOCKING DEVICES	2 EACH
3	RAIL HOLD-DOWN ASSEMBLY, COMPLETE	2 EACH
4	THREADED ANCHOR INSERT	2 EACH
5	HDP INSULATING PADS (3/16" THICKNESS)	1 EACH

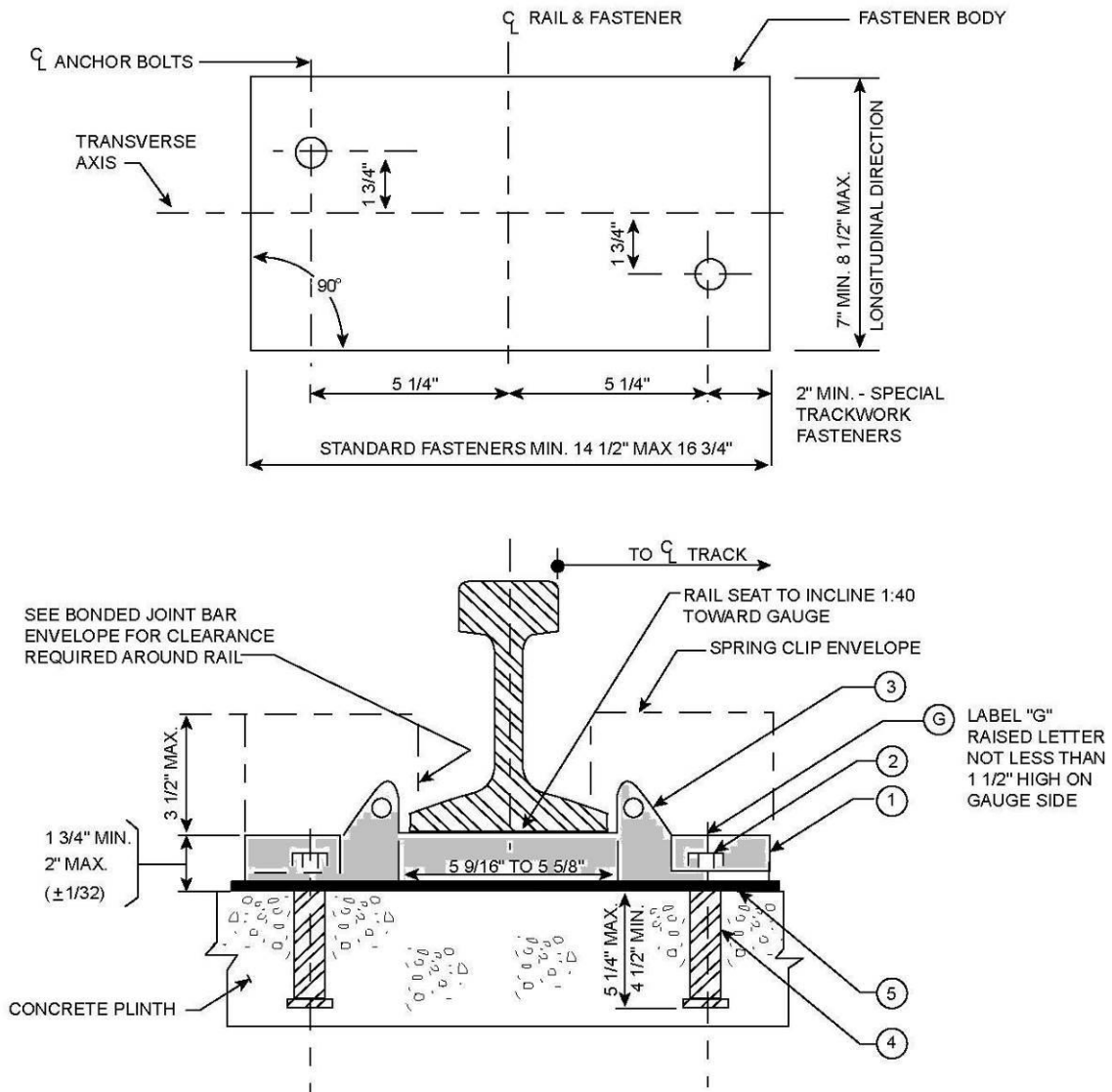
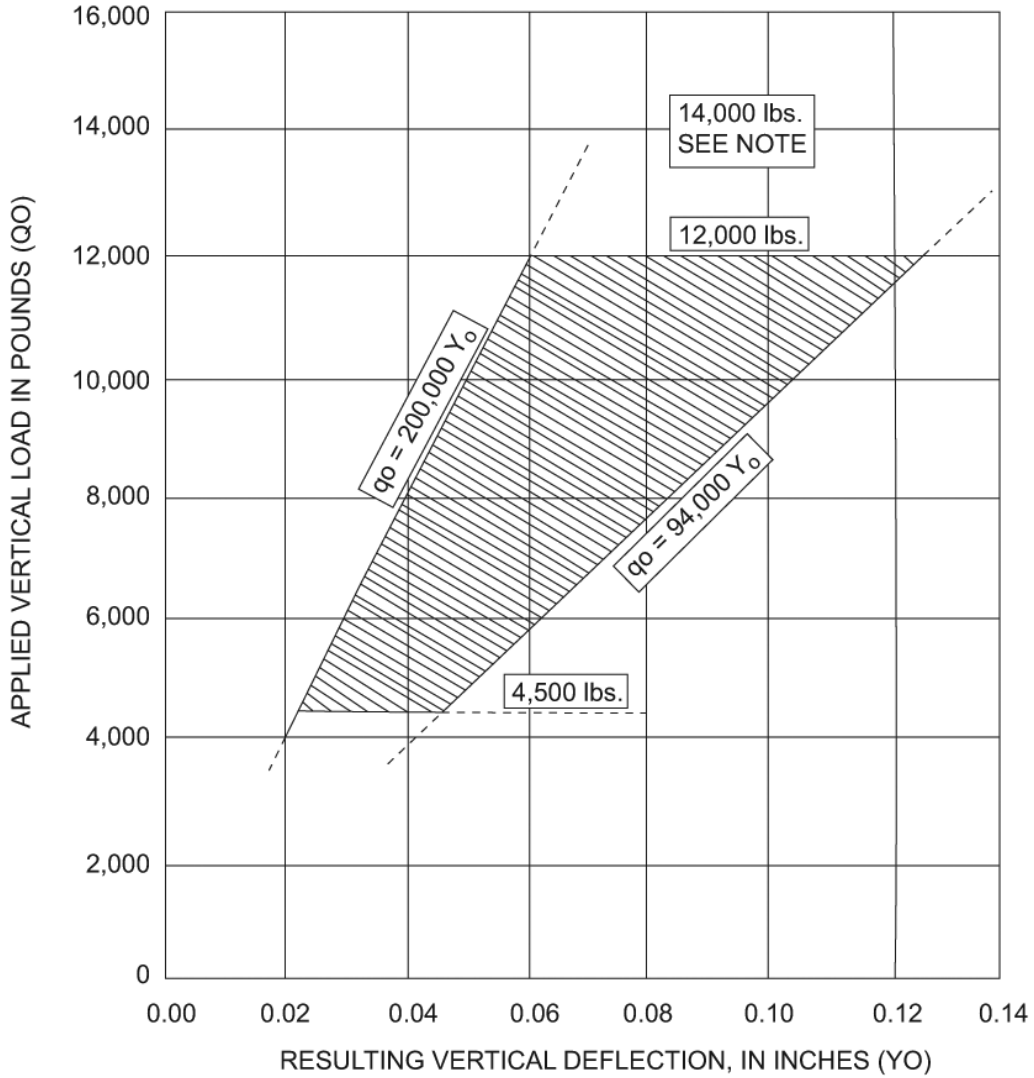


Figure 02868-2

VERTICAL DEFLECTION LIMITS



NOTES:

1. MAXIMUM DEFLECTION AT 14,000 LBS. SHALL NOT EXCEED 25% OF THE UNCOMPRESSED THICKNESS OF ELASTOMER PAD.
2. FASTENER SPRING RATE MUST BE BETWEEN 94,000 LBS./IN. AND 200,000 LBS./IN. FOR ALL LOADS BETWEEN 4,500 LBS. AND 12,000 LBS.

Figure 02868-3

LONGITUDINAL RESTRAINT LIMITS

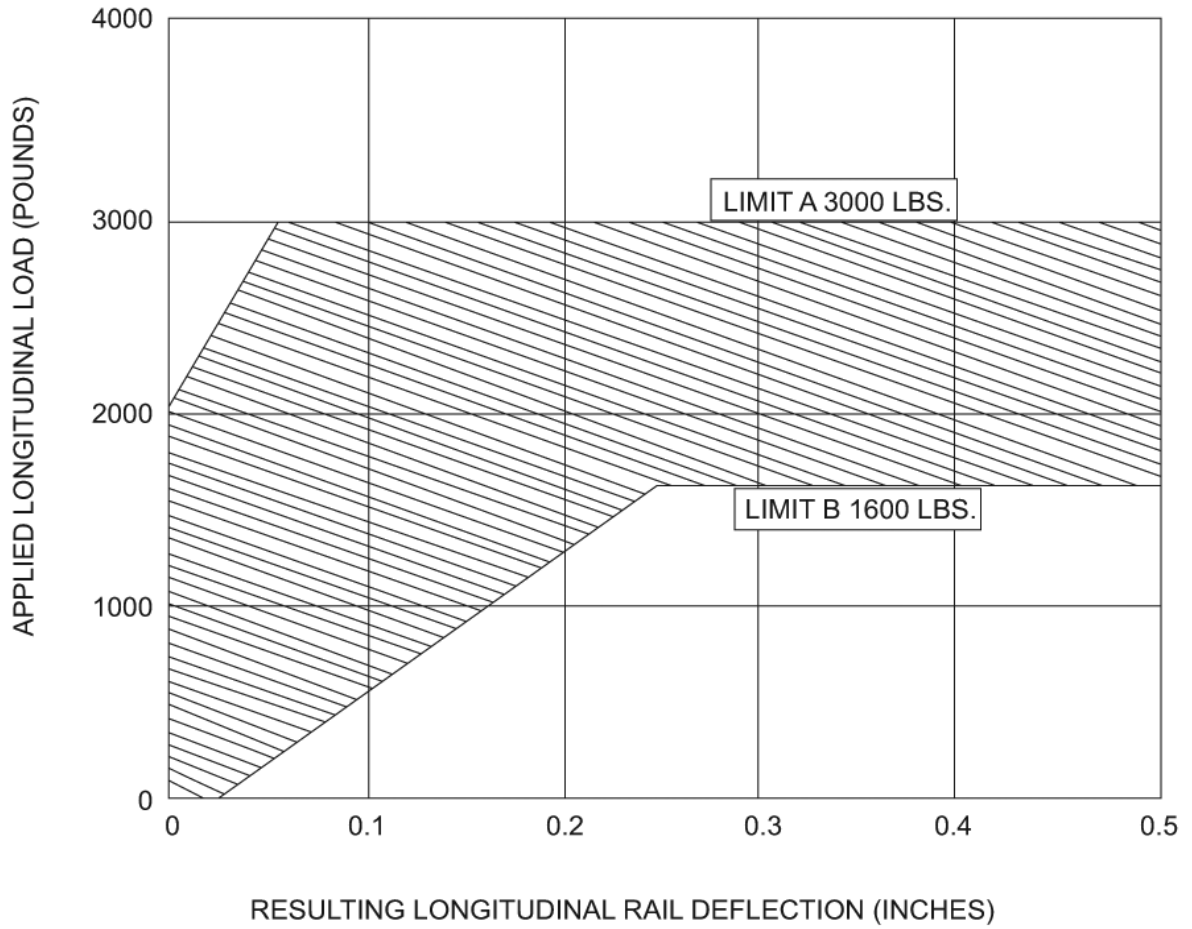
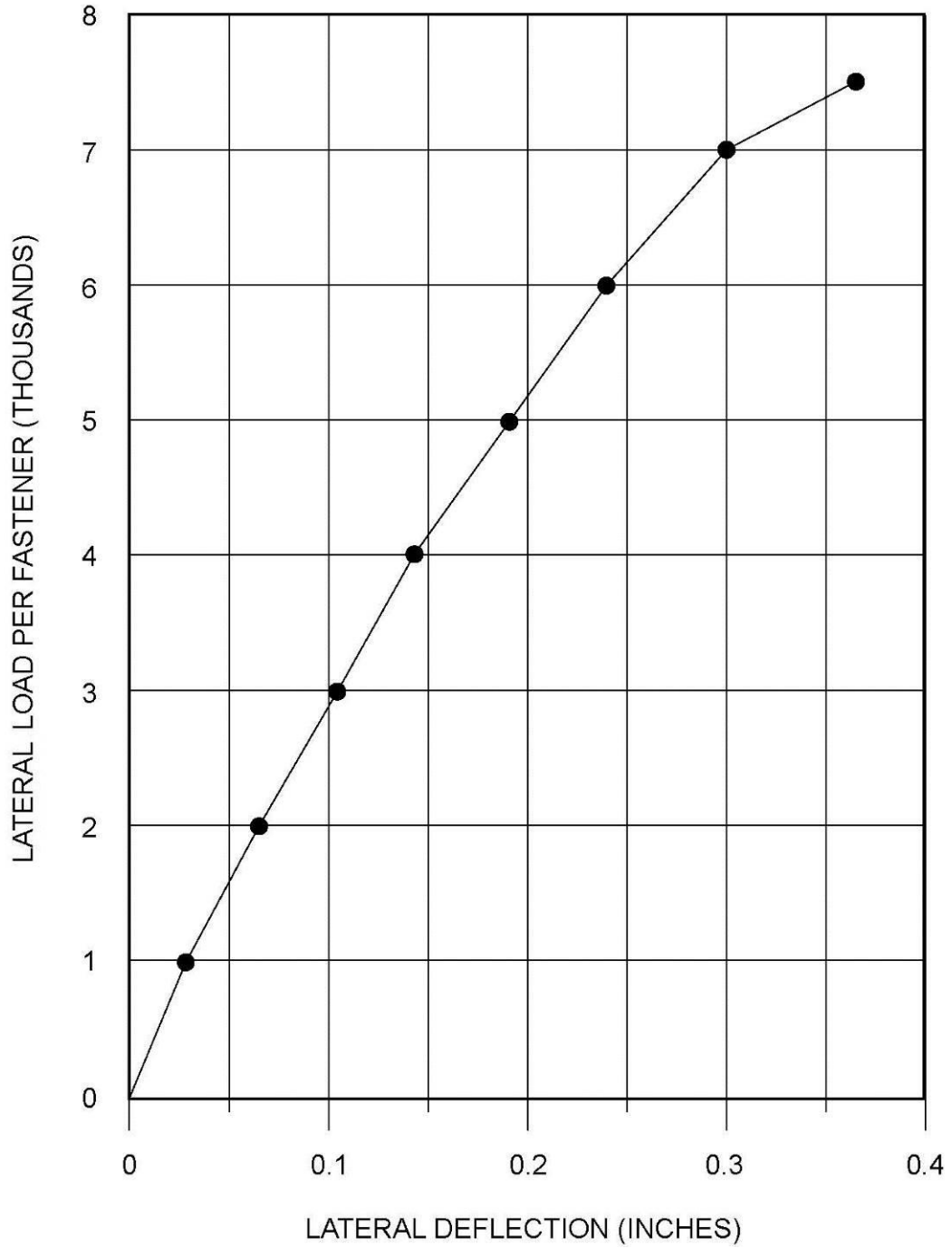


Figure 02868-4

LATERAL LOAD TEST



SECTION 02889

ASPHALTIC UNDERLAYMENTS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This section specifies requirements for the installation of asphaltic underlayment at areas of LRT turnouts and special track work.
- B. Underlayment locations will be in accordance with the contractor drawings and MBTA Commuter Rail Book of Standard Plans Dwg. No. 1030 and Section 02513 – BITUMINOUS CONCRETE PAVEMENT.

1.2 SUBMITTALS

- A. The following submittals shall be made to the Engineer for review and approval prior to procuring any material or performing any work required under this Section:
 - 1. Submit mix design and product data for the material furnished together with certification that the material meets the requirements of this specification.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. **Bituminous Emulsions**
 - 1. Asphaltic Emulsions: AASHTO M140, grade RS-1 for prime coat or tack coat.

2.2 CLASS I BITUMINOUS CONCRETE MIXES

- A. Furnish Hot Mix Asphalt (HMA) underlayment mix conforming to Article 2.2 in Section 02513 – BITUMINOUS CONCRETE PAVEMENT.

PART 3 - EXECUTION

3.1 SPREADING AND FINISHING

- A. **General**
 - 1. HMA can be placed only after the subgrade is prepared as specified in Section 02850 – LIGHT RAIL TRACK CONSTRUCTION.
 - 2. HMA mix shall be laid in one course depositing sufficient materials to provide a finished compacted mat 5 inches thick.

3. The mixture shall be placed and compacted only at such times that allow for proper inspection and checking by the independent testing agency hired by the design-builder.
4. The mixture shall be placed only upon approved surfaces that are clean and dry and only when weather conditions are suitable.

B. Machine Spreading

1. Deposit mixtures in the approved mechanical spreader, spread immediately, and strike off in a uniform layer to the full width required and to such depth that each course, when compacted, shall have the required thickness and shall conform to the indicated grade and cross section contour.
2. Deposit mixture in the center of the hoppers, exercising care to avoid overloading and spilling. Operate the pavers, while the mixture is being spread, at a speed which will produce a uniform surface texture.
3. Immediately after each course is screeded and before roller compaction is started, check the surface, adjust any irregularities, remove accumulation from the screed by rake or lute, and remove and replace any unsatisfactory spots in the course. Correct irregularities in line and grade along outside edges by addition or removal of material before the edge is rolled. Indiscriminate casting of mix on the new screeded surface, where irregularities are not evident, will not be permitted.
4. All edges shall be true and uniform.

C. Compaction Procedures

1. Roll the mixture longitudinally, diagonally, and transversely as may be necessary to produce the required contour of the surface. Start longitudinal rolling at the side and proceed toward the center of the pavement, except on superelevated curves start at the low side and progress to the high side, overlapping on successive trips by at least 12 inches.
2. Continue the rolling so that all roller marks, ridges, porous spots, and impressions are eliminated and the surface has the required contour and grade. Maintain the motion of the rollers at all times slow enough to avoid any displacement of the hot mixture. Correct any displacement or marring of the surface resulting from reversing the direction of the roller or from any other cause.
3. To prevent adhesion with the mixture, keep the wheels of steel rollers lightly moistened with water. Excess water or oil for this purpose will not be permitted.
4. To prevent "rolloff" of the pavement edges and longitudinal joints on deep lift paving, leave the outer eight inches of the deep lift mixture unrolled until the temperature of the mix ranges between 150 and 180 degrees F., whereupon compact it with a steel roller.
5. Along curbs, structures, and all places not accessible with a roller, compact the surface thoroughly with mechanical tamping devices, smooth and true to established line, grade, and contour.

6. The densities of compacted bituminous concrete shall not be less than 95% of the density obtained from laboratory compaction of a mixture composed of the same material in like proportions or 92% maximum theoretical density of said mixture. The independent testing agency hired by the Design-Builder shall conduct confirmatory testing.

3.2 PREPARATION OF MIXTURES

- A. Prepare, transport and deliver mixtures in accordance with Section 02513 – BITUMINOUS CONCRETE PAVEMENT.

3.3 PLACING INITIAL LAYER OF BALLAST

- A. No loads shall be permitted on the newly completed pavement until adequate stability has been attained and the material has cooled sufficiently to prevent distortion or loss of fines.
- B. After laying HMA refer to Section 02850 – LIGHT RAIL TRACK CONSTRUCTION for the requirement of placing ballast.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02890

TRAFFIC SIGNAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work under this section shall consist of the installation of traffic control systems complete and ready for operation at various intersections throughout the Green Line Extension project.
- B. The traffic control signals shall be in operation during the appropriate construction phases as specified on the plans. This work shall include furnishing, installing, and maintaining traffic control equipment including controller and cabinet, mast arms and foundations, pedestrian signal poles and foundations, signal heads, and pedestrian push buttons until the system is operational and has been accepted.
- C. Work shall include mobilization and set-up of boring equipment, the drilling of hollow stem auger borings, drive sample borings, and rock core borings, the retrieval of soil samples, the visual classification of the soil, the recording of boring logs and samples, and the dismantling and transporting of the equipment to and from each site, as required for the mast arm foundation design.
- D. Work shall include furnishing and installing a service connection, and all materials and equipment necessary for a video detection system including video cameras, video detection processor, wire and cable, and all incidental materials and labor necessary for operating and controlling a traffic control signal at this location, as shown on the plans and as specified herein, all in accordance with the applicable provisions of the Traffic Control Devices Specification (Section 800), the NEMA Specification, the Manual of Traffic Control Devices (Current Edition), and the MassDOT Standard Specifications for Highways and Bridges (Latest Edition).
- E. The work under this section shall include the removal and stacking of all existing traffic signal equipment (if necessary) upon the completion of the project or when determined by the Owner to no longer be required. If the local municipality maintains ownership, and prefers to retain the existing equipment, the Design-Builder shall provide all necessary manpower and equipment to load, transport and unload the equipment to a location designated by the municipality. Otherwise, the Design-Builder shall retain ownership of all equipment, and transport and dispose of the equipment in a manner that meets all applicable local, state and federal requirements.
- F. **Related Work:** The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 02577 – PAVEMENT MARKINGS
 - 3. Section 02800 – EXTERIOR CONDUIT SYSTEMS
 - 4. Section 03300 – CAST IN PLACE CONCRETE

1.2 SUBMITTALS

A. Borings

1. Upon completion of all borings, the Design-Builder shall submit two copies of the typewritten boring logs to the Owner.
2. Supplemental Samples
 - a. The Design-Builder shall submit to the Owner quart jar samples which shall have positive identification of the contents by typewritten glued-on labels. The following information shall be shown:
 1. Name and address of boring contractor
 2. Date sample was taken
 3. Location and name of project
 4. Location of borehole by station and offset or identifying number of borehole, if so identified on the plan
 5. Depth below ground surface at which sample was obtained and recorded blow counts of 6 inches of penetration of the sampler

B. Shop Drawings and brochures shall be submitted for all Traffic Signal items to be furnished.

C. Submittals required under this section include, but are not limited to, the following:

1. Traffic Signal Equipment
2. Signal Supports
3. A list of equipment
4. Manufacturer's Equipment Specifications

1.3 GUARANTEE

- A. The Design-Builder shall diagnose (troubleshoot) the complete traffic control system and, at his own expense, replace any part of the traffic signal control equipment found to be defective in the workmanship, material or manner of functioning during its required operation until the final acceptance of the system.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. A list of the major traffic signal items required at each location is included on the Sequence and Timing Plans.
- B. All materials incorporated into the traffic control system shall be without flaws or defects. Only those materials included in the latest MassDOT "Approved Equipment List" shall be approved for use in the project.

- C. All materials incorporated into the traffic control system shall be durable, tamper resistant, and vandal resistant.

2.2 SERVICE CONNECTION

- A. The service connection shall be made at the closest above ground location to the traffic signal controller cabinet. The Design-Builder shall determine the exact location from the servicing utility, arrange with them to complete the service connections, and be responsible for all charges incidental thereto.

2.3 CONTROLLER AND CABINET

- A. Work shall include furnishing and installing a TS 2, Type 1 or TS 1 controller and cabinet as shown on the plans. The controller and all other ancillary traffic signal control components included in the traffic control cabinet shall comply with the latest National Electrical Manufacturers Association (NEMA) standards. The controller and cabinet assemblies shall be supplied in an 8 phase TS 2 or TS 1 configuration.
- B. New cabinets shall be made of aluminum and painted aluminum and shall comply with Section 7 of the specifications set forth in NEMA TS-2, 1998. Controller cabinets shall be mounted on a concrete foundation. The controller cabinet shall also be supplied with a Manual Police Button to manually control the operations of the traffic signal via the Police Door Access Panel.
- C. Controller cabinet and foundation shall not obstruct a sidewalk or crosswalk so that passage by physically challenged persons would be impaired (36-inch min.).

2.4 SIGNAL HEADS

- A. All signal heads shall be equipped with 12” red/yellow/green ball or red/yellow/green arrow light emitting diode (LED) traffic module.

2.5 LED VEHICLE SIGNAL MODULE

- A. All LED Vehicle Signal Modules used on the project shall conform to the following:
 1. The LED signal module shall conform to “Interim LED Purchase Specification of the Institute of Transportation Engineers, Vehicle Traffic Control Signal Heads – Part 2: Light Emitting Diode (LED) Vehicle Traffic Signal Modules”, July, 1998, or most current version, Institute of Transportation Engineers (ITE), 525 School St., S.W., Suite 410, Washington, DC 20024-2797, Telephone: (202) 554-8050, FAX: (202) 863-5486, and shall conform to the following: (In the case of a conflict, the following special provision shall overrule.)
 2. An independent laboratory shall certify that the LED signal module complies with Section 6 Quality Assurance of the above state ITE LED Purchase Specification.
 3. LED signal modules must be type-testing and approved by MassDOT according to the requirements of Subsection 815.21 of the Standard Specifications.
 4. The LED signal module will be replaced or repaired by the manufacturer if it exhibits a failure due to workmanship or material defects during the field operation.

2.6 MAST ARMS

- A. The mast arm structures and foundations shall be fabricated and constructed in conformance with the MassDOT Highway Division standard drawings. The location of the traffic signal poles shown on the plans is a relative location. The poles may need to be relocated to accommodate field conditions, construction activity and utility conflicts. Any additional pole(s) required to be relocated shall be done at no additional cost.
- B. Mast arm base foundations shall not obstruct a sidewalk or crosswalk so that passage by physically challenged persons would be impaired (36-inch min.).
- C. The mast arm foundation sizes and depths shall be selected from the Foundation Design charts for the calculated moment at existing ground. The Design-Builder should assume wet sandy soils, unless directed by the Owner who is present during the auguring for the foundation and determines otherwise based on the soils encountered.
- D. The mast arm foundation sizes and depths shall be selected from the MassDOT Foundation Design charts for the calculated moment at existing ground. All measurements to determine the exact dimensions and clearances between the mast arm structures and existing overhead utility lines shall be made in the field by the Design-Builder in the presence of the Owner for incorporation into the erection plans and shop drawings which are submitted for approval.

2.7 POST AND BASES

- A. Signal posts shall have aluminum shafts, 8 feet or 10 feet in height, with transformer bases. Signal base foundations shall not obstruct sidewalks or crosswalks so that passage by physically challenged persons would be impaired (36-inch min.).

2.8 PEDESTRIAN SIGNAL HEADS

- A. The pedestrian signal head indications shall be illuminated LED type displaying the graphical symbols of a walking person and/or upraised hand and countdown timers. The countdown timers shall be beneath of the overlaid of the walking person and upraised hand symbols. All pedestrian signal heads shall be equipped with cap visors.

2.9 PEDESTRIAN PUSH BUTTONS

- A. Pedestrian push button controls shall be raised from or flush with their housings and shall be a minimum of 2" in the smallest dimension. The force required to activate the controls shall be no greater than 5 Pound Force.
- B. Location of pedestrian push buttons shall comply with the current editions of the Manual of Traffic Control Devices), Americans with Disability Act Accessibility Guideline for Buildings and Facilities (ADAAG), and the Massachusetts Architectural Access Board Regulations .
- C. Mounting height shall be approximately 42" but no more than 48" above the finish sidewalk grade for the pedestrian push buttons.

2.10 ELECTRICAL WIRE

- A. Electrical wire and cable shall be as specified in Section 813 of the MassDOT Standard Specifications.

2.11 VIDEO DETECTION SYSTEM

- A. Work shall include the installation of a video detection system, as shown on the plans, specified below or an approved equal.
 - 1. General
 - a. This specification sets forth the minimum requirements for a system that detects vehicles on a roadway using only video images of vehicle traffic.
- B. System Hardware
 - 1. The video detection system shall consist of a single integrated camera on each mast arm as shown on the plans with video detection processor (VDP), a cabinet interface (ICC) which mounts in a standard detector rack or as a stand-alone shelf mount unit, and a pointing device.
- C. System Software
 - 1. The system shall include software that detects vehicles in multiple lanes using only the video image. Detection zones shall be defined using only an on board video menu and a pointing device to place the zones on a video image. Up to 6 detection zones per system shall be available. A separate computer shall not be required to program the detection zones.
- D. Functional Capabilities
 - 1. The VDP shall process video from the integrated camera. The video shall be in NTSC composite video format and shall be digitized and analyzed in real time.
 - 2. The VDP shall detect the presence of vehicles in up to 6 detection zones per system. A detection zone shall be approximately the width and length of one car.
 - 3. Detection zones shall be programmed via an on-board menu displayed on a video monitor and a pointing device connected to the ICC. The menu shall facilitate placement of detection zones and setting of zone parameters or to view system parameters. A separate computer shall not be required for programming detection zones or to view system operation.
 - 4. The VDP shall store up to three different detection zone patterns. The VDP can switch to any one of the three different detection patterns within 1 second of user request via menu selection with the pointing device. Each configuration can be uniquely labeled for identification and the current configuration identifier is displayed on the monitor.
 - 5. The VDP shall detect vehicles in real time as they travel across each detector zone.
 - 6. The ICC shall have an RS232 port for communications with an external computer for diagnostic and remote management applications.

7. The VDP shall accept new detector patterns from an external computer through the RS-232 port on the ICC when the external computer uses the correct communications protocol for downloading detector patterns. A Windows™ based software designed for local or remote connection and providing video capture, real-time detection indication and detection zone modification capability shall be provided with the system.
8. The VDP shall send its detection patterns to an external computer through the RS-232 port on the ICC upon request when the external computer uses the appropriate communications protocol for uploading detector patterns.
9. A shelf mount version of the ICC shall be available to avoid the need of rewiring the detector rack for high voltage input, by enabling the user to plug power into the front of the module from a standard plug arrangement. The shelf mount ICC module's output shall be connected to the cabinet circuitry by an 8-wire cable.
10. VDP and ICC communications shall be accommodated by methods using differential signals to reject electrically coupled noise.
11. The VDP shall be able to transmit the composite video signal, with minimal signal degradation, up to 1000 feet under ideal conditions.
12. The associated VDP shall default to a safe condition, such as a constant call on each active detection channel, in the event of loss of video signal.
13. The system shall be capable of automatically detecting a low-visibility condition such as fog and respond by placing all defined detection zones in a constant call mode. The system shall automatically revert to normal detection mode when the low-visibility condition no longer exists.

E. Vehicle Detection

1. Six detection zones shall be supported and each detection zone shall be user definable in size and shape to suit the site and the desired vehicle detection region.
2. A single detection zone shall be able to replace multiple inductive loops and the detection zones shall be OR'ed as the default or may be AND'ed together to indicate vehicle presence on a single phase of traffic movement.
3. Placement of detection zones shall be done by using only a pointing device, and a graphical interface built into the VDP and displayed on a video monitor, to draw the detection zones on the video image from the video camera. No separate computer shall be required to program the detection zones. Detection zones shall be drawn on live video from the video camera.
4. A minimum of 3 detection zone patterns shall be saved within the VDP memory. The VDP's memory shall be non-volatile to prevent data loss during power outages. The VDP shall continue to operate (e.g. detect vehicles) using the existing zone configurations even when the operator is defining/modifying a zone pattern. The new zone configuration shall not go into effect until the configuration is saved by the operator.
5. The selection of the detection zone pattern for current use shall be done through a local menu selection or remote computer via RS-232 port on the ICC. When a new configuration pattern is selected it becomes active within 1 second.

6. When a vehicle is detected crossing a detection zone, confirmation of detection is with a distinct visual indication on the video overlay.
7. Detection shall be at least 98% accurate in good weather conditions and at least 96% accurate under adverse weather conditions (rain, snow, or fog) with optimal installation.
8. The VDP shall provide 2 channels of vehicle presence detection per system through a standard detector rack edge connector or cable interface from the shelf mounted version of ICC.
9. The VDP shall provide dynamic zone reconfiguration (DZR) to enable normal detector operation of existing channels except the one where a zone is being added or modified during the setup process. The VDP shall output a constant call on any detection channel corresponding to a zone being modified.
10. Up to six detection zones shall be capable to count the number of vehicles detected. The count value shall be internally stored for later retrieval through the RS-232 port on the ICC. The data collection interval shall be user definable in periods of 10 or 20 seconds or 1, 5, 15, 30 or 60 minutes.

F. ICC Module

1. The ICC shall be specifically designed to mount in a standard NEMA TS-1, TS-2, 2070 ATC, 170 type detector rack, using the edge connector or AC power input on front to obtain power and provide contact closure outputs. Detector rack rewiring shall not be required or shall be minimized.
2. The ICC shall operate in a temperature range from -35°F to +165°F and a humidity range from 0% to 95% relative humidity, non-condensing.
3. The ICC shall be powered by 100 to 240 volts 50 or 60Hz. This module shall automatically compensate for the different input voltages/frequencies.
4. System power consumption shall not exceed 25watts within the specified input voltage range.
5. The VDP shall utilize non-volatile memory technology to enable the loading of modified or enhanced software through the RS232 port on the ICC without modifying the VDP hardware.
6. The ICC shall include detector output pin out compatibility with industry standard detector racks.
7. The front of the ICC shall include detection indications, such as LED's, for each channel of detection that display detector outputs in real time when the system is operational.
8. The front of the ICC shall include one BNC video output providing real time video output that can be routed to other devices. A RCA type connector/jack for video output is not allowed.
9. The front panel of the ICC shall have a detector test switch to allow the user to place calls on each channel. The test switch shall be able to place either a constant call or a momentary call depending on the position of the switch.

G. Video Detection Processor Module

1. The camera shall produce a useable video image of the bodies of vehicles under all roadway lighting conditions, regardless of time of day. The minimum range of scene luminance over which the camera shall produce a useable video image shall be the minimum range from nighttime to daytime, but not less than the range 1.0 lux to 10,000 lux.
2. The imager luminance signal to noise ratio (S/N) shall be more than 50 dB.
3. The VDP electronics shall include automatic gain control (AGC) to produce a satisfactory image at night.
4. The VDP shall be housed in a weather-tight sealed enclosure. The enclosure shall be made of 6061 anodized aluminum. The housing shall be field rotatable to allow proper alignment between the VDP and the traveled road surface.
5. The VDP enclosure shall be equipped with a sunshield. The sunshield shall include a provision for water diversion to prevent water from flowing in the camera's field of view. The camera enclosure with sunshield shall be less than 5" diameter, less than 18" long, and shall weigh less than 5 pounds.
6. The VDP enclosure shall include a proportionally controlled heater, where the output power of the heater varies with temperature, to assure proper operation of the lens functions at low temperatures and prevent moisture condensation on the optical faceplate of the enclosure.
7. The front of the enclosure shall be made from glass and shall have an anti-reflective coating to minimize light and image reflections. The front of the enclosure shall not be made from any thermoplastic or synthetic polymer (PVC, Acrylic, Polythene or similar).
8. When mounted outdoors in the enclosure, the VDP shall operate satisfactorily in a temperature range from -31°F to +140°F and a humidity range from 0% RH to 100% RH.
9. The VDP enclosure shall be equipped with a single, weather-tight connector.

H. Installation

1. The cable to be used between the VDP and the ICC in the traffic cabinet shall be three (3) twisted pairs. Various styles including IMSA 39-2 are suitable for correct operation. The cable shall be a continuous unbroken run from the VDP to the ICC. This cable shall be suitable for installation in conduit or overhead with appropriate span wire. Pluggable connectors supplied should be used at both the VDP and ICC ends. The cable, and installation tools shall be approved by the supplier of the video detection system, and the manufacturer's instructions must be followed to ensure proper connection.
2. The video detection system shall be installed as recommended by the supplier and documented in installation materials provided by the supplier. Proof of factory certification shall be provided.

I. Railroad Preemption

1. The existing railroad preemption shall remain operational and function as shown on the plans during the traffic signal system operation.

2.12 PULLBOXES

- A. Work shall conform to the relevant provisions Section 801 of the MassDOT Standard Specification.

PART 3 - EXECUTION

3.1 EXCAVATING AND BACKFILLING

- A. Section 02300 - EARTHWORK.

3.2 BORINGS

- A. Hollow stem auger borings shall be taken at the locations of the proposed traffic signal foundations as shown on the plans and as directed by the Owner. The Owner shall be notified a minimum of seventy-two hours before borings are taken.
- B. Two types of samples will be required in vertical soil borings:
 - 1. Standard Sample.
 - a. A standard penetration test using a split spoon sampler shall be made at the ground surface and at every change in soil stratum, but the sampling intervals shall not exceed 5 feet in a continuous stratum. The auger hole shall terminate at the required bottom elevation and a split spoon sample shall be taken at the bottom of the hole.
 - 2. Supplemental Sample.
 - a. A volume sample shall be taken at 5-foot intervals in order to classify the subsurface soils with respect to grain size and visual classification as required. Each sample shall consist of the remainder of the spoon sample and shall be contained in quart jars appropriately labeled. The purpose of this method along with its sampling procedure is to determine the visual properties, arrangement, and thickness of the various soil strata as they exist in the ground. The elevations/depths at which any change in stratification occurs shall be located and recorded on the log by the driller. Detection of stratum changes should be made by careful observation of the soil as it exists in the augured hole and by the rate of penetration of the auger during drilling. The auger casing I.D. shall be a minimum of 2- 3/4 inches for all holes in which split spoon samples are required. The O.D. shall be a maximum of 7 inches to limit the size of the resulting hole.
- C. Obstructions
 - 1. Obstructions, other than ledge, shall be considered in accordance with Section 190.60E of the MassDOT Standard Specifications. The actual location of the additional boring will be specified by the Owner. When ledge is encountered a rock core boring shall be made in accordance with Section 190.63 of the Standard Specifications.
- D. Rock Core

1. If rock is encountered at an elevation above the specified highest bottom elevation, then a rock core boring shall be made in accordance with Section 190.63 of the Standard Specifications. The core hole shall be large enough to accommodate the required auger casing so that sampling may be continued past the rock obstruction. The minimum cored depth shall be 10 feet.

E. Practical Refusal

1. Practical refusal of the sample spoon or “refusal” is as defined by Section 190.60F of the MassDOT Standard Specifications.
2. Due to the size of the resulting auger hole, it is particularly important that upon completion, all borings shall be backfilled with clean, well-graded sand and tamped to fill all voids created during the augering procedure.

F. Advancing the Boring for Soil Sampling

1. As the boring is advanced, care shall be taken to note and record the depth where wet soil is encountered if this should occur.
2. If groundwater is encountered, then the water level in the hollow stem shall be maintained at the top of the casing at all times during the sampling operation to avoid unequal hydrostatic pressure that could result in blow-in of fine-granular soils and inaccurate blow counts.
3. In each boring, the driller shall record the water level prior to backfilling and whenever possible, prior to the start of each day’s work.
4. Each boring shall be advanced by using a hollow stem auger with cutting head and center rod and plug assembly. The hollow stem auger will advance and case the hole simultaneously to the required sampling levels. The center rod and plug assembly is held in place by the cap and inside drill rod connecting the auger and its assembly to the rotating spindle on the drilling machine to prevent soil from entering the mouth of the auger. Upon reaching the sampling level, the plug is to be retreated by withdrawing the center rod to permit lowering of the sampler through the auger.
5. The sample shall be obtained by driving the sampler 18 inches into the undisturbed material below the bottom of the auger. The sampling and handling procedure shall be as specified under Section 190.61 of the Standard Specifications.
6. After the sampling operations are completed and the sampler has been retracted, the plug is re-inserted and held in place by the center rod; another auger section is connected to the first, together with one additional center rod section to secure the plug to the cap and the hole is advanced.
7. This procedure shall be repeated until the required bottom elevation is reached. The auger shall be stopped at any depth level to allow normal sampling practices upon request by the Owner.
8. If, in the judgment of the Owner, the borehole cannot be advanced by the hollow stem auger method due to the material encountered (with the exception of bedrock) and every attempt has been made by the driller to complete the boring using the conventionally cased, drive

sample, wash boring method as specified in Section 190 of the Standard Specifications, then the borehole shall be cored.

3.3 PERFORMANCE

- A. All work on the traffic signal shall be performed in accordance with the applicable requirements of Section 800 of the MassDOT Standard Specifications. NEMA Standards, the Manual on Uniform Traffic Control Devices and the following:
 - 1. Timing, sequence, and operation shall be as shown on the Sequence and Timing chart included in the Contract Drawings.
- B. The work shall include provision and connection of proposed controller to service connection as specified under Section 813. of the MassDOT Standard Specifications. The Design-Builder shall make all necessary arrangements with the Electric Company in connection with the performance of this work and bear all charges incurred thereby.

3.4 FLASHING OPERATION

- A. Changes from automatic flashing to stop-and-go operation and from stop-and-go to automatic flashing operation shall occur as set forth in Section 4D.29 of the current MUTCD.

3.5 FINE TUNING AND ADJUSTMENT PERIOD

- A. Included in this Section shall be all time for a signal technician and/or electrician to modify and adjust the timing and phasing as required by the Owner.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02891

TRAFFIC SIGNS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The work under this section shall include furnishing and erecting warning clusters and signs, overhead and roadside guide signs, warning and regulatory signs, route and project markers, street name signs, delineators, sign supports, and all necessary hardware, concrete, and excavation. Concrete for sign foundations shall conform to the applicable requirements of Section 03300 - CAST-IN-PLACE CONCRETE.
- B. The work under this section shall also include the dismantling, removal, transporting, and resetting of the existing signs at the location shown on the plans. The work also includes the removal and disposal of the existing sign supports determined by the Engineer to be unusable and the removal and disposal of the existing foundations. Signs removed and reset shall be reset on new posts as specified. The Contractor shall backfill with compacted gravel all holes resulting from the removal of the existing signs and their foundations and restore the area to match the existing conditions of adjacent areas.
- C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 02052 – MAINTENANCE OF TRAFFIC THROUGH WORK AREAS
 - 2. Section 10440 – SITE SIGNAGE

PART 2 - PRODUCTS

2.1 MATERIALS

- A. A list of the major traffic sign items required at this location is included on the Sign Plans.
- B. Signs shall be fabricated in conformance with the current editions of the Manual on Uniform Traffic Control Devices, the Massachusetts Amendments to the 2009 Manual on Uniform Traffic Control Devices, and the Standard Municipal Traffic Code, Section 828 of the MassDOT Standard Specifications and Supplemental Specifications.

2.2 SIGN SUPPORTS

- A. Sign Supports shall conform to the relevant provisions of Section 840 of the current MassDOT Standard Specifications and Supplemental Specifications. Steel posts shall be used for the permanent signs and timber posts for temporary signs. The location of the permanent and temporary posts (if needed) shown on the plans is a suggested location. The posts may need to be relocated to accommodate field conditions, construction activity, utility conflicts, and requests by local authorities. Any post(s) required to be relocated shall be relocated at no additional cost.

PART 3 - EXECUTION

3.1 PERFORMANCE

- A. All work on the traffic signs shall be performed in accordance with the applicable requirements of Section 800 of the Standard Specifications and Supplemental Specifications, the Manual on Uniform Traffic Control Devices, and the following:
 - 1. Locations and installation of all signs shall be as shown on the construction plans in the Contract Drawings.
 - 2. Sign horizontal and vertical clearances shall meet the requirements set for in the MUTCD.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02910

EXTERIOR STORAGE FACILITIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies furnishing and installing Station Storage Facilities as described herein, complete, with components in conformity with the Contract Documents, manufacturer's specifications, and located to the lines and grades shown on the Contract Documents.
- B. Related Work:
 - 1. Section 02100 – SITE PREPARATION
 - 2. Section 03300 – CAST-IN-PLACE CONCRETE
 - 3. Section 09900 – PAINTING
 - 4. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK

1.2 QUALITY CONTROL

- A. Design of the station storage facility shed shall meet all applicable requirements as provided in the current edition of the Commonwealth of Massachusetts State Building Code, as noted on the Contract Documents, and as specified below:
 - 1. Basic Snow Load, Zone 2, shall be a minimum of 30 psf, modified for specialized roof characteristics as appropriate.
 - 2. Wind Load, Exposure C, Zone 3, shall be a minimum of 21 psf, applied where and as required.
 - 3. Special Impact Load, 200 lbs., applied at location to cause maximum effect.
 - 4. No Earthquake Load required.

1.3 SUBMITTALS

- A. The following shall be submitted for review:
 - 1. Manufacturer's literature, brochures and/or specifications for all material as specified herein and as shown on the Contract Documents.

1.4 PROCUREMENT, DELIVERY, STORAGE AND HANDLING

- A. Procure, store and deliver work under this Section in a manner to prevent damage to components during transit and/or from the elements.
- B. Deliver storage facilities and set in locations as shown on the Contract Documents.

- C. Each storage facility shed shall be protected from scratches, gouges, or rough handling which may mar the surface finish during installation.
- D. Damaged items shall be replaced without additional cost.

PART 2 - PRODUCTS

2.1 STORAGE FACILITIES

- A. The size of each storage facility shall be a minimum of 20'-0" long by 8'-0" wide by 8'-6" high, out- to-out dimensions.
- B. Storage facilities shall be a 'Conex' type steel portable storage container, as manufactured by Genstar Container Corporation; a precast modular building, Model Micro 1012, as manufactured by Concrete Systems, Inc., Londonderry, NH; or similar products manufactured by Mobile Mini, Inc.; Williams Scotsman, In.; or equal.
- C. Storage facilities shall be constructed of either 16 gauge sheet steel or of an equivalent design in precast concrete. Roof ventilation openings shall be provided as required for the size of the shelter. Lifting bars shall be provided to facilitate the movement of the storage facility. All embedded structural and sheet steel shall be hot dipped galvanized.
- D. Storage facilities shall be provided with a double front door of vandal resistant design. In each door, there shall be a minimum of two ventilation openings, covered with fine mesh stainless steel, copper, or brass screening. The exterior of the ventilation opening shall be hooded to minimize the entrance of precipitation. The interior of the ventilation opening shall be equipped with a sliding plate to allow the adjustment of airflow. The doors shall be hinged and provide a weatherproof seal design employing a water shedding gasket. Steel doors shall be provided with cast iron handles, welded to a three-point locking device which will ensure that the door cannot be locked until it is in the fully closed position. Other materials shall have an equivalent design. Doors shall be provided with a two-position retaining device to secure the door when open.
- E. Hinges shall be separate castings welded to the housing and door. The hinges shall be equipped with manufacturer's standard hinges and pins and shall be lubricated by the manufacturer before the storage facility is shipped.
- F. Anchoring hardware shall be galvanized steel, in sizes and configurations recommended by the manufacturer. Where anchor bolts are located inside the shed, removable covers shall be provided for access to the foundation bolts. Where anchors, bolts or fasteners are exposed, they shall be configured or secured in such a way as to prevent their casual removal by use of vandal-proof heads or fastenings.
- G. Exterior of storage facilities shall be painted a color selected by the MBTA. Painting shall conform to the requirements of Section 09900, Painting.
- H. Utilities:
 - 1. Branch Circuit Panel Boards
 - a. The storage facilities shall be provided with one branch circuit panel board for power supply conforming to the requirements of Section 16050.

- b. Power supply shall be brought into each storage facility through the floor of the building through the cable entrance pipes located below the branch circuit panel board.
- 2. Lighting
 - a. Each shed shall be provided with (cold weather rated ballast) fluorescent fixtures. The fluorescent fixture shall provide complete illumination of 30 foot candles minimum in all areas of the building. Lights shall be operated from wall mounted switches conveniently placed near each door
- 3. Convenience Outlets (Receptacles)
 - a. Three convenience outlets shall be furnished and installed along the interior of the perimeter walls, four feet above the floor. All receptacles shall have Ground Fault Circuit Interrupted (GFCI) protection.
- 4. Branch Circuit Wiring
 - a. Wiring for lights, and convenience outlets shall be minimum #14 AWG, flexible, THHN wire installed in Electrical Metallic Tubing (EMT).

PART 3 - EXECUTION

3.1 GENERAL

- A. Locate and install the storage facility as shown on the Contract Drawings. The facility shall be set plumb and level, true to line and grade. The installation shall be coordinated with the concrete pad and ramp installation.
- B. Concrete pad and ramp placement, curing, testing, reinforcing and protection, and form work shall be as specified in Section 03300, Cast-In-Place Concrete, and shown on the Contract Drawings. The size of the concrete pad shall in no instance extend beyond the sides of the storage facility shed.
- C. Anchoring of the storage facility shall comply with the manufacturer's recommendations, applicable code or regulation, and best construction practices for the work to be performed.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 02920

SEEDING

PART 1 – GENERAL

1.1 GENERAL

- A. The Work shall be performed in accordance with the following documents as issued by the Massachusetts Bay Transportation Authority:
 - 1. The Contract Specifications, which include Volume 1 DB Contract Terms and Conditions; Volume 2 Technical Provisions; and applicable Sections of Divisions 2 through 16.

1.2 SUMMARY

- A. This Section specifies design and construction performance requirements for Seeding:
 - 1. Seeding.
 - 2. Watering, fertilizing, mowing and maintenance of seeded areas.
- B. Other Specification sections that relate to the work include, but are not limited to, the following:
 - 1. VOLUME 2 TECHNICAL PROVISIONS, EXHIBIT 21, “ADDITIONAL. PROJECT REQUIREMENTS
 - 2. Section 02060 – EROSION AND SEDIMENTATION CONTROL
 - 3. Section 02300 – EARTHWORK
 - 4. Section 02930 – PLANTING
 - 5. Section 02932 – PLANTING SOILS
 - 6. Section 02970 – LANDSCAPE MAINTENANCE

1.3 REFERENCE STANDARDS

- A. Comply with applicable requirements of:
 - 1. Commonwealth of Massachusetts, Standard Specifications for Highways and Bridges, Department of Public Works, latest edition, Boston, Massachusetts.
 - 2. American Association of Nurserymen, American Standards for Nursery Stock, (ANSI Z60.1), latest edition, published by the American Association of Nurserymen, 1250 I Street, N.W., Suite 500 Washington, D.C. 20005.
 - 3. ASTM: American Society of Testing Materials.
 - 4. ANSI: American National Standards Institute.
 - 5. AOAC: Association of Official Agricultural Chemists.
 - 6. USDA: United States Department of Agriculture.

1.4 SUBMITTALS

- A. Submittals: in accordance with Volume 2 Technical Provisions, Subsection 2.7, “Design Submittal Review Management” and Subsection 2.8, “Construction Submittal Requirements”.
- B. Product Data: Submit manufacturer's information for:
 - 1. Maintenance Fertilizer
 - 2. Seed Mixtures
 - 3. Protective fencing materials.
 - 4. Erosion control blanket.
- C. Certificates: Submit:
 - 1. Submit manufacturer's certificates of compliance with each shipment of each seed type. Certificate from seed supplier shall indicate seed is true to variety indicated on packaging. Certificates shall include guaranteed percentages of purity, weed content and germination of seed, net weight and date of shipment. No seed may be sown until certificates have been submitted.

1.5 QUALITY ASSURANCE

- A. Qualifications: Design-Builder shall have minimum five years-experience in seed installation.
 - 1. Submit written project list and references for other seed installation project work.
- B. Regulatory Requirements
 - 1. Secure permits, licenses, and pay fees including traffic control.
 - 2. Comply with laws, regulations, and quarantines for agricultural and horticultural products.

1.6 PROJECT CONDITIONS

- A. Environmental Requirements: do not deliver, handle or place soils when dry, wet, or frozen.
 - 1. Field Test
 - a. Form soil in palm of hand, if soil retains shape and crumbles upon touching, the soil may be worked.
 - b. If soil will not retain shape it is too dry and shall not be worked.
 - c. If soil retains shape and will not crumble, it is too wet and shall not be worked.

1.7 SEQUENCING AND SCHEDULING

- A. Perform seeding work only after planting and other work affecting ground surface has been completed.

1.8 SUBSTANTIAL COMPLETION

- A. Upon completion of seed installation, request the MBTA's review to determine if work is substantially complete. Submit request a minimum of five days prior to the anticipated inspection date. If work is substantially complete, the MBTA will issue a Substantial Completion letter identifying commencement of 90 day Maintenance Period.
 - 1. If work is not substantially complete, the MBTA will issue a written list of outstanding work to be done on a timely schedule agreed upon by Design-Builder and the MBTA.
 - 2. Design-Builder shall notify the MBTA when outstanding work is completed and ready for review. When outstanding work is complete, as determined by the MBTA, a letter of Substantial Completion will be issued.

1.9 90 DAY MAINTENANCE PERIOD

- A. Maintain seeded areas until Final Acceptance.

1.10 FINAL ACCEPTANCE

- A. After the 90 day maintenance period seeded areas will be reviewed for final acceptance.
- B. Conditions of Final Acceptance
 - 1. Seeded areas acceptance shall be given for entire area. No partial acceptance shall be given.
 - 2. Seeded areas shall exhibit uniform, thick, well-developed stand of grass. Lawn areas shall have no bare spots in excess of four inches in diameter and bare spots shall comprise no more than two % of total area of lawn.
 - 3. No seeded areas shall exhibit signs of damage from erosion, washouts, gullies, or other causes.
 - 4. Pavement surfaces and site improvements adjacent to seeded areas shall be clean and free of spills from placing or handling of lawn soil and seeding operations.
- C. Inspection and Final Acceptance
 - 1. Upon completion of 90 Day Maintenance Period, request the MBTA's review to determine if work is acceptable. Submit request a minimum of five days prior to the anticipated inspection date. If work is acceptable, the MBTA will issue a Final Acceptance letter. From this date forward, lawn maintenance will be the responsibility of the MBTA. Following acceptance of seeded areas, the MBTA will be given access to lawn areas for maintenance work.
 - a. If work is not accepted, the MBTA will issue a written list of outstanding work. Maintenance period to be extended until completion of work.
 - b. Design-Builder shall notify the MBTA when outstanding work is completed and ready for review. When work is complete, as determined by the MBTA, a letter of Final Acceptance will be issued.

PART 2 - PRODUCTS

2.1 LANDSCAPE SOILS AND AMENDMENTS

- A. See Section 02932 – PLANTING SOILS

2.2 MAINTENANCE FERTILIZER

- A. Maintenance Fertilizer to be mixed with soil:

1. Complete, fertilizer made from all-natural ingredients complying with State and Federal fertilizer laws. Fertilizer shall contain the following available plant food by weight, unless soils test indicate a need for different composition:

<u>Nitrogen</u>	<u>Phosphorus</u>	<u>Potash</u>
5%	3%	4%

2. Fertilizer: Pro Gro 5-3-4 manufactured by North Country Organics, Bradford, Vermont 05033, (802)222-4277, or approved equal.
3. Fertilizer to be delivered in original unopened standard size bags showing weigh, analysis ingredients and manufacturer's name.

2.3 SEED MIXTURES

- A. Seed mixtures: fresh, clean, new crop seed. Seed can be mixed by an approved method on site or can be mixed by dealer. If seed is mixed on site, each variety shall be delivered in original containers bearing dealer's guaranteed analysis. If seed is mixed by dealer, Design-Builder shall furnish to the MBTA, the dealer's guaranteed statement of composition of mixture and percentage of purity and germination of each variety.

- B. Lawn Mix:

1. Smart Seed Pro Tall Fescue and Kentucky Bluegrass Mix (turf-type tall fescue) by Pennington Seed, Inc., P.O. Box 290, Madison, GA 30650, Phone: 1-800-285-7333, or approved equal.

	<u>Proportion of mix after purity</u>	<u>Minimum germination</u>
Rebel Xtreme Tall Fescue	30% +/-	85%
Penn RK4 Tall Fescue	30% +/-	85%
Rebel XLR Tall Fescue	30% +/-	85%
Ridgeline Kentucky Bluegrass	10% +/-	85%

2. Application Rates: 350 lbs. / Acre or 8.05 lbs. / 1,000 SF, and as manufacture's recommendation.

- C. Erosion Control / Restoration Mix:

1. New England Erosion Control/Restoration Mix for Dry Sites, as supplied by New England Wetland Plants, Inc., 820 West Street, Amherst, MA 01002. Phone: (413) 518-8000. Website: www.newp.com, or approved equal, and include the following species:

- a. Creeping Red Fescue, (*Festuca rubra*), Canada Wild Rye, (*Elymus Canadensis*), Annual Ryegrass, (*Lolium multiflorum*), Perennial Ryegrass, (*Lolium perenne*), Little Bluestem, (*Schizachyrium scoparium*), Indian Grass, (*Sorghastrum nutans*), Rough Bentgrass/Ticklegrass, (*Agrostis scabra*), Upland Bentgrass, (*Agrostis perennans*).
2. Application Rates: 35 lbs. / Acre or 1 lb. / 1,250 SF
- D. Meadow Mix:
- 1. New England Wildflower Mix, as supplied by New England Wetland Plants, Inc., 820 West Street, Amherst, MA 01002. Phone: (413) 518-8000. Website: www.newp.com, or approved equal, and include the following species:
 - a. Little Bluestem, (*Schizachyrium scoparium*), Creeping Red Fescue, (*Festuca rubra*), Indian Grass, (*Sorghastrum nutans*), Canada Wild Rye, (*Elymus Canadensis*), Virginia Wild Rye, (*Elymus virginicus*), Partridge Pea, (*Chamaecrista fasciculata*), Showy Tick Trefoil, (*Desmodium canadense*), Blue Vervain, (*Verbena hastata*), Black Eyed Susan, (*Rudbeckia hirta*), Beard Tongue, (*Penstemon digitalis*), Wild Bergamot, (*Monarda fistulosa*), Common Milkweed, (*Asclepias syriaca*), Smooth Blue Aster, (*Symphotrichum laeve*), New England Aster, (*Symphotrichum novae-angliae*), Spotted Joe Pye Weed, (*Eutrochium maculatum*), Joe Pye Weed, (*Eupatorium fistulosum*), New York Ironweed, (*Vernonia noveboracensis*), Golden Alexanders, (*Zizia aurea*), Starved/Calico Aster, (*Aster lateriflorus*), Flat-top Goldentop, (*Euthamia graminifolia*), Early Goldenrod, (*Solidago juncea*).
 - 2. Application Rates: 23 lbs. / Acre or 1 lb. / 1,900 SF

2.4 WATER

- A. Water: furnished by Design-Builder, suitable for irrigation and free from ingredients harmful to plant life. Hose and other watering equipment furnished by Design-Builder.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verification of Conditions: in the event field conditions are not in conformance with Contract Documents, notify the MBTA in writing.
 - 1. Spot and Invert Elevations: verify that field elevations of the existing site conditions such as drainage and utility fixtures, pavements, existing plantings, and subsurface piping conform to the Existing Conditions Plan.
 - 2. Finish Grades: verify with the MBTA that final grades and contours are acceptable.

3.2 PREPARATION AND PLACEMENT OF PLANTING SOIL

- A. See Section 02932 – PLANTING SOILS.

3.3 PREPARATION FOR NEW SEEDED AREAS

A. Protection:

1. Dust Control: upon acceptance of finish grade provide dust control.
2. Erosion Control: upon acceptance of finish grade provide erosion control.
3. Agricultural Chemicals: protect site improvements from contact with agricultural chemicals, soil amendments, and fertilizers.

B. Surface Preparation:

1. Clean new lawn bed, pavement or other site improvements prior to installation.

3.4 SOIL PREPARATION

A. See Section 02932 – PLANTING SOILS.

B. Thoroughly irrigate areas to receive seed.

C. Scarification: cross rake areas to receive seed, so surface of soil will be receptive to holding seed.

D. Grade lawn areas smooth, free draining and even surface with a loose, uniformly fine texture. Roll and rake; remove ridges and fill depressions as required to drain.

E. Restore prepared areas if eroded, settled, or otherwise disturbed after fine grading and prior to seeding.

3.5 APPLICATION OF PRE PLANTING FERTILIZER

A. Pre-plant Fertilizer application: As specified in Section 02932 – PLANTING SOILS.

3.6 MAINTENANCE

A. Maintenance begins immediately after seed is installed and continues until Final Acceptance as follows:

1. a uniform, thick, well-developed stand of grass is established.
2. Mow seeded areas at seven-day intervals.
 - a. First mowing: when grass has grown to 3” height. Cut grass to 2 ½” height.
 - b. Subsequent Mowings: cut grass to 3” height.
 - c. Mow in Autumn until growth of grass ceases, and resume in Spring when grass grows to 3 1/2” height.
3. Mow sloped areas a minimum of once during maintenance period. 90 day maintenance period shall be extended to include required cutting.

4. Apply uniform application of maintenance fertilizer (5-3-4) at rate of 20 per 1000 square feet 30 days after new lawn has been installed.
5. Continue watering as described above.
6. After grass has started, areas failing to show uniform, thick, well-developed stand of grass shall be immediately re-seeded until areas are covered with satisfactory growth of grass as determined by the MBTA.
7. Repair damage from erosion, gullies, washouts, or other causes immediately by filling with loam borrow, tamping, re-fertilizing and re-seeding.

3.7 CLEANING

- A. Wash and sweep clean paving, site improvements and building surfaces. Clean spills and over-sprays immediately. Remove and dispose off-site excess planting mixture, soil and debris.
- B. Following Final Acceptance of lawn areas, remove materials and equipment not required for other planting or maintenance work. Materials and equipment remaining on site shall be stored in locations that do not interfere with the MBTA's maintenance of accepted seeded areas or other construction operations.

3.8 PROTECTION

- A. Protect lawn areas until Final Acceptance.

PART 4 – MEAUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02930

PLANTING

PART 1 – GENERAL

1.1 GENERAL

- A. The Work shall be performed in accordance with the following documents as issued by the Massachusetts Bay Transportation Authority:
1. The Contract Specifications, which include Volume 1 DB Contract Terms and Conditions; Volume 2 Technical Provisions; and applicable Sections of Divisions 2 through 16.

1.2 SUMMARY

- A. This Section specifies design and construction performance requirements for Lawns:
1. Planting trees, shrubs, groundcovers, and other woody and herbaceous plant materials.
 2. Tree stabilization.
 3. Incorporating of planting additives, bio-stimulants, pruning, mulching, fertilizing and watering plantings.
- B. Related Sections include the following:
1. VOLUME 2 TECHNICAL PROVISIONS, EXHIBIT 21, “ADDITIONAL. PROJECT REQUIREMENTS
 2. Section 02300 – EARTHWORK
 3. Section 02310 – FINE GRADING
 4. Section 02920 – SEEDING
 5. Section 02932 – PLANTING SOILS
 6. Section 02970 – LANDSCAPE MAINTENANCE

1.3 REFERENCE STANDARDS

- A. Comply with applicable requirements of:
1. Commonwealth of Massachusetts, Standard Specifications for Highways and Bridges, Department of Public Works, latest edition.
 2. ASTM: American Society of Testing Materials.
 3. AAN: American Association of Nurserymen.
 4. ISA: International Society of Arboriculture.
 5. ANSI: American National Standards Institute.
 6. AOAC: Association of Official Agricultural Chemists.
 7. USDA: United States Department of Agriculture.

1.4 DEFINITIONS

- A. Balled and Burlapped Stock: Exterior plants dug with firm, natural balls of earth in which they are grown, with ball size not less than diameter and depth recommended by ANSI Z60.1 for type and size of tree or shrub required; wrapped, tied, rigidly supported, and drum-laced as recommended by ANSI Z60.1.
- B. Container-Grown Stock: Healthy, vigorous, well-rooted exterior plants grown in a container with well-established root system reaching sides of container and maintaining a firm ball when removed from container. Container shall be rigid enough to hold ball shape and protect root mass during shipping and be sized in accordance with the provisions of the American Standard for Nursery Stock, ANSI Z60.1 - latest edition, for kind, type, and size of exterior plant required.
- C. Finish Grade: Elevation of finished surface of planting soil.
- D. Subgrade: Surface or elevation of subsoil remaining after completing excavation, or top surface of a fill or backfill, before placing planting soil.

1.5 SUBMITTALS

- A. Submittals: in accordance with Volume 2 Technical Provisions, Subsection 2.7, “Design Submittal Review Management” and Subsection 2.8, “Construction Submittal Requirements”.
- B. Product Data: Submit most recent printed information from manufacturers for:
 - 1. Antidesiccant
 - 2. Liquid Seaweed Concentrate
 - 3. Plant Growth Biostimulant
 - 4. Mycorrhizae Granules
 - 5. Tree Staples for staking
 - 6. Non-biodegradable flagging tape for marking Tree Staples.
- C. Samples: Submit samples of:
 - 1. Bark Mulch: Submit one cubic foot sample and manufacturer/supplier's name.
 - 2. Crushed Bluestone Mulch: Submit one cubic foot sample and manufacturer/supplier's name
 - 3. Tree Stabilization System.
- D. Certificates:
 - 1. Submit manufacturer's certificates of compliance listing analysis for:
 - a. Bulb Booster
 - 2. Submit certification of Massachusetts state arborist.
- E. Landscape Design-Builder:

1. Submit in writing information and qualifications for the planting Design-Builder, including name, address, telephone number, experience on projects of a similar size and complexity, a minimum of three references and supervisor for planting Design-Builder.

F. Plant List:

1. Within 30 days of award of Contract, submit plant list for review by the MBTA which includes:
 - a. plant materials proposed for project and corresponding nursery source where plants are to be selected.
 - b. for plants indicating names of plants in accordance with American Joint Committee on Horticultural Nomenclature.
2. Schedule for review at nursery source by the MBTA with Design-Builder present.
3. Substitutions: plant list shall indicate unavailable materials and document a thorough search for materials. For unavailable materials list sources contacted with telephone number, date and person's name at source.

1.6 QUALITY ASSURANCE

- A. Planting shall be performed by a certified landscape Design-Builder with a minimum of five years planting work experience on projects of a similar size and complexity and under full time supervision of a qualified supervisor.
- B. Pruning shall be performed by a Massachusetts certified and/or an International Society of Arboriculture certified arborist. Pruning shall comply with ANSI A300 pruning standards.

1.7 PRE-CONSTRUCTION MEETING

- A. At the project pre-construction meeting, the following items relating to the work of this Item shall be specifically discussed:
 1. Nursery sources for plant materials.
 2. Schedule of plant tagging, delivery and installation.
 3. Review benchmark dates at which time the MBTA shall make site visits.

1.8 SELECTION AND INSPECTION OF PLANTS

- A. Plants shall be selected by the MBTA at place of growth for conformity to specification requirements as to quality, size and variety prior to purchase and planting. Such approval shall not impair right of inspection and rejection upon delivery at site or during progress of work. Cost of replacement shall be borne by Design-Builder.
- B. Source Limitations:
 1. Plants shall have been grown under climatic conditions similar to those in the locality of the project for at least the previous two years. Unless approved by the MBTA, plants shall have been grown at a latitude of not more than 325 km (200 miles) north or south of the latitude of

the project unless the provenance of the plant can be documented to be compatible with the latitude and cold hardiness zone of the planting location.

2. B&B plants shall have been freshly dug (during the most recent favorable harvest season).
3. Color photographs of representative plant material shall be submitted for initial review of alternate nursery sources. Photographs are to include a scale rod or other measuring device and be taken from an angle that depicts the size and condition of the typical plant to be furnished. Photographs shall show actual plant material available for selection at that time.

C. Plant Selection / Coordination

1. For trees, within 90 days of the Notice to Proceed, submit tree sources and schedule selection and tagging of trees so the MBTA can tag trees for project at place of growth. The MBTA will perform on trip to the nursery(s) to select and tag trees and a second trip to the nursery(s) review and confirm the acceptability of the trees immediately prior to digging for delivery to the site. Source information shall state the place of growth and the approximate quantity of trees available for inspection. The MBTA may refuse inspection at this time if, in his or her judgment, sufficient quantities of plants are not available for inspection.
2. For shrubs and other plants, submit plant sources by January 1 of the planting year for Spring plantings, and July 1 for Fall plantings, schedule selection and tagging of shrubs so the MBTA can tag representative shrubs for project at place of growth. Source information shall state the place of growth and the approximate quantity of trees available for inspection. The MBTA may refuse inspection at this time if, in his or her judgment, sufficient quantities of plants are not available for inspection.
3. Inform the MBTA of selection schedule a minimum of one month (30 day minimum) in advance of selection/tagging dates so the MBTA can make proper travel arrangements. If Design-Builder fails to provide one month (30 day minimum) notice, any additional travel expenses shall be back-charged to Design-Builder. If the MBTA has to make additional trips to select/tag plants in the event that inadequate, insufficient or unacceptable plant material was available at the inspection location, then additional travel expenses to be backcharged to Design-Builder.
4. If nurseries and/or stock submitted for review are not acceptable to the MBTA, submit alternate sources within seven (7) business days.
5. If Design-Builder cannot locate appropriate plant material, Design-Builder shall enlist a plant broker to locate the material. Submit a report from the plant broker describing alternate sources.
 - a. Trips to nurseries shall be efficiently arranged to allow the MBTA to maximize his/her viewing time. Only undug trees (trees that are in the ground) shall be considered for approval. The MBTA may choose to attach their seal to each plant, or representative samples. Each tree may have a specific location and orientation on the proposed plan that the Design-Builder shall follow closely during installation.
 - b. Plant material that has been selected and sealed shall be secured by Design-Builder within ten (10) business days of the MBTA having reviewed or sealed the material.
 - c. The MBTA's seals shall not be removed until final plantings have been approved by the MBTA. Removal of seals prior to the MBTA's review of plantings shall be considered grounds for rejection of plant material.

D. Expenses

1. Design-Builder to pay for the MBTA's travel expenses: air fare, car rental, automobile mileage and tolls; meals and overnight accommodations if necessary, for the MBTA during time period required to select and tag plant material. Planting Design-Builder shall provide representative to travel with the MBTA while tagging plant material.

E. Plant Shipment to Site/ On Site Review

1. Notify the MBTA a minimum of five business days prior to each shipment of proposed arrival of plant material on site.
2. Layout tree locations, bed outlines and individual planting on site for inspection by the MBTA prior to planting. Arrange for adequate manpower and equipment on site at time of plant material inspection and installation to provide complete staked layout and to unload, open and handle plant material during inspection.

1.9 DELIVERY, STORAGE AND HANDLING OF PLANTS

- A. Plants during shipping and delivery and plants requiring storage on site shall be properly wrapped and covered to prevent wind drying and desiccation of branches, leaves, or buds. Plant balls shall be firmly bound, unbroken, and reasonably moist to indicate watering prior to delivery and during storage. Trees shall be free from fresh scars and damage in handling. Root masses of container grown plants shall be kept moist and containers screened from direct sun.
- B. Wrap tree trunks at nursery prior to shipping then unwrap for inspection by the MBTA prior to installation. Report damaged plants to the MBTA.
- C. Apply anti-desiccant to plants before digging at nursery and/or as directed by the MBTA once plants are delivered to site.

1.10 PROJECT/SITE CONDITIONS

- A. Environmental Requirements: do not deliver or handle soils when dry, wet, or frozen.
 1. Field Test
 - a. Form soil in palm of hand, if soil retains shape and crumbles upon touching, the soil may be worked.
 - b. If the soil will not retain shape it is too dry and shall not be worked.
 - c. If the soil retains shape and will not crumble, it is too wet and shall not be worked.
- B. Planting Season: planting seasons shall be those indicated below. Plants planted out-of-season shall receive special attention as directed. Out-of-season planting and or transplanting shall be at Design-Builder's risk and expense. No planting shall be done in frozen or muddy ground or when snow covers ground, or soil is otherwise in an unsatisfactory condition for planting.

1. Seasons for Planting:

Spring: Deciduous Materials – April 1 to June 15
Evergreen Materials – April 1 to June 15

Fall: Deciduous Materials – September 1 - October 15
Evergreen Materials – September 1 - October 15

2. Variance: If special conditions exist that warrant a variance in the above planting dates, a written request shall be submitted to the MBTA a minimum of 4 weeks prior to the scheduled planting date stating the special conditions and the proposed variance. Permission for the variance will be given if warranted in the opinion of the MBTA and upon condition that the Guarantee Period be extended for an additional period of up to 24 months at no additional cost to the MBTA.

1.11 SUBSTANTIAL COMPLETION

- A. See Section 02970 – LANDSCAPE MAINTENANCE.

1.12 MAINTENANCE

- A. See Section 02970 – LANDSCAPE MAINTENANCE.

1.13 ACCEPTANCE

- A. See Section 02970 – LANDSCAPE MAINTENANCE.

1.14 GUARANTY

- A. Start of Guaranty Period: when the MBTA issues Letter of Acceptance.
- B. Term: One year for plants.
- C. Requirements: plant material to be alive and in healthy, vigorous condition.
1. Quarterly reviews will be made with Design-Builder and the MBTA during guaranty period. Reviews will assess condition of installed plant materials.
2. Replace plants that are dead or, as determined by the MBTA, are in an unhealthy or unsightly condition, and have lost their natural shape due to dead branches, or other causes.
- D. End of Guaranty Period: when the MBTA issues letter of Final Acceptance, two years from date of substantial completion.
- E. If a Planting Season Variance is granted, the Guarantee Period for the affected plant materials shall extend through the spring (June 30) of the 12-month period following the initial Guarantee Period, without further cost to the City.

1.15 FINAL ACCEPTANCE

- A. The MBTA reviews work and finds it complete and in accordance with the Specifications.

- B. The MBTA will issue a letter of Final Acceptance, at which time project becomes responsibility of the MBTA.

PART 2 - PRODUCTS

2.1 PLANTS

- A. Plant Identification and Standards: Nomenclature conforms to current edition of Standardized Plant Names, published by American Joint Committee on Horticultural Nomenclature. Plants conform to varieties and sizes specified in plant list, and to code of standards set forth by AmericanHort, in the American Standard for Nursery Stock, ANSI Z60.1 - latest edition. Substitutions shall not be permitted without consent of the MBTA. Plants shall be properly identified with plant labels securely attached to plants, in order to identify plants on site. Information regarding sources of plant material shall be furnished to the MBTA.
- B. General Plants: Unless specified otherwise, plants shall be nursery grown under climatic conditions similar to those in locality of project and shall have been previously been transplanted or root pruned at least once in last three years. Plants shall possess a normal balance between height and spread. Plants shall be typical of their species and variety with a normal habit of growth, densely foliated when in leaf, and a well-developed branch structure with a fibrous, healthy root system with no girdling roots. Plants shall be sound and healthy, free from dead wood, defects, disfiguring knots, sun scald, injuries or abrasions of roots or bark. Plants shall be freshly dug. No heeled-in plants or plants from cold storage shall be used. Parts of plant shall be moist and show active green cambium when cut. Plants shall be free of plant diseases, insects, pests, eggs, larvae, and forms of infestations.
- C. Plant relationship between Root Flare and Finished Grade: nursery source shall properly plant, maintain and dig plants to maintain the natural relationship of the plants root flare, slightly above the soil of the root ball. Plants which have or show signs of previously having soil placed over their root flares from planting too deep when initially lined out, maintenance practices that turn over and mound up the soil to keep down weeds and or placing excavated soils over original root flare and root ball soil level will be rejected.
- D. Balled and Burlapped Plants: "B&B" plants shall be dug with root systems as solid units. Diameter and depth of balls of soil shall be sufficient to encompass fibrous and feeding root system necessary for healthy development of plants. Balls shall be wrapped firmly with biodegradable material, and bound carefully with twine or cord. Tree balls may also be placed in a wire basket of diameter suitable for the size of the root ball. No plant shall be accepted when ball of earth surrounding roots has been badly cracked or broken, either before or during process of planting, or after burlap and ropes, required for transplanting have been unfastened. Plants and root balls shall remain intact as a unit during operations. Plants that cannot be planted at once shall be protected and watered.
- E. Bare Root Plants: "BR" plants shall be dug while dormant. Bare root plants shall be maintained in a healthy condition during storage, transportation, and operations.
- F. Container-Grown Plants: Container grown plants shall have been acclimatized for one growing season in container. Container plants shall be well established in container, and shall have sufficient roots to hold earth intact after removal, without being in a root-bound condition. Plants shall remain in container until planted.
- G. Trees:

1. Tree branching height to begin at 7' above finished grade without adversely impacting the overall appearance of the tree.
 2. Tree canopies, except when a clump form is designated shall be straight and symmetrical with a crown having a persistent single, main leader, tapered trunk free of co-dominant stems and growing from a single, unmutated crown of roots, and typical of the species or cultivar. No part of trunk shall be conspicuously crooked as compared with normal trees of same variety. Crown shall be free of large voids and not be significantly deformed by wind, pruning practices, pests, or other factors. Live crown ratio (distance which supports healthy foliage from bottom of canopy to the top/tree height) shall be at least 60%.
 3. Trunk shall be free of wounds (except for properly-healed pruning wounds), damaged bark or branches, abrasions, disfiguring knots, sunscald, conks, bleeding, galls, signs of insects or disease, and girdling ties, sunscald, frost cracks, or wounds resulting from abrasions, fire, or other causes. No pruning wounds shall be present having diameter of more than two inches (2") and wounds shall show vigorous bark on edges. Pruning wounds over 3/4 inch in diameter shall be completely calloused over.
 4. Trees shall stand erect without a supporting stake.
 5. Main scaffold branches shall be less than 2/3 the trunk diameter, free of bark inclusions (places where bark is embedded within the crotch preventing the formation of a normal branch bark ridge), and well-spaced. They shall be distributed radially around and vertically along the trunk, forming a generally symmetrical crown typical for the species.
 6. Evergreen trees shall be branched to within one foot of the ground. Height of trees, measured from crown of roots to top of top branch, and caliper, measured as specified herein.
 7. Take caliper measurements 6 in. above ground on trees up to and including 4 in. caliper, and at 12 in. above ground for larger sizes.
- I. Shrubs and Small Plants: Shrubs and small plants, unless otherwise designated, shall be well-formed and bushy with well-spaced side branches, and shall have a crown and stem(s) typical of species and variety. Plants shall be well-branched to ground. Measurements for height are to be taken from ground level to average height of top of shrub and not to longest branch. Thickness of each shrub shall correspond to trade classification "No. 1". Single stemmed or thin plants will not be accepted.
 - J. Plants larger than required may be used if approved by the MBTA, but use of such plants shall not increase the Contract Price. If use of larger plants is approved, spread of roots or ball of earth shall be increased in proportion to size of plant.

2.2 PLANTING ADDITIVES

- A. Liquid Seaweed Concentrate: Dry, water soluble seaweed extract powder from *Ascophym nodosum*. Stress-X as manufactured by North Country Organics, Bradford, Vermont 05033, ph# 802.222.4277, or equal.
- B. Plant Growth Biostimulant: Dry, water soluble plant growth biostimulant made from beneficial bacteria humic extracts, cold water sea kelp extract, essential amino acids, vitamins, root growth factors and sugars. Bio- Magic as manufactured by North Country Organics, Bradford, Vermont 05033, ph# 802.222.4277, or equal.

- C. Mycorrhizae granules: transplant granules for inoculating plants with beneficial mycorrhizal fungi prior to planting. Myco-Magic as manufactured by North Country Organics, Bradford, Vermont 05033, ph# 802.222.4277, or equal.

2.3 BARK MULCH

- A. Bark mulch: shredded granular outer bark of evergreen trees and minimum of hardwood bark and shall be aged for period of at least 6 months and not longer than two years. Bark mulch shall not have be subjected to anaerobic conditions and shall be partially decomposed and dark brown in color, Bark chunks shall average 1/2 inch to 2 inches in length and no chunks three inches or more in size and thicker than 1/4 inch shall be left on site. Moisture content shall be 40 % or more, retained with normal watering and/or rainfall. Mulch shall be free of dirt, leaves, twigs, and other materials deleterious to plant life. Mulch shall not contain chipped construction materials.

2.4 POST PLANTING FERTILIZER

- A. Post Planting Fertilizer:
 - 1. Complete, fertilizer made from all-natural ingredients complying with State and Federal fertilizer laws. Fertilizer shall contain the following available plant food by weight, unless soils test indicate a need for different composition
 - 2. Pro Start 5-3-4 manufactured by North Country Organics, Bradford, Vermont 05033, ph# 802.222.4277, or approved equal.
 - 3. Fertilizer to be delivered in original unopened standard size bags showing weigh, analysis ingredients and manufacturer's name.

2.5 WATER

- A. Water: furnished by Design-Builder, unless otherwise specified, and suitable for irrigation and free from ingredients harmful to plant life. Hose and other watering equipment required for work shall be furnished by Design-Builder.

2.6 TREE STABILIZATION MATERIALS

- A. Tree Stabilization: Below grade root ball anchoring system shall be DUCKBILL Root Ball Kit as manufactured by Foresight Products, 6430 East 49th Drive, Commerce City, CO 80022. Phone: (800) 325-5360. Email: sales@duckbill.com, or approved equal.
 - 1. For tree sizes up to 3": Model 68 RBK Kit
 - 2. For tree sizes up to 6": Model 88 RBK Kit
 - 3. Maintain planting in plumb condition and in order to withstand the environmental conditions of the site.

2.7 ANTIDESSICANT

- A. Antidesiccants: emulsions or materials which provide a protective film over plant surfaces permeable enough to permit transpiration and specifically manufactured for that purpose. Antidesiccant shall be delivered in manufacturer's containers and used according to manufacturer's instructions.

2.8 CHEMICALS, HERBICIDES, FUNGICIDES AND INSECTICIDES

- A. Provide chemicals, herbicides, fungicides and insecticides, as needed, for fungus or pest control. Chemicals and insecticides shall be approved by Massachusetts Department of Environmental Protection for intended use and application rates. No pesticides shall be used on site without knowledge and approval of the MBTA. Pesticides shall be handled by State licensed operators only.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verification of Conditions: in the event field conditions are not in conformance with Contract Documents, notify the MBTA in writing.
 - 1. Spot and Invert Elevations: verify that field elevations of all existing site conditions, such as drainage and utility fixtures, pavements, existing plantings, and subsurface piping conform to Existing Conditions Plan.
 - 2. Finish Grade: Finish Grades: verify with the MBTA that final grades and contours are acceptable.

3.2 PREPARATION

- A. Protection:
 - 1. Contact "Dig Safe" prior to doing excavation on site. If work is to be done around underground utilities, appropriate authority of utility shall be notified of impending work. Hand excavate areas adjacent to utilities. Design-Builder shall be responsible for damages done by himself or his personnel to existing utilities, which shall be repaired or paid for by Design-Builder.
 - 2. Dust Control: provide dust control.
 - 3. Erosion Control: provide erosion control.
 - 4. Agricultural Chemicals: protect site improvements from contact with agricultural chemicals, soil amendments, and fertilizers.

3.3 DIGGING, HANDLING, AND PROTECTION OF PLANTS

- A. Dig balled and burlapped (B&B) plants with firm natural balls of earth, of sufficient diameter and depth to include fibrous roots and conforming to The American Standard for Nursery Stock ANSI Z60.1 – latest addition, as provided by AmericanHort. No synthetic burlap will be accepted. No plant moved with a ball will be accepted if ball is cracked or broken before or during planting operations.

- B. Protect roots or balls of plants from sun and drying winds.
- C. For balled and burlapped plants which cannot be planted immediately upon delivery, set plants on ground in shady location and protect with soil, bark mulch, or other acceptable materials,. Water stored plants and regularly verify rootballs are moist. The MBTA will reject stored plants found with dried rootballs.
- D. Open bundles of plants immediately and plants and separate before roots are covered. Care shall be taken to prevent air pockets among roots. During planting operations, bare roots shall be covered with canvas, hay or other suitable material. No plant shall be bound with wire or rope as to damage the bark or break branches.

3.4 OBSTRUCTIONS BELOW GROUND

- A. If rock, underground construction work, or other obstructions are encountered in plant pit excavation work, alternate locations may be selected by the MBTA at no additional cost to the MBTA.
- B. Where locations cannot be changed, obstruction shall be removed, subject to the MBTA's approval, to a depth of not less than three feet (3') below grade and no less than six inches (6") below bottom of ball or roots when plant is properly set at required grade.
- C. Removal of rock and underground obstructions encountered as specified in Section 02300 – Earthwork.

3.5 PREPARATION AND PLACEMENT OF PLANTING MEDIUMS AND UNDERDRAINAGE COMPONENTS

- A. See Section 02932 – PLANTING SOILS.

3.6 FINE GRADING

- A. See Section 02310 – FINE GRADING.

3.7 PLANTING OPERATIONS

- A. Stake out locations of plants and secure the MBTA's approval before excavating plant pits.
- B. Excavating
 1. Place tree next to tree pit excavation and remove burlap from top of root ball. If trunk flair is not visible gently loosen and remove soil with a blunt tool or air spade until trunk flair and large horizontal lateral roots are located. Use care not to damage root system. Following removal of excess soil over root ball measure depth of root ball to determine depth of tree pit excavation.
 2. Dig tree pits and plant pits by hand and take care not to disturb utilities. If utilities are disturbed during planting operation, Design-Builder shall repair damage at Design-Builder's expense.
 3. Excavate plant pits with sloping sides so planting hole is saucer shaped. Plant pit shall be no deeper than root ball.
 4. Tree pits shall be four times diameter of soil ball in width.

C. Setting, Backfilling and Fertilizing

1. In the event trees are containerize in wire baskets, lay tree on its side and cut the bottom of the cage off, roll the tree into the hole and remove the sides of the wire basket.
2. Solar Orientation: Trees marked on the north side of the trunk while growing at the Nursery shall be planted with the same orientation as they originally grew to reduce trunk damage due to sun-scald, wherever feasible.
3. Set plants in center of pits plumb, straight and at an elevation where after settlement the root flare and lateral roots of plant will be at surrounding finished grade. Root ball shall not be broken. When trees are set, compact base material under the root balls to fill voids and support plants at proper height. Remove burlap and rope from upper two thirds of balls and have the MBTA inspect removal prior to backfilling.
4. Remove groundcovers and perennials from containers immediately before planting. Handle plants carefully to prevent damaging roots. Groundcover plants may be planted after bark mulch is placed.
5. Following removal of top 1/3 of burlap in accordance with manufacturer's recommendations, sprinkle mycorrhizal granules continuously around perimeter of root ball as well as incorporating granules into top of rootball.
6. Mix liquid seaweed concentrate or plant growth bio-stimulant with water at a rate of 3 grams of liquid seaweed concentrate powder per gallon of water or 1 teaspoon of plant growth biostimulant per gallon of water.
7. Before backfilling around root balls and with the burlap removed, roughen the surface of the nursery ball sides. This action will serve to break and score any glazing of the nursery soil which frequently occurs through digging and handling. The micro-fissures so created help to decrease hydraulic barriers between these soils.
8. Backfill hole around plants to two-thirds full, sprinkle mycorrhizal granules continuously around perimeter of root ball and on top of rootball, firm soil, flood with water mixed with additives, after water has drained away backfill to finished grade without additional firming. Immediately after plant pit is backfilled, a shallow basin slightly larger than pit shall be formed with ridge of soil to facilitate and contain water. After planting, cultivate soil in shrub beds between shrub pits, rake smooth and outline beds neatly.

3.8 DRAINAGE TEST

- A. Perform drainage test on trees and in representative shrub beds.
 1. After excavation, fill pit twice successively with water.
 2. Water shall drain out of plant pit minimum 2 inches per hour.
 3. Plant pits draining slower than 2 inches per hour will require provision for drainage.
- B. Documentation: note on the planting plan, pits that pass drainage test and plants that fail drainage test.

3.9 FIELD QUALITY CONTROL

A. Observation:

1. The MBTA to review plant pit excavation and planting.

3.10 TREE STABILIZATION

- A. Install below grade root ball anchoring system as per manufacturer's recommendations
- B. Maintain trees in upright, vertical position, as determined by the MBTA.

3.11 PRUNING

- A. Pruning shall be performed by a Massachusetts certified and/or an International Society of Arboriculture certified arborist. Pruning cuts to correct injury, damage or branching structure shall comply with the provisions of Tree, Shrub and Other Woody Plant Management - Standard Practices – Part 1 – Pruning (ANSI A300), latest edition. Pruning to preserve natural character of plant and as directed by the MBTA. No leaders shall be cut.
- B. Prune trees and shrubs only with approval of the MBTA to remove limbs that are below 7' above finished grade to maintain pedestrian clearance, dead, broken and crossing branches. Plants shall not be heavily pruned at the time of planting. In no case shall more than one-quarter of the branching structure be removed.
- C. Pruning is required at planting time to correct defects in the tree structure, including removal of injured branches, double leaders, waterspouts, suckers, and interfering branches. Healthy lower branches and interior small twigs shall not be removed except as necessary to clear walks and roads. Retain the normal or natural shape of the plant.
- D. Prune with clean, sharp tools. Dead wood or suckers and broken or badly bruised branches shall be removed back to live bud, branch, or stem.
- E. Pruning above head height shall be done from a hydraulic man-lift or using other mechanisms such that it is not necessary to climb the tree.

3.12 PLACEMENT OF BARK MULCH

- A. Immediately after planting operations are completed, cover tree and shrub pits and planting beds with a two inch layer of specified mulch. Taper depth of mulch to be two inches at mulched perimeter and decreasing in depth toward trunk to be flush where trunk or stem meets root ball. Do not place bark mulch against trunk or stem. Cover tree, shrub and groundcover planting beds with bark mulch.

3.13 WATERING

- A. Flood plants with water twice within first 24 hours of time of planting, and water plants during the maintenance period at least twice per week. At each watering thoroughly saturate the soil around each tree or shrub. If sufficient moisture is retained in soil, as determined by the MBTA, required watering may be reduced. Each tree will require a minimum of ten gallons of water.

3.14 POST PLANTING FERTILIZER

- A. Apply uniform application of Post Planting Fertilizer (5-3-4) at rate of 5 lbs. per 1000 square feet, 30 days after planting.

3.15 CLEANING

- A. Wash and sweep clean paving, site improvements and building surfaces. Clean spills and over-sprays immediately. Remove and dispose off-site excess planting mixture, soil and debris.
- B. Following Acceptance at the end of 90 Maintenance Period of planting areas, remove materials and equipment not required for other planting or maintenance work. Materials and equipment remaining on site shall be stored in locations which do not interfere with the MBTA's maintenance of accepted lawns or other construction operations.

3.16 LANDSCAPE MAINTENANCE

- A. Landscape Maintenance and Aftercare: in accordance with Section 02970 – LANDSCAPE MAINTENANCE.

PART 4 – MEAUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02932

PLANTING SOILS

PART 1 - GENERAL

1.1 GENERAL

- A. The Work shall be performed in accordance with the following documents as issued by the Massachusetts Bay Transportation Authority:
 - 1. The Contract Specifications, which include Volume 1 DB Contract Terms and Conditions; Volume 2 Technical Provisions; and applicable Sections of Divisions 2 through 16.

1.2 DESCRIPTION OF WORK

- A. This Section specifies administrative and procedural requirements for manufactured planting mediums including, but not limited, to the following:
 - 1. Evaluation of rough subgrade water infiltration.
 - 2. Planting soil material acquisition
 - 3. Testing and analysis for specification conformance.
 - 4. Inspection and testing of subgrade for preparation of subgrade.
 - 5. Preparation of soil mediums and testing for conformance.
 - 6. Installation and placement of soils.
 - 7. De-compaction of soils.
 - 8. Final in-place testing of soils.
 - 9. Coordination.
 - 10. Clean-up.
- B. Related Sections include the following:
 - 1. VOLUME 2 TECHNICAL PROVISIONS, EXHIBIT 21, "ADDITIONAL. PROJECT REQUIREMENTS 2. Section 02300 – EARTHWORK
 - 2. Section 02310 – FINE GRADING
 - 3. Section 02930 – PLANTING
 - 4. Section 02920 – SEEDING
 - 5. Section 02970 – LANDSCAPE MAINTENANCE

1.3 REFERENCES

- A. Comply with applicable requirements of:
 - 1. Commonwealth of Massachusetts, Standard Specifications for Highways and Bridges, Department of Public Works, latest edition.
 - 2. American Association of Nurserymen, American Standards for Nursery Stock, (ANSI Z60.1), latest edition, published by the American Association of Nurserymen, 1250 I Street, N.W., Suite 500 Washington, D.C. 20005.

3. ASTM: American Society of Testing Materials.
4. ANSI: American National Standards Institute.
5. AOAC: Association of Official Agricultural Chemists.
6. USDA: United States Department of Agriculture.

1.4 SUBMITTALS

- A. Submittals: in accordance with Volume 2 Technical Provisions, Subsection 2.7, “Design Submittal Review Management” and Subsection 2.8, “Construction Submittal Requirements” and the source approval, sample provision and material testing requirements of Specification SECTION 02300 – EARTHWORK, Subsection 1.5, “Submittals”.
- B. Product Data: provide most recent printed information from manufacturer.
 1. Fertilizers
 2. Ground Limestone
 3. Superphosphate
- C. Samples
 1. Existing Base Topsoil
 2. Imported Base Topsoil
 3. Organic Amendment Materials
- D. Test Reports for each of the above samples: Submit sample from each proposed source for testing and approval. Deliver samples to testing laboratory and pay costs. Send testing report directly to the MBTA.
 1. Inform testing agency soil test is for both tree and shrub planting.
 2. Mechanical and chemical analysis shall be conducted by a public extension service agency or a certified private testing laboratory in accordance with the current “standards” of the Association of Official Agriculture Chemists.
 3. Test soil for agricultural suitability analysis including:
 - a. particle size and characteristics
 - b. soil pH by water pH and buffer (smp) pH tests.
 - c. percentage organic content
 - d. nitrate nitrogen
 - e. ammonium nitrogen
 - f. phosphorus
 - g. potassium
 - h. calcium
 - i. aluminum
 - j. magnesium
 - k. manganese

- l Micronutrients
 - m. Toxins including but not limited to lead, cadmium, arsenic and mercury.
4. Tests shall be by combined hydrometer and wet sieving in compliance with ASTM D422 after destruction of organic matter by ignition.
5. Test results: test data and recommendations for soil amendments including but not limited to: nitrogen, phosphorus, potassium and limestone.

1.5 QUALITY ASSURANCE

- A. Soils Testing Laboratory: to be approved by the MBTA. Lab shall have ability to make tests and provide soil recommendations.
- B. Qualifications: Design-Builder shall have minimum five years-experience in soil preparation work.
- C. Regulatory Requirements
 - 1. Comply with laws, regulations, and quarantines for agricultural and horticultural products.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Packing and Shipping: deliver materials in unopened containers bearing manufacturer's name and guaranteed statement of analysis. Transport materials without damage. Protect finishes from abrasion, dirt, oils, grease, and chemicals. Pack materials to protect from weather.
- B. Acceptance at Site: verify in writing that delivered materials conform to specifications and approved submittals.
- C. Storage and Protection:
 - 1. Materials shall be uniform in composition, dry and free flowing. Store materials in dry place, on pallets, off the ground; protect from sun. Store materials in a manner which does not diminish their usability and effectiveness.
 - 2. Protect materials from theft, damage, weather, dirt, oils, grease, and construction.

1.7 PROJECT/SITE CONDITIONS

- A. Environmental Requirements: do not deliver or handle soils when dry, wet, or frozen.
 - 1. Field Test
 - a. Form soil in palm of hand, if soil retains shape and crumbles upon touching, the soil may be worked.
 - b. If the soil will not retain shape it is too dry and shall not be worked.
 - c. If the soil retains shape and will not crumble, it is too wet and shall not be worked.

PART 2 - MATERIALS

2.1 BASE TOPSOIL

- A. Base topsoil shall be existing topsoil and imported soil as may be required.
 - 1. Existing Base Topsoil, stripped and stockpiled, shall be sampled and tested for grains size distribution and organic content according to tests as specified. Test results shall be reported to the Soil Scientist who may make minor adjustments to specified approximate mixing ratios and mix requirements for each mix type.
 - 2. Imported Base Topsoil, as may be required to meet project requirements, shall be taken from a well-drained, arable site, and shall be free of subsoil, large stones, earth clods, sticks, stumps, clay lumps, roots or other objectionable, extraneous matter or debris. Base Topsoil shall also be free of quack-grass rhizomes, Agropyron Repens, and the nut-like tubers of nutgrass, Cyperus Esculentus, and all other primary noxious weeds. Imported Base Topsoil shall not be delivered or used for planting while in a frozen or muddy condition. Imported Topsoil shall conform to the following grain size distribution for material passing a Number 10 Sieve and following additional requirements:
- B. Base Topsoil shall conform to the following grain size distribution for material passing the #10 sieve:

U.S. Sieve No.	% Passing by Weight	
	Minimum	Maximum
10	100	-
18	85	100
35	70	95
60	50	85
140	36	53
270	30	42
0.002 mm	3	6

- C. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 20% by weight of the total sample.
- D. The ratio of the particle size for 80% passing (D80) to the particle size for 40% passing (D40) shall be 5.0 or less. (D80/D40 < 5.0)
- E. The organic content shall be between 4.0 and 8.0 %.

2.2 ORGANIC AMENDMENT MATERIALS (COMPOST):

- A. Compost for amending base loam shall be a stable, humus-like material produced from the aerobic decomposition of organic residues. The residues, if biosolids, shall consist of compost meeting MA DEP Type 1 requirements or approved equal. The compost shall be a dark brown to black color and be capable of supporting plant growth with appropriate management practices in conjunction with addition of fertilizer and other amendments as applicable, with no visible free water or dust, with no unpleasant odor, and meeting the following criteria as reported by the producer.

- B. The ratio of carbon to nitrogen shall be in the range of 10:1 to 25:1.
- C. Stability shall be assessed by either a CO₂ evolution test or a re-heating test or Solivita procedure. Protocols for each are specified by the coalition of Northeastern Governors Source Reduction Task Force (CONEG) in their 1966 report, "Model Procurement Specifications for Source Separated Compost" and the Solivita manual (version 3.5). For the CO₂ test, the compost respiration shall be no more than 6 mg CO₂-C/gBVS day. For re-heating using the Dewar self-heating test, the maximum heat rise shall be no greater than 9 degrees C above room temperature (20 to 25 degree C). For the Solivita test, the compost shall achieve a maturity index of 6 or more. Stability tests shall be conducted by Wood End Research Laboratory, Mt Vernon, Maine.
- D. Pathogens/Metals/Vector Attraction reduction shall meet 40 CFR Part 503 rule, Table 3, page 9392, Vol. 58 No. 32, and Commonwealth of Massachusetts 310 CMR 32.00 (for applications to soils with human activity).
- E. Organic Content: Shall be at least 40 % (dry weight). 100 % of the material shall pass a 3/8-inch (or smaller) screen. Debris such as metal, glass, plastic, wood (other than residual chips), asphalt or masonry shall not be visible and shall not exceed one % dry weight. Organic content shall be determined by weight loss on ignition for particles passing a number 10 sieve according to procedures performed by the testing laboratory as follows:
1. A 50 cc sub-sample of the screened and mixed compost is ground to pass the number 60 sieve.
 2. 2 to 3 grams (+ 0.001g) of ground sample, dried to a constant weight at 105 degrees C is placed into a muffle furnace.
 3. The temperature is slowly raised (5C/minute) to 300C.
 4. The sample is removed to oven to equilibrate at 105C and the weight is taken.
 5. Organic matter is calculated as loss on ignition.
- F. pH: The pH shall be between 5.5 to 8.0 as determined from a 1:1 soil-distilled water suspension using a glass electrode pH meter American Society of Agronomy Methods of Soil Analysis, Part 2, 1986.
- G. Salinity: Soluble salts shall not exceed 2.0 mmhos/cm (dS/m).
- H. The compost shall be screened to 3/8 inch maximum particle size and shall contain not more than 3% material finer than 0.002mm as determined by hydrometer test on ashed material. The compost shall have a texture suitable for incorporation without causing loss of hydraulic conductivity of the soil mix.
- I. Nutrient content shall be determined by the University of Massachusetts Soil Testing Laboratory or equivalent laboratory and utilized to evaluate soil required amendments for the mixed soils. Chemical analysis shall be undertaken for Nitrate Nitrogen, Ammonium Nitrogen, Phosphorus, Potassium, Calcium, Aluminum, Magnesium, Iron, Manganese, Lead, Soluble Salts, Cation Exchange Capacity, soil reaction (pH) and buffer pH.

2.3 SAND

- A. Sand shall be uniformly graded coarse sand consisting of clean, inert, rounded grains of quartz or other durable rock free from loam or clay, surface coatings, mica or other deleterious materials with the following gradation:

U.S. Sieve Size Number	% Passing by Weight	
	Minimum	Maximum
10	100	-
18	60	80
35	25	45
60	8	20
140	0	8
270	0	3
0.002mm	0	0.5

- B. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 15% by weight of the total sample.
- C. The ratio of the particle size for 70% passing (D70) to the particle size for 20% passing (D20) shall be 3.0 or less. ($D70/D20 < 3.0$).
- D. Tests shall be by combined hydrometer and wet sieving in compliance with ASTM D422 after destruction of organic matter by ignition.

2.4 PLANTING MIXTURE

- A. Planting Mixture shall consist of a blend of approximately equal parts by volume of Base Topsoil, Sand and Organic Amendment. Blending of the components shall be carried out with earth moving equipment prior to placement. Components shall be blended to create a uniform mixture as determined by the MBTA. The final mix shall have the properties specified below.

- B. Gradation for material passing a Number 10 sieve:

U.S. Sieve No.	% Passing by Weight	
	Minimum	Maximum
10	100	-
18	73	93
35	55	83
60	28	55
140	20	35
270	16	23
0.002 mm	1	4

- C. Maximum size shall be one-inch largest dimension. The maximum retained on the #10 sieve shall be 20% by weight of the total sample.
- D. The ratio of the particle size for 80% passing (D80) to the particle size for 30% passing (D30) shall be 4.5 or less. ($D80/D20 < 4.5$).
- E. Organic content shall be between 5 and 8 %.

- F. Tests shall be by combined hydrometer and wet sieving in compliance with ASTM D422 after destruction of organic matter by ignition.

2.5 PRE-PLANT FERTILIZER

- A. Complete, fertilizer made from all-natural ingredients complying with State and Federal fertilizer laws. Fertilizer shall contain the following available plant food by weight, unless soils test indicate a need for different composition:

	Nitrogen	Phosphorus	Potash
Deciduous Trees and Shrubs	2%	3%	3%
Evergreen Trees and Shrubs	2%	3%	3%

- B. Fertilizer: Pro Start 2-3-3 manufactured by North Country Organics, Bradford, Vermont 05033, ph# 802.222.4277.
- C. Fertilizer to be delivered in original unopened standard size bags showing weight, analysis ingredients and manufacturer’s name.

2.6 SOIL AMENDMENTS

- A. Follow soil report recommendations for soil additives for landscape soils.
- B. Superphosphate: finely ground phosphate rock, commonly used for agricultural purposes and shall contain not less than 20 % available phosphoric acid.
- C. Ground Limestone: dolomitic limestone and contain not less than 50 % of total carbonates and 25 % total magnesium with a neutralizing value of at least 100 %. Material shall be ground to such fineness that 40 % will pass 100 mesh U.S. standard sieve and 98 % will pass through 20 mesh U.S. standard sieve.

2.7 EQUIPMENT

- A. Chisel Plow or disk harrow or bucket of backhoe: for subsoil cultivation.
- B. Rotovator or disk harrow: for planting mixture/soil cultivation.

2.8 WATER

- A. Water: furnished by Design-Builder, unless otherwise specified, and suitable for irrigation and free from ingredients harmful to plant life. Hose and other watering equipment furnished by Design-Builder.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verification of Conditions: in the event field conditions are not in conformance with Contract Documents, notify the MBTA in writing.
 - 1. Spot and Invert Elevations: verify that field elevations of all existing site conditions, such as drainage and utility fixtures, pavements, existing plantings, and subsurface piping conform to Existing Conditions Plan.
 - 2. Finish Grade: Finish Grades: verify with the MBTA that final grades and contours are acceptable.

3.2 PREPARATION

- A. Protection:
 - 1. Design-Builder required to contact "Dig Safe" prior to doing excavation on site. If work is to be done around underground utilities, appropriate authority of utility shall be notified of impending work. Hand excavate areas adjacent to utilities. Design-Builder shall be responsible for damages done by himself or his personnel to existing utilities, which shall be repaired or paid for by Design-Builder.
 - 2. Prior to installation field locate and protect from damage site improvements such as drainage and utility fixtures, pavements, and existing plantings.
 - 3. Dust Control: upon acceptance of finish grade provide dust control.
 - 4. Erosion Control: upon acceptance of finish grade provide erosion control.
 - 5. Agricultural Chemicals: protect site improvements from contact with agricultural chemicals, soil amendments, and fertilizers.

3.3 PREPARATION OF PLANTING MIXTURE

- A. Correct deficiencies in soil as directed by soil test results. Thoroughly incorporate amendments into planting mixture to ensure even distribution.
- B. Incorporate pre plant fertilizer at a rate of 30 pounds per cubic yard of planting mixture. Amendment rate will be 6 times square foot application rate per cubic yard of planting mixture.

3.4 PLACEMENT OF PLANTING MIXTURE

- A. After subgrade levels have been reached, and immediately prior to placing Planting Mixture, the entire subgrade area shall be loosened to a minimum depth of two inches utilizing the teeth on the bucket of a backhoe or equivalent equipment.

- B. After loosening, the area shall be recompactd by tamping or with the tracks of a small bulldozer. No vibratory compaction of the subgrade shall take place. After the soils have been loosened, recompressed and inspected, Planting Mixture shall then be spread in lifts not greater than eight inches and compacted to a density between 76 and 80 % Standard Proctor Maximum Dry Density. Surface area of each lift shall be scarified by raking prior to placing next lift.
- C. Place and spread planting mixture and soil to a depth greater than required such that after settlement, finished grade blends smoothly with existing slope of land. Ensure proper drainage in an uninterrupted pattern free of hollows and pockets.
- D. Remove stiff clods, lumps, brush, roots, stumps, litter and other foreign material and stones over one inch in diameter and dispose of legally off site.

3.5 CLEANING

- A. Clean up debris generated under work of this section.
- B. Site Improvements
 - 1. Wash and sweep clean site improvements such as drainage and utility fixtures, pavements, existing plantings, and site furnishings.
 - 2. Clean site furnishings of grout, adhesives, concrete, and other debris.

3.6 PROTECTION

- A. Protect work of this section until Final Acceptance.
- B. Protect prepared soils from compaction by construction traffic and from contamination by

PART 4 – MEAUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 02970

LANDSCAPE MAINTENANCE

PART 1 - GENERAL

1.1 GENERAL

- A. The Work shall be performed in accordance with the following documents as issued by the Massachusetts Bay Transportation Authority:
 - 1. The Contract Specifications, which include Volume 1 DB Contract Terms and Conditions; Volume 2 Technical Provisions; and applicable Sections of Divisions 2 through 16.

1.2 DESCRIPTION OF WORK

- A. This Section contains the following:
 - 1. Post Planting Tree Care, Pruning, Monitoring and Aftercare
 - 2. Guaranty and replacement of unacceptable plants.
 - 3. Maintenance Manual.
- B. Related Sections include the following:
 - 1. Section 02310 – FINE GRADING
 - 2. Section 02930 – PLANTING
 - 3. Section 02932 – PLANTING SOILS

1.3 REFERENCES/STANDARDS

- A. Comply with applicable requirements of:
 - 1. Commonwealth of Massachusetts, Standard Specifications for Highways and Bridges, Department of Public Works, latest edition.
 - 2. American Association of Nurserymen, American Standards for Nursery Stock, (ANSI Z60.1), latest edition, published by the American Association of Nurserymen, 1250 I Street, N.W., Suite 500 Washington, D.C. 20005.
 - 3. Best Management Practices: Tree Planting. International Society of Arboriculture, P.O. Box 3129, Champaign, IL 61826-3129. 2005.
 - 4. American Standard for Pruning, ANSI A300-2001. American National Standards Institute, Inc. 1819 L Street, NW, Sixth Floor, Washington, DC 20036.

1.4 DEFINITIONS

- A. Maintenance: consists of keeping plants in healthy growing condition including watering, weeding, cultivating, re-mulching, tightening and repairing of guys, removal and replacement of dead plant material, resetting plants to proper grades or upright positions and maintaining saucer.

1.5 SUBMITTALS

- A. Submittals: in accordance with Volume 2 Technical Provisions, Subsection 2.7, “Design Submittal Review Management” and Subsection 2.8, “Construction Submittal Requirements”.
- B. Materials List: provide list of materials to be used in maintenance; materials shall be the same as approved in related sections:
 - 1. Fertilizers, soil amendments, testing see Section 02932 – PLANTING SOILS.
 - 2. Plant materials, mulch, and related materials, see Section 02930 - PLANTING.
- C. Maintenance Manual
 - 1. Submit a Maintenance Manual to the MBTA describing schedule and operations for on-going upkeep of the installed plants for the entire Guaranty Period. The manual shall address itself to:
 - a. Post Planting Plant Materials Care, Pruning, Monitoring and Aftercare including addressing care and long-term maintenance of the specified plants.
 - b. Guaranty and replacement of unacceptable plants.
 - 2. Provide specific information on the following items:
 - a. Post Planting Tree Care Monitoring and Aftercare including addressing care and long-term maintenance of the specified plants.
 - b. Fertilization: Fertilizing seasons; analysis for fertilizer selection; application rates and methods; preparation and conditions; application times; application equipment; post-application operations and care; precautions for fertilizer use.
 - c. Liming: Liming season; analysis for liming; application rate; method and equipment for application.
 - d. Pruning: Pruning goals and purposes; methods and techniques (relate to species); equipment; season; cleanup and disposal; precautions.
 - e. Miscellaneous plant maintenance: Weeding and weed control; pest and disease control; leaf and litter removal; professional assistance for plant care;
 - f. Replacement of unacceptable plants.
 - 3. Include a month-by-month calendar of maintenance procedures, indicating operations listed above.
 - 4. Submit a copy of maintenance manual to the MBTA for approval. Submit prior to planting completion. The MBTA may request revisions to manual to meet intent of project design.
 - 5. Submit three copies of manual to the MBTA at acceptance meeting for planting work. Acceptance shall not be granted until manual has been submitted and approved.

1.6 QUALITY ASSURANCE

- A. Qualifications: Design-Builder shall have minimum five years experience in landscape maintenance.
- B. Regulatory Requirements
 - 1. Secure permits, licenses, and pay fees including traffic control.
 - 2. Comply with laws, regulations, and quarantines for agricultural and horticultural products.

1.7 DELIVERY, STORAGE AND HANDLING

- A. Packing and Shipping: deliver materials in unopened containers bearing the manufacturer's name. Transport materials without damage. Protect finishes from abrasion, dirt, oils, grease, and chemicals. Pack materials to protect from weather.
- B. Acceptance at Site: verify in writing that delivered materials conform to specifications and approved submittals.
- C. Storage and Protection:
 - 1. Store materials in dry place, on pallets, off the ground; protect from sun.
 - 2. Protect materials from theft, damage, weather, dirt, oils, grease, and construction.

1.8 PROJECT/SITE CONDITIONS

- A. Environmental Requirements: do not work soils when dry, wet, or frozen.
 - 1. Field Test
 - a. Form soil in palm of hand, if soil retains shape and crumbles upon touching, the soil may be worked.
 - b. If soil will not retain shape it is too dry and shall not be worked.
 - c. If soil retains shape and will not crumble, it is too wet and shall not be worked.
- B. Planting Seasons: see Section 02930 – PLANTING.

1.9 SUBSTANTIAL COMPLETION

- A. Upon completion of planting, request the MBTA's review to determine if work is Substantially Complete. If work is determined to be Substantially Complete, the MBTA will issue a Letter of Substantial Completion that establishes the effective date of the start of the 90-day Maintenance Period and one year Guaranty Period.
 - 1. If work is not substantially complete, the MBTA will make a list of outstanding work to be done on a timely schedule agreed upon by Design-Builder and the MBTA.
 - 2. Design-Builder shall notify the MBTA when outstanding work is accomplished and ready for review. When outstanding work is complete, in the judgment of the MBTA, a Letter of Substantial Completion will be issued.

1.10 90-DAY MAINTENANCE PERIOD/PRELIMINARY ACCEPTANCE

- A. Maintain planting until the end of 90-day maintenance period and until the receipt of the Letter of Preliminary Acceptance. After the 90-day Maintenance Period, work will be reviewed for completeness.
- B. Plantings shall be in thriving and vigorous condition at the time of review for Preliminary Acceptance.
 - 1. If plantings are acceptable, the MBTA will issue a Letter of Preliminary Acceptance establishing the effective date of the one-year Guaranty Period.
 - 2. Replace plants that are dead or, as determined by the MBTA, are in an unhealthy or unsightly condition, and have lost their natural shape due to dead branches, or other causes.
 - 3. Replacement work shall be done immediately and in accordance with related work of other sections.
 - 4. At the conclusion of remedial work, the MBTA will review work and extend the Maintenance Period another 90 days to incorporate new plantings.

1.11 FINAL ACCEPTANCE

- A. Start of Guaranty Period: when the MBTA issues letter of Preliminary Acceptance.
- B. Quarterly reviews will be made with Design-Builder and the MBTA during guaranty period. Reviews will assess condition of installed plant materials.
- C. Plant material to be alive and in healthy, vigorous condition.
- D. Replace plants that are dead or, as determined by the MBTA, are in an unhealthy or unsightly condition, and have lost their natural shape due to dead branches, or other causes.
- E. End of Guaranty Period: one year from date of Preliminary Acceptance, the MBTA will review plantings. If plantings are acceptable, the MBTA will issue a letter of Final Acceptance. If plantings are unacceptable, plantings shall be replaced until condition of plantings are acceptable as determined by the MBTA.
- F. Upon receipt of letter of Final Acceptance, the project becomes responsibility of the the MBTA.

PART 2 - MATERIALS

2.1 POST PLANTING TREE CARE, PRUNING, MONITORING AND AFTERCARE

- A. Materials for Planting Maintenance
 - 1. Materials utilized during the maintenance period shall be the same specified in the work of the related sections:
 - a. Fertilizers, soil amendments, testing, see Section 02932 – PLANTING SOILS.
 - b. Plants and related materials, see Section 02930 - PLANTING.

- B. Biological, Herbicidal and Other Pest Control
 - 1. Materials and Specifications shall be by a licensed pest control operator, with authority to purchase, utilize, and specify agricultural chemicals and agricultural products.
 - 2. Use the least hazardous, least intrusive materials and methods.

2.2 EQUIPMENT

- A. Vehicles: in good working order so oil and grease does not stain pavements and poison plantings. Signs identifying the vehicles shall be clearly displayed.
- B. Machinery: in good working order so oil and grease does not stain pavements and poison plantings.

2.3 WATER

- A. Water: Furnished by Design-Builder, suitable for irrigation and free from ingredients harmful to plant life.
- B. Hose and other watering equipment: furnished by Design-Builder.

PART 3 - EXECUTION

3.1 PROTECTION FROM AGRICULTURAL CHEMICALS

- A. Protect site improvements from contact with agricultural chemicals, soil amendments, and fertilizers.

3.2 PLANTS

- A. Maintain plants in vigorous condition throughout the Maintenance and Guaranty Periods.
- B. Replace plants that are missing, dead, not true to name or size as specified, or not in satisfactory growth, as determined by the MBTA. Replace plants found unacceptable within one month or in first month of next growing season, whichever comes first.
- C. Plants shall show a minimum of 75% healthy head with obvious growth since planting. Signs of disease, injury, or damage shall have been successfully treated or plant shall be rejected as determined by the MBTA.
- D. Replacements plants shall be same kind and size as specified in plant list. Furnish and plant. Cost of replacement borne by Design-Builder except where it can be shown loss resulted from vandalism, fire, theft, or other causes beyond Design-Builder's control. Restore areas damaged or disturbed by replacement operations to their original condition.

3.3 SOIL DRAINAGE

- A. Observe drainage in plant soil areas with hand soil augur.
- B. Verify plant soil areas are draining; plant soils that are not draining shall be identified on the plan and brought to the attention of the MBTA.

3.4 PRUNING

- A. Pruning to be performed in accordance with American Nurserymen's Association Standards and will be overseen by an MCLP or certified Arborist. Pruning to preserve natural character of plant and as directed by the MBTA. No leaders shall be cut.
- B. Prune trees and shrubs only with approval of the MBTA to remove limbs that are below 7' above finished grade to maintain pedestrian clearance, remove dead, broken and crossing branches. Plants shall not be heavily pruned at the time of planting. In no case shall more than one-quarter of the branching structure be removed.
- C. Pruning is required at planting time to correct defects in the tree structure, including removal of injured branches, double leaders, waterspouts, suckers, and interfering branches. Healthy lower branches and interior small twigs shall not be removed except as necessary to clear walks and roads. Retain the normal or natural shape of the plant.
- D. Prune with clean, sharp tools. Dead wood or suckers and broken or badly bruised branches shall be removed back to live bud, branch, or stem.
- E. Pruning above head height shall be done from a hydraulic man-lift or using other mechanisms such that it is not necessary to climb the tree.

3.5 TREE STABILIZATION SYSTEM

- A. Trees: maintain plumb; adjust flexible ties.
- B. Each tree shall be stabilized with a subsurface stabilization system approved by the MBTA immediately following planting. Plants shall stand be maintained plumb.

3.6 FINISH GRADE

- A. Maintain finish grades around plantings, at pavement edges, and at irrigation fixtures.

3.7 FIELD QUALITY CONTROL

- A. Post Plant Soil Tests: see Section 02930 - PLANTING

3.8 ADJUSTING

- A. Re-set settled plants to proper grade and position.
- B. Restore planting saucer and adjacent material.

3.9 CLEANING

- A. Clean up, remove and dispose off-site excess planting mixture, soil and debris generated under work of this section.
- B. Remove and dispose of stakes, guys and other accessories at end of Guaranty Period.
- C. Wash and sweep clean site improvements and building surfaces. Clean spills and oversprays immediately.

- D. Repair damage caused by maintenance operations.

3.10 PROTECTION

- A. Protect work of this section until Final Acceptance.
- B. Protect planted areas and soils from compaction by construction traffic and from contamination by construction materials.

PART 4 – MEAUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 03371

SHOTCRETE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies shotcrete applied by a dry-mix or wet-mix process.
- B. Shotcrete may be used for placing the concrete facing on steel sheet pile walls and for other uses throughout the project.

1.2 RELATED SECTIONS

- A. Section 01800 – SUSTAINABILITY REQUIREMENTS
- B. Section 03300 – CAST-IN-PLACE CONCRETE
- C. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS

1.3 DEFINITIONS

- A. Shotcrete: A prepackaged, single-component, shrinkage-compensated, microsilica enhanced, cement concrete with non-metallic fibers, applied by the wet or dry process, from a spray nozzle by means of compressed air.
- B. Dry-Mix Process: Shotcrete which is applied by the addition of water at the spray nozzle located on the end of the delivery hose.
- C. Wet-Mix process: Shotcrete which is applied with its ingredients mixed prior to introduction into a delivery hose.
- D. Rebound: Dry shotcrete that is rebounded from the wall, and treated as waste.
- E. Waste: Shotcrete that is used for charging the hoses, is mixed or sprayed, and is not applied to the walls as part of the work.

1.4 SUBMITTALS

- A. Product Data: For manufactured materials and products including reinforcement and forming accessories, shotcrete materials, admixtures, and curing compounds.
- B. Shop Drawings: For details of fabricating, bending, and placing reinforcement. Include support and anchor details, number and location of splices, and special reinforcement required for openings through shotcrete structures.
- C. Samples: Approximately 24 inches by 24 inches by 2 inches thick, to illustrate quality of finishes, colors, and textures of exposed surfaces of shotcrete.
- D. Design Mixes: For each shotcrete mix.
- E. Qualification Data: For Installer and testing agency.

- F. Material Test Reports: For shotcrete materials.
- G. Field quality-control test reports.

1.5 QUALITY ASSURANCE

- A. Manufacturer's Technical Representative: Furnish and pay for the services of a technical field representative during project startup to insure the proper application of the shotcrete system.
- B. Installer Qualifications:
 - 1. The Installer shall have a minimum of four years in the application of wet process shotcrete for concrete restoration. The contractor must have a minimum of 5 years of experience in similar types of work.
 - 2. Nozzlemen before employment on the work shall be a qualified Nozzleman as specified in ACI 506.2. In addition, the Foremen, Nozzlemen, and Crewmen shall satisfy the MBTA that each has done satisfactory work in similar capacities elsewhere for a sufficient period of time to be fully qualified to properly perform the work in accordance with the requirements indicated. Foremen shall have had at least three years' experience as nozzlemen and at least two years' experience on similar work. Nozzlemen shall be qualified workmen, having had at least three years' experience in similar work.
 - 3. Hold Point - Each shotcreting crew will be required to fabricate one acceptable test panel for each shooting position which the crew will encounter in the work, prior to application of shotcrete in the work, using the exact type of equipment intended to be used by the crew as identified by this specification.
 - 4. Should the results of control testing indicate that deficient shotcrete application is being produced by a crew, the crew may be required to be requalified for the shooting position in question.
- C. Testing Agency Qualifications: An independent agency qualified according to ASTM C 1077 and ASTM E 329 for testing indicated, and acceptable to authorities having jurisdiction.
- D. Comply with provisions of the following, unless more stringent requirements are indicated:
 - 1. ACI 301 "Specifications for Structural Concrete".
 - 2. ACI 506.2 "Specification for Shotcrete".
- E. Preconstruction Testing Service: Contractor shall engage a qualified independent testing agency to perform preconstruction testing and inspections indicated below:
 - 1. Produce test panels before shotcrete placement according to requirements in ACI 506.2 and ASTM C 1140 for each design mix, shooting orientation, and nozzle operator. Produce test panels with dimensions of 24 by 24 inches minimum and of average thickness of shotcrete, but not less than 5 inches. From each test panel, testing agency will obtain six test specimens: one set of three specimens unreinforced and one set of three specimens reinforced. Agency will perform the following:
 - a. Test each set of unreinforced specimens for compressive strength according to ASTM C42.
 - b. Visually inspect each set of reinforced shotcrete cores taken from test panels and determine mean core grades according to ACI 506.2.
- F. Sample Area: Apply a prepackaged single component, microsilica enhanced, cement shotcrete on a

sample area not less than ten square feet in size. When approved, the sample area shall serve as a standard of acceptance for all subsequent application of products specified hereinafter.

G. Determination of Shotcrete Proportions and Placement Procedures:

1. Notification Point - Not less than 30 days in advance of the shotcrete placement, notify the MBTA in writing as to the intended sources of shotcrete materials. Appropriate samples of shotcrete materials will be obtained by the contractor. Forward such samples to the MBTA for testing and acceptance.
2. At a time and place mutually agreeable to the Contractor and MBTA, provide the following for use in determination of shotcrete proportions and placement procedures, in sufficient quantities to perform the testing herein specified:
 - a. Shotcrete materials as accepted
 - b. Plywood back forms, each two feet square
 - c. Reinforcement of the types, sizes, and configurations to be used in the shotcrete, sufficient to place in one half of each test panel
 - d. Equipment of the exact type proposed for use in applying shotcrete
 - e. Personnel for operation of the shotcreting equipment
3. For the prepackaged shotcrete mix, fabricate test panels for each shooting position (i.e. slab, vertical, overhead) to be encountered in the work. Use trial mixes as designated by the Engineer, and modify as directed by the Engineer to produce satisfactory test panels. Test panels shall have reinforcement installed over one half of the panel in the sizes and configurations to be installed in the work.
4. Satisfactory test panels shall consist of a minimum 5 inch thickness of dense, uniform shotcrete without rebound inclusions, segregation, voids, or weakness of bond between layers. For each satisfactory test panel produced, record the water content and details of the placement procedure such as nozzle distance, rate and angle of application, thickness of layers, time lapse between layers, time lapse between mixing and application, and the like. Cure satisfactory test panels in accordance with ASTM C31.
5. Satisfactory test panels will be tested by the MBTA to determine conformance of the shotcrete to the specified requirements. Where the results of tests are unacceptable, fabricate additional satisfactory test panels using materials, mixing and application equipment, or application procedures, until acceptable test panels are achieved.
6. Hold Point - Do not apply any shotcrete in the work until the prepackaged mix and placement equipment and procedures have been accepted as specified herein. Approved mockups may become part of the completed Work if undamaged at time of Substantial Completion. Damaged panels must be removed and replaced at no additional cost to the MBTA.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials to the site in original packages or containers bearing the manufacturer's labels and identification. Liquid admixtures if used must never experience temperatures below their recommended minimum temperature. Shotcrete installer must supply shipping records attesting to this fact. Materials experiencing temperatures below their minimum temperature will be rejected and shall not be used in the work. Materials shall be replaced at no additional cost to the MBTA.
- B. Store and handle materials to prevent inclusion of foreign matter and water and store at manufacturer's recommended temperatures and humidity. The shipping and storage temperature for the material shall be between 50 and 90 degrees F, unless indicated otherwise.

- C. Protection:
 - 1. Protect the railroad tracks, platforms, catenary system and ancillary systems from overspray and buildup of shotcrete, using plywood shields or other methods approved by the MBTA.
 - 2. Protect electrical equipment, tunnel and railroad systems, including but not limited to CCTV, signal, telephone, track, and electrical cables, from overspray.

1.7 PROJECT CONDITIONS

- A. Cold-Weather Shotcreting: Protect shotcrete work from physical damage or reduced strength caused by frost, freezing, or low temperatures according to ACI 306.1 and as follows:
 - 1. Discontinue shotcreting when ambient temperature is 40 deg F and falling. Uniformly heat water and aggregates before mixing to obtain a shotcrete shooting temperature of not less than 50 deg F and not more than 90 deg F.
 - 2. Do not use frozen materials or materials containing ice or snow.
 - 3. Do not place shotcrete on frozen surfaces or surfaces containing frozen materials.
 - 4. Do not use calcium chloride, salt, or other materials containing antifreeze agents.
- B. Hot-Weather Shotcreting: Mix, place, and protect shotcrete according to ACI 305R when hot-weather conditions and high temperatures would seriously impair the quality and strength of shotcrete, and as follows:
 - 1. Cool ingredients before mixing to maintain shotcrete temperature at time of placement below 100 deg F for dry mix or 90 deg F for wet mix.
 - 2. Reduce temperature of reinforcing steel and receiving surfaces below 100 deg F before shotcreting.

PART 2 - PRODUCTS

2.1 FORM MATERIALS

- A. Forms: Form-facing panels that will provide continuous, straight, smooth, concrete surfaces. Furnish panels in largest practicable sizes to minimize number of joints.

2.2 REINFORCING MATERIALS

- A. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.
- B. Low-Alloy-Steel Reinforcing Bars: ASTM A 706/A 706M, deformed.
- C. Galvanized Reinforcing Bars: ASTM A 767/A 767M, Class II, zinc coated, hot-dip galvanized after fabrication and bending, as follows:
 - 1. Steel Reinforcement: ASTM A 615/A 615M, Grade 60, deformed.
- D. Plain-Steel Wire: ASTM A 82, galvanized after fabrication.
- E. Plain-Steel-Welded Wire Fabric: ASTM A 185, fabricated from galvanized steel wire into flat sheets.
- F. Deformed-Steel-Welded Wire Fabric: ASTM A 497, flat sheet.
- G. Supports: Bolsters, chairs, spacers, ties, and other devices for spacing, supporting, and fastening

reinforcing steel in place according to CRSI's "Manual of Standard Practice" and as follows:

1. For uncoated reinforcement, use CRSI Class 1, plastic-protected bar supports.
 2. For zinc-coated reinforcement, use galvanized wire or dielectric-polymer-coated wirebar supports.
- H. Reinforcing Anchors: ASTM A 36/A 36M, unheaded rods or ASTM A 307, Grade A, hex-head bolts; carbon steel; and carbon-steel nuts.
1. Finish: Hot-dip zinc coating, ASTM A 153/A 153M, Class C.
- I. Headed welded studs shall conform to Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS.

2.3 SHOTCRETE MATERIALS

- A. Portland Cement: ASTM C 150, Type I or II. Use only one brand and type of cement for Project.
1. Fly Ash: ASTM C 618, Class F only.
 2. Ground Granulated Blast-Furnace Slag: ASTM C 989, Grade 100 or 120.
- B. Silica Fume: ASTM C 1240, amorphous silica.
- C. Normal-Weight Aggregates: ASTM C 33, from a single source, and as follows:
1. Aggregate Gradation: ACI 506R, Gradation No. 1 with 100 percent passing 3/8-inch sieve.
- D. Lightweight Aggregates: ASTM C 330.
1. Aggregate Gradation: ACI 506R, Gradation No. 1 with 100 percent passing 3/8-inch sieve.
- E. Water: Potable, complying with ASTM C 94/C 94M, free from deleterious materials that may affect color stability, setting, or strength of shotcrete.
- F. Synthetic Fiber: Fibrillated polypropylene fibers engineered and designed for use in shotcrete, complying with ASTM C 1116, Type III, not less than 3/4 inch long.
- G. Ground Wire: Provide one of the following:
1. High-strength steel wire, 0.8 to 1 mm in diameter.
 2. Stainless steel thickness pins, 0.8 to 1 mm in diameter.
- H. Joint Filler Strips: ASTM D 1751, asphalt-saturated cellulosic fiber, ASTM D 1752, cork or self-expanding cork, or ASTM D 7174, closed-cell polyolefin.

2.4 CHEMICAL ADMIXTURES

- A. General: ASTM C 1141, Class A or B, but limited to the following admixture materials. Provide admixtures for shotcrete that contains not more than 0.1 percent chloride ions. Certify compatibility of admixtures with each other and with other cementitious materials.
1. Air-Entraining Admixture: ASTM C 260.

2. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
3. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
4. Water-Reducing and Accelerating Admixture: ASTM C 494/C 494M, Type E.
5. High-Range, Water-Reducing Admixture: ASTM C 494/C 494M, Type F.
6. Accelerating Admixture: ASTM C 494/C 494M, Type C.

2.5 CURING MATERIALS

- A. Water: Potable.
- B. Clear, Waterborne, Membrane-Forming Curing Compound: ASTM C 309, Type 1, Class B, as recommended by the shotcrete manufacturer.

2.6 SHOTCRETE MIXTURES (WET AND DRY)

- A. General Intent: It is the intent that the prepackaged materials used for this work shall be adequate with a demonstrated successful track record, for the purpose intended and under the conditions normally expected in work of this type. All materials for the shotcrete shall be provided by the same manufacturer.
- B. Mixes: Provide a prepackaged single component, specially formulated combination of shrinkaged compensated microsilica and fibers along with processed cement and carefully graded aggregate resulting in a high build, low absorption, machine applied mortar. The low water cement ratio will insure high early and ultimate strengths. The combination of microsilica and fibers shall result in a shotcrete with tremendous adhesion to the substrate concrete with extremely low rebound and excellent freeze-thaw resistance.

Property	Conditions	Requirement
Coefficient of Thermal Expansion		6.0 X 10 ⁻⁶ deg. C max
Compressive Strength ASTM C-109	@ 1 day	3,000 psi min
-	@ 7 days	6,000 psi min
-	@ 28 days	7,500 psi min
Flexural Strength ASTM C-348	@ 28 days	1,500 psi min
Splitting Tensile Strength ASTM C-882	@ 28 days	650 psi min
Slant Shear Strength ASTM C-88	@ 28 days	2,250 psi min
Water Absorption ASTM C-140		1% absorb max
Freeze-Thaw Resistance MSMT-725, MDDOT	@ 28 days	-0.162% max
Setting time		
Working Time		45 minutes max
Initial Set	@ 75°F 50% RH	2 hours max
Final Set	@ 75°F 50% RH	3 hours max
Shrinkage ASTM C-157	@ 28 days	0.04% max
Wet Density		130 lb/cf (min.)

2.7 SHOTCRETE EQUIPMENT

- A. Mixing Equipment: Capable of thoroughly mixing shotcrete materials in sufficient quantities to maintain continuous placement, as recommended by the shotcrete manufacturer.
- B. Dry-Mix Delivery Equipment: Capable of discharging aggregate-cement mixture into delivery hose under close control and maintaining continuous stream of uniformly mixed materials at required velocity to discharge nozzle. Equip discharge nozzle with manually operated water-injection system for directing even distribution of water to aggregate-cement mixture.
 - 1. Provide uniform, steady supply of clean, compressed air rated to deliver air at 350-750 CFM to maintain constant nozzle velocity while simultaneously operating blow pipe for cleaning away rebound.
 - 2. Use a rotary pot-type shotcrete machine with a Browning-type nozzle. Provide hoses of sufficient size to allow rapid delivery of the dry mix shotcrete to the nozzle.
 - 3. Provide water supply with uniform pressure at discharge nozzle to ensure uniform mixing with aggregate-cement mix. Provide water pump to system if line water pressure is inadequate.
 - 4. Provide a premoistener at the dry mix pump for minimizing dust for work within the tunnels, or as directed by the MBTA.
- C. Wet-Mix Delivery Equipment: Capable of discharging aggregate-cement-water mixture accurately, uniformly, and continuously.
 - 1. Use a rotary stator pump capable of introducing materials to the delivery hose at a uniform rate, with ejection from the nozzle at velocities that will afford adherence of material to the surface to be treated with a minimum rebound and maximum adherence and density. Swing tube shotcrete pumps will not be allowed.
 - 2. The air compressor shall be rated between 350 - 750 cubic feet per minute and capable of 100 - 125 psi pressure. Gunning is performed at 50 - 85 psi or as recommended by the product manufacturer.
 - 3. The nozzle shall be a center feed nozzle, Thompson type, or approved equal.
 - 4. Hoses shall be made for wet-process shotcrete with pure gum rubber tube, good flexibility and high resistance to kinking. The contractor shall submit for approval by the Engineer a suitable method of ducting through the fresh air flues. Hose length is limited to a maximum of 100 feet from pump to nozzle and must be no larger than 2 inches in diameter.

2.8 BATCHING AND MIXING

- A. Dry-Mix Process: Measure mix proportions by weight batching according to ASTM C 94/C 94M or by volume batching complying with ASTM C 685/C 685M requirements, or as recommended by the shotcrete manufacturer.
 - 1. In volume batching, adjust fine-aggregate volume for bulking. Test fine-aggregate moisture content at least once daily to determine extent of bulking.
 - 2. Prepackaged shotcrete materials may be used at Contractor's option. Predampen prepackaged shotcrete materials and mix before use.

- B. Wet-Mix Process: Measure, batch, mix, and deliver shotcrete according to ASTM C 94/C 94M and furnish batch ticket information.
 - 1. Comply with ASTM C 685/C 685M when shotcrete ingredients are delivered dry and proportioned and mixed on-site.

PART 3 - EXECUTION

3.1 PREPARATION

- A. General Inspection: Prior to installation of materials, inspect the substrate and report any unsatisfactorily conditions. Commencement of work shall constitute Contractor's acceptance of substrate.
- B. Concrete :
 - 1. Areas to be patched or resurfaced shall be clean, sound and free of standing or flowing water.

The concrete surface and exposed reinforcing steel, shall be waterblasted at a pressure in excess of 2,500 psi to remove all contaminants and rust. Only areas that can be successfully shotcreted in one shift shall be cleaned and have shotcrete applied. If cleaned areas are not shotcreted during the same shift, cleaning that area shall be rewashed by the contractor at no expense to the owner.
 - 2. The demolition of the existing shotcrete shall be performed by using chipping hammers, Pavement breakers and robotic demolition equipment will not be allowed. The Chipping Hammer must not exceed 30 pounds with the bit removed. Aluminum chipping hammers will not be allowed.
 - 3. Where reinforcing steel is encountered with insufficient concrete cover, less than 2 inches, the concrete around and under the bar(s) shall be chipped out to a depth where the bar(s) covered with at least 1 in. of shotcrete. Any reinforcing that has been exposed shall be realigned, if required, to ensure proper concrete cover. Embedded steel that has been completely exposed shall be cleaned of loose scale and corrosion prior to shotcrete repair application.
 - 4. The contractor shall replace missing or deteriorated reinforcing steel as directed.
 - 5. Abrasive blast or hydroblast existing surfaces that do not require chipping to remove paint, oil, grease, or other contaminants and to provide roughened surface for proper shotcrete bonding.
- C. Earth: Compact and trim to line and grade before placing shotcrete. Do not place shotcrete on frozen surfaces. Dampen surfaces before shotcreting.
- D. Rock: Clean rock surfaces of loose materials, mud, and other foreign matter that might weaken shotcrete bonding.
- E. Steel: Clean steel surfaces by abrasive blasting according to SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning".

3.2 FORMS

- A. General: Design, erect, support, brace, and maintain forms, according to ACI 301, to support shotcrete and construction loads and to facilitate shotcreting. Construct forms so shotcrete members

and structures are secured to prevent excessive vibration or deflection during shotcreting.

1. Fabricate forms to be readily removable without impact, shock, or damage to shotcrete surfaces and adjacent materials.
 2. Construct forms to required sizes, shapes, lines, and dimensions using ground wires and depth gages to obtain accurate alignment, location, and grades in finished structures. Construct forms to prevent mortar leakage but permit escape of air and rebound during shotcreting. Provide for openings, offsets, blocking, screeds, anchorages, inserts, and other features required in the Work.
- B. Form openings, chases, recesses, bulkheads, keyways, and screeds in formwork. Determine sizes and locations from trades providing such items. Accurately place and securely support items built into forms.

3.3 STEEL REINFORCEMENT

- A. General: Comply with CRSI's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.
- B. Clean reinforcement of loose rust and mill scale, earth, ice, and other materials that weaken shotcrete bonding.
- C. Securely embed reinforcing anchors into existing substrates, located as required.
- D. Accurately position, support, and rigidly secure reinforcement against displacement by formwork, construction, or shotcreting. Locate and support reinforcement by metal chairs, runners, bolsters, spacers, and hangers, as required.
- E. Place reinforcement to obtain minimum coverage for shotcrete protection. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during shotcreting. Set wire ties with ends directed into shotcrete, not toward exposed shotcrete surfaces.
- F. Install welded wire fabric in lengths as long as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.
- G. Welded wire fabric shall be cut to fit the shape of the patch and fastened securely in place. Use approved spacers and tie wire at 16 inch intervals in both directions. Install fasteners around the perimeter of the welded wire fabric at a 16 inch interval. Wire fabric shall not be placed and secured until the abrasive blasting is completed.

3.4 JOINTS

- A. Construction Joints: Locate and install construction joints tapered to a 1:1 slope where joint is not subject to compression loads and square where joint is perpendicular to main reinforcement. Continue reinforcement through construction joints, unless otherwise indicated.
- B. Contraction Joints: Construct contraction joints in shotcrete using saw cuts 1/8-inch-wide-by-1/3 slab depth or joint-filler strips 1/4-inch-wide-by-1/3 shotcrete depth, unless otherwise indicated.
1. After shotcrete has cured, remove strip inserts and clean groove of loose debris.
 2. Space joints at centers indicated horizontally and vertically.

3. Tool edges round on each side of strip inserts if floated or troweled finishes are required.

3.5 ALIGNMENT CONTROL

- A. Ground Wires: Install ground wires to establish thickness and planes of shotcrete surfaces. Install ground wires at corners and offsets not established by forms. Pull ground wires taut and position adjustment devices to permit additional tightening.
 1. Stainless steel thickness pins may be used as a substitute for ground wires.

3.6 EMBEDDED ITEMS

- A. Place and secure anchorage devices and other embedded items required for adjoining work that is attached to or supported by shotcrete. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

3.7 APPLICATION

- A. Apply temporary protective coverings and protect adjacent surfaces against deposit of rebound and overspray or impact from nozzle stream.
- B. Moisten wood forms immediately before placing shotcrete where form coatings are not used.
- C. Apply shotcrete according to ACI 506.2.
- D. Apply dry-mix shotcrete materials within 45 minutes after predampening and wet-mix shotcrete materials within 90 minutes after batching.
- E. Deposit shotcrete continuously in multiple passes, to required thickness, without shadowing, cold joints, or laminations developing. Place shotcrete with nozzle held perpendicular to receiving surface. Begin shotcreting in corners and recesses. Remove and dispose of rebound and overspray materials during shotcreting to maintain clean surfaces and to prevent rebound entrapment.
- F. Maintain reinforcement in position during shotcreting. Place shotcrete to completely encase reinforcement and other embedded items. Maintain steel reinforcement free of overspray and prevent buildup against front face during shotcreting.
- G. Do not place subsequent lifts until previous lift of shotcrete is capable of supporting new shotcrete.
- H. Do not permit shotcrete to sag, slough, or dislodge.
- I. Remove hardened overspray, rebound, and laitance from shotcrete surfaces to receive additional layers of shotcrete; dampen surfaces before shotcreting.
- J. Do not disturb shotcrete surfaces before beginning finishing operations.
- K. Remove ground wires or other alignment control devices after shotcrete placement.
- L. Shotcrete Core Grade: Apply shotcrete to achieve mean core grades not exceeding 2.5 according to ACI 506.2, with no single core grade exceeding 3.0.
- M. Installation Tolerances: Place shotcrete without exceeding installation tolerances permitted by ACI 117R, increased by a factor of 2.

3.8 SURFACE FINISHES

- A. General: Finish shotcrete according to descriptions in ACI 506R for the following finishes:
- B. Natural Finish:
 - 1. Gun Finish: Natural undisturbed finish.
 - 2. Finish-Coat Finish: After screeding and rodding surface, apply shotcrete finish coat, 1/4 to 1 inch thick, using ACI 506R, Gradation No. 1, fine-screened sand modified with maximum aggregate size not exceeding No. 4 sieve to provide a finish of uniform texture and appearance.
 - 3. Wood Float: After screeding surface, finish the shotcrete using a wood float.
 - 4. Steel Trowel: Finish the shotcrete using a steel trowel, in locations where a smooth finish is required.

3.9 CURING

- A. Protect freshly placed shotcrete from premature drying and excessive cold or hot temperatures.
- B. Start initial curing as soon as free water has disappeared from shotcrete surface after placing and finishing.
- C. Curing Exposed Surfaces: Cure shotcrete by one of the following methods:
 - 1. Moisture Curing: Keep surfaces continuously moist for at least five days with water, continuous water-fog spray, water-saturated absorptive covers, or moisture-retaining covers. Lap and seal sides and ends of covers.
 - 2. Curing Compound: Apply curing compound uniformly in continuous operation by power spray according to manufacturer's written instructions. Recoat areas subjected to heavy rainfall within three hours after initial application. Maintain continuity of coating and repair damage during curing period. Apply curing compound to natural or gun-finished shotcrete at rate of 1 gal./100 sq. ft.
- D. Curing Formed Surfaces: Cure formed shotcrete surfaces by moist curing with forms in place for full curing period or until forms are removed. If forms are removed, continue curing by methods specified above, as applicable.

3.10 FORM REMOVAL

- A. Forms not supporting weight of shotcrete may be removed after curing at not less than 50 deg F for 24 consecutive hours after gunning, provided shotcrete is hard enough not to be damaged by form-removal operations and provided curing and protecting operations are maintained.
 - 1. Leave forms supporting weight of shotcrete in place until shotcrete has attained design compressive strength. Determine compressive strength of in-place shotcrete by testing representative field-cured specimens of shotcrete.
 - 2. Remove forms only if shores have been arranged to permit removal of forms without loosening or disturbing shores.

- B. Clean and repair surfaces of forms to be reused in the Work. Split, frayed, delaminated, or otherwise damaged form-facing materials are unacceptable for exposed surfaces. Apply new form-coating compound as specified for new formwork.

3.11 FIELD QUALITY CONTROL

- A. Contractor shall engage a qualified independent testing agency to sample materials, visually grade cores, perform tests, and submit reports during shotcreting.
- B. Shotcrete Temperature: ASTM C 1064/C 1064M; 1 test hourly when air temperature is 40 deg F and below and when 80 deg F and above, and 1 test for each set of compressive-strength specimens.
- C. Test Panels: Make a test panel, reinforced as in structure, for each shotcrete mix and for each workday or for every 50 cu. yd. of shotcrete placed; whichever is less. Produce test panels with dimensions of 24 by 24 inches minimum and of average thickness of shotcrete, but not less than 4-1/2 inches. From each test panel, testing agency will obtain six test specimens: one set of three specimens unreinforced and one set of three specimens reinforced.
 - 1. Test each set of unreinforced specimens for compressive strength according to ASTM C 1140 and construction testing requirements in ACI 506.2.
 - 2. Visually inspect each set of reinforced shotcrete cores taken from test panels and determine mean core grades according to ACI 506.2.
- D. In-Place Shotcrete: Take a set of 3 unreinforced cores for each mix and for each workday or for every 50 cu. yd. of shotcrete placed; whichever is less. Test cores for compressive strength according to ACI 506.2 and ASTM C 42. Do not cut steel reinforcement.
- E. Strength of shotcrete will be considered satisfactory when mean compressive strength of each set of 3 unreinforced cores equals or exceeds 85 percent of specified compressive strength, with no individual core less than 75 percent of specified compressive strength.
 - 1. Mean compressive strength of each set of 3 unreinforced cubes shall equal or exceed design compressive strength with no individual cube less than 88 percent of specified compressive strength.

3.12 REPAIRS

- A. Remove and replace shotcrete that is delaminated or exhibits laminations, voids, or sand/rock pockets exceeding limits for specified core grade of shotcrete.
 - 1. Remove unsound or loose materials and contaminants that may inhibit bond of shotcrete repairs.
Chip or scarify areas to be repaired to extent necessary to provide sound substrate. Cut edges square and 1/2 inch deep at perimeter of work, tapering remaining shoulder at 1:1 slope into cavity to eliminate square shoulders. Dampen surfaces and apply new shotcrete.
- B. Repair core holes from in-place testing according to repair provisions in ACI 301 and match adjacent finish, texture, and color.

3.13 CLEANING

- A. Immediately Remove and dispose of rebound and overspray materials from final shotcrete surfaces and areas not intended for shotcrete placement.

PART 4 - MEASUREMENT AND PAYMENT

4.1 MEASUREMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 03410

PLANT-PRECAST STRUCTURAL CONCRETE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies plant-precast structural concrete units.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. SUSTAINABILITY REQUIREMENTS - Volume 2 Technical Provisions Exhibit 2I "Additional Project Requirements"
 - 2. Section 02202 – MECHANICALLY STABILIZED EARTH RETAINING WALLS
 - 3. Section 02356 – SOLDIER PILE AND LAGGING RETAINING WALLS
 - 4. Section 02358 – SOIL NAIL RETAINING WALLS
 - 5. Section 02359 – MODULAR PRECAST BLOCK RETAINING WALLS
 - 6. Section 03300 – CAST-IN-PLACE CONCRETE
 - 7. Section 07842 – FIRE-RESISTIVE JOINT SYSTEMS; joint filler materials for fire-resistance-rated construction.
 - 8. Section 07920 – JOINT SEALANTS; elastomeric joint sealants and sealant backings.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Design Mixes: For each precast concrete mix. Include compressive strength and water absorption tests.
- C. Shop Drawings: Detail fabrication and installation of precast structural concrete units. Indicate member locations, plans, elevations, dimensions, shapes, cross sections, openings, support conditions and types of reinforcement, including special reinforcement.
 - 1. Indicate welded connections by AWS standard symbols. Detail loose and cast-in hardware, inserts, connections, and joints, including accessories.
 - 2. Indicate locations and details of anchorage devices to be embedded in other construction.
 - 3. Indicate location of each precast unit by same identification mark placed on unit.
 - 4. Indicate estimated camber for slabs with concrete toppings.
 - 5. Include and locate openings larger than 10 inches.
 - 6. Indicate location of lifting points and or embedded lifting devices.
- D. Samples: For each type of finish indicated on exposed surfaces of precast structural concrete units, in sets of 3, illustrating quality of finishes, colors, and textures; approximately 12 inches by 12 inches by 2 inches.
- E. Samples of bearing pads.

- F. Welding Qualifications: Copies of qualifications for welding procedures and personnel.
- G. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects with project names and addresses, names and addresses of architects and owners, and other information specified.
- H. Material Certificates: Signed by manufacturers certifying that each of the following items complies with requirements:
 - 1. Concrete materials.
 - 2. Reinforcing materials and prestressing tendons.
 - 3. Admixtures.
 - 4. Bearing pads.
- I. Inspection and test reports from independent testing agency.
- J. Design calculations: Shall be prepared by a Professional Engineer, registered in the Commonwealth of Massachusetts, hired by the Design-Builder, indicating the handling, transportation and erection stresses of the precast and prestressed concrete units. In addition, the design calculations shall include the sizing of all lifting devices that are to be embedded in the units. Calculations shall be submitted for review and approval prior to fabrication.

1.3 QUALITY CONTROL/QUALITY ASSURANCE

- A. Quality Control shall be in accordance with relevant portion of Section 03300 CAST-IN-PLACE CONCRETE.
- B. Installer Qualifications: An experienced installer who has completed precast structural concrete work similar in material, design, and extent to that indicated for this Project and whose work has resulted in construction with a record of successful in-service performance.
- C. Fabricator Qualifications: A firm that has plant certification by the Precast Concrete Institute and is experienced in manufacturing precast structural concrete units similar to those indicated for this Project and with a record of successful in-service performance. The plant is subject to inspection by the MBTA.
- D. Testing Agency Qualifications: An independent testing agency, acceptable to the MBTA, qualified according to ASTM C 1077 and ASTM E 329 to conduct the testing indicated, as documented according to ASTM E 548.
- E. Design Standards: Comply with ACI 318 and the design recommendations of PCI MNL 120, "PCI Design Handbook--Precast and Prestressed Concrete".
- F. Quality-Control Standard: For manufacturing procedures and testing requirements, quality-control recommendations, and camber and dimensional tolerances for types of units required, comply with PCI MNL 116, "Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products".
- G. Welding: Qualify procedures and personnel according to AWS D1.1, "Structural Welding Code--Steel"; and AWS D1.4, "Structural Welding Code--Reinforcing Steel".

- H. Calculated Fire Resistance: Where indicated, provide precast structural concrete units whose fire resistance has been calculated according to PCI MNL 124, "Design for Fire Resistance of Precast Prestressed Concrete", or ACI 216.1/TMS 0216.1, "Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies", and is acceptable to the MBTA.
- I. Fire-Test-Response Characteristics: Provide precast structural concrete units that comply with the following requirements:
 - 1. Fire-response testing performed by UL, ITS or another testing and inspecting agency that is acceptable to the MBTA and that performs testing and follow-up services.
 - 2. Fire-resistance-rated assemblies, which are indicated by design designations from UL's "Fire Resistance Directory", from ITS's "Directory of Listed Products" or from the listings of another testing and inspecting agency, are identical in materials and construction to those tested per ASTM E 119.
 - 3. Products are identified with appropriate markings of applicable testing and inspecting agency.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver precast structural concrete units to Project site in such quantities and at such times to ensure continuity of installation. Store units at Project site to prevent cracking, distorting, warping, staining, or other physical damage, and so identification markings are visible and units can be inspected.
- B. Lift and support units only at designated lifting and supporting points as shown on Shop Drawings.
- C. Handle and transport units in a position in order to avoid excessive stresses that would cause cracking or damage.

1.5 SEQUENCING

- A. Furnish anchorage items to be embedded in other construction without delaying the Work. Provide setting diagrams, templates, instructions, and directions, as required, for installation.

PART 2 - PRODUCTS

2.1 MOLD MATERIALS

- A. Molds: Provide molds and, where required, form-facing materials of metal, plastic, wood, or another material that is nonreactive with concrete and dimensionally stable to produce continuous and true precast concrete surfaces within fabrication tolerances and suitable for required finishes.

2.2 REINFORCING MATERIALS

- A. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.
- B. Epoxy Coating for Reinforcing Bars: Shall conform to ASTM A 775/A 775M.
- C. Deformed Steel Welded Wire Reinforcement: ASTM A 497/A 497M, flat sheet.
- D. Supports: Manufacturer's bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded wire fabric in place according to CRSI's "Manual of Standard Practice", PCI MNL 116, and as follows:
 - 1. For uncoated reinforcement, use CRSI Class 1 plastic-protected bar supports.

2. For zinc-coated reinforcement, use galvanized wire or dielectric-polymer-coated wire bar supports.

2.3 PRESTRESSING REINFORCEMENT

- A. High Strength Steel Wire: ASTM A 421
- B. High Strength Steel Bars: ASTM A 722, Grade 150, uncoated, deformed.
- C. Prestressing Strand: ASTM A 416/A 416M, Grade 250 or 270 as indicated, uncoated, 7-wire, low-relaxation strand.

2.4 CONCRETE MATERIALS

- A. Precast concrete shall have a minimum specified compressive strength of 5,000 psi at 28 days in accordance with the relevant provisions of Section 03300 Cast-in-Place Concrete.
- B. Concrete for prestressed members shall have a minimum compressive strength of 6,500 psi at 28 days, and a minimum compressive strength at time of initial prestress of 4,000 psi.
- C. Portland Cement: ASTM C 150, Type III cement mitigated with a pozzolan to prevent alkali-silica reactivity.
- D. Normal-Weight Aggregates: Except as modified by PCI MNL 116, ASTM C 33.
- E. Lightweight Aggregates: Except as modified by PCI MNL 116, ASTM C 330.
- F. Water: Potable, free from deleterious material that may affect color stability, setting, or strength of concrete and complying with chemical limits of PCI MNL 116.
- G. Air-Entraining Admixture: ASTM C 260, certified by manufacturer to be compatible with other required admixtures.
- H. Fly Ash Admixture: ASTM C 618, Class F only.
- I. Silica Fume Admixture: ASTM C 1240.

2.5 STEEL CONNECTION MATERIALS

- A. Carbon-Steel Shapes and Plates: ASTM A 36/A 36M.
- B. Carbon-Steel Headed Studs: ASTM A 108, AISI 1018 through AISI 1020, cold finished; AWS D1.1, Type A or B, with arc shields.
- C. Malleable Steel Castings: ASTM A 47.
- D. Deformed-Steel Wire or Bar Anchors: ASTM A 496 or ASTM A 706/A 706M.
- E. Carbon-Steel Bolts and Studs: ASTM A 307, Grade A; carbon-steel, hex-head bolts and studs; carbon-steel nuts; and flat, unhardened steel washers.

- F. Finish: For exterior steel items, steel in exterior walls, and items indicated for galvanizing, apply zinc coating by hot-dip process according to ASTM A 123/A 123M, after fabrication, and ASTM A 153/A 153M, as applicable.
 - 1. Galvanizing Repair Paint: High-zinc-dust-content paint with dry film containing not less than 94% zinc dust by weight, and complying with DOD-P-21035A or SSPC-Paint 20.
- G. Welding Electrodes: Comply with AWS standards.
- H. Accessories: Provide clips, hangers, plastic or steel shims, and other accessories required to install precast structural concrete units.
 - 1. All steel accessories shall be Hot Dip Galvanized.

2.6 STAINLESS-STEEL CONNECTION MATERIALS

- A. Stainless-Steel Plate: ASTM A 666, Type 304, of grade suitable for application.
- B. Stainless-Steel Bolts and Studs: ASTM F 593, alloy 304 or 316, hex-head bolts and studs; stainless-steel nuts; and flat, stainless steel washers. Lubricate threaded parts of stainless steel bolts with an antiseize thread lubricant during assembly.
- C. Stainless-Steel Headed Studs: ASTM A 276.

2.7 BEARING PADS

- A. Provide bearing pads for precast structural concrete units as follows:
 - 1. Elastomeric Pads: AASHTO M 251, plain, vulcanized, 100% polychloroprene (neoprene) elastomer, molded to size or cut from a molded sheet, 50 to 70 Shore A durometer, minimum tensile strength 2250 psi per ASTM D 412.
 - 2. Frictionless Pads: Tetrafluoroethylene, glass-fiber reinforced, bonded to mild-steel plate, of type required for in-service stress.

2.8 GROUT MATERIALS

- A. Sand-Cement Grout: Portland cement, ASTM C 150, Type I or II, and clean, natural sand, ASTM C 144. Mix at ratio of 1 part cement to 2-1/2 parts sand, by volume, with minimum water required for placement and hydration.
- B. Nonmetallic, Nonshrink Grout: Premixed, nonmetallic, noncorrosive, nonstaining grout containing selected silica sands, Portland cement, shrinkage-compensating agents, plasticizing and water-reducing agents, complying with ASTM C 1107, of consistency suitable for application.

2.9 CONCRETE MIXES

- A. Prepare design mixes for each type of precast concrete required.
 - 1. Limit use of fly ash and silica fume to not exceed, in aggregate, 25% of Portland cement by weight.
- B. Design mixes shall be prepared by a qualified independent testing agency or by qualified precast plant personnel at precast structural concrete fabricator's option.

- C. Limit water-soluble chloride ions to the maximum percentage by weight of cement permitted by ACI 318.
- D. Normal-Weight Concrete: Proportion mixes by either laboratory trial batch or field test data methods according to ACI 211.1, with materials to be used on Project, to provide normal-weight concrete with the following properties:
 - 1. Compressive Strength (28 Days): 5,000 psi or 6,500 psi as indicated.
 - 2. Maximum Water-Cementitious Materials Ratio: 0.40.
 - 3. Slump: 4 inches maximum.
 - 4. Units subject to freeze-thawing shall be air-entrained. Add air-entraining admixture at manufacturer's prescribed rate to result in normal-weight concrete at point of placement having an air content as follows, with a tolerance of plus or minus 1-1/2%:
 - a. Air Content: 3% to 6%.
- E. Lightweight Concrete: Proportion mixes by either laboratory trial batch or field test data methods according to ACI 211.2, with materials to be used on Project, to provide lightweight concrete with the following properties:
 - 1. Compressive Strength (28 Days): 5,000 psi or 6,500 psi as indicated.
 - 2. Unit Weight: Calculated equilibrium unit weight of 115 lb/cu. ft., plus or minus 3 lb/cu. ft. (48 kg/cu. m), according to ASTM C 567.
 - 3. Add air-entraining admixture at manufacturer's prescribed rate to result in lightweight concrete at point of placement having an air content as follows:
 - a. Air Content: 4% to 6% for 3/4-inch-nominal maximum aggregate size.
- F. Other Admixtures: Use water-reducing, high-range water-reducing, water-reducing and accelerating, or water-reducing, corrosion inhibitor and retarding admixtures according to manufacturer's written instructions.
 - 1. Corrosion Inhibitor: Provide minimum of 3 Gallon per cubic yard of Calcium Nitrate Corrosion inhibitor (DCI or approved equal) when used.
- G. Concrete Mix Adjustments: Concrete mix design adjustments may be proposed if characteristics of materials, Project conditions, weather, test results, or other circumstances warrant.

2.10 FABRICATION

- A. Formwork: Accurately construct forms, mortar tight, of sufficient strength to withstand pressures due to concrete-placement operations and temperature changes and for pretensioning and detensioning operations. Maintain formwork to provide completed precast concrete units of shapes, lines, and dimensions indicated, within fabrication tolerances.
 - 1. Coat surfaces of forms with bond-breaking compound before reinforcement is placed. Provide commercial-formula, form-coating compounds that will not bond with, stain, or adversely affect concrete surfaces and that will not impair subsequent treatments of concrete surfaces requiring bond or adhesion. Apply in compliance with manufacturer's written instructions.
 - 2. Unless forms for precast, prestressed concrete units are stripped before detensioning, design forms so stresses are not induced in precast concrete units because of deformation or movement of concrete during detensioning.

- B. Built-in Anchorages: Accurately position built-in anchorage devices and secure to formwork. Locate anchorages where they do not affect position of main reinforcement or concrete placement. Do not relocate bearing plates in units unless approved by MBTA.
- C. Lift Devices, and Accessories: Provide concrete inserts, reglets, anchors, brackets, and fasteners as indicated or required for fabrication and installation of the work. Locate Lifting Device as required by design. All items shall be zinc-coated or galvanized in accordance with ASTM A153 or ASTM A123, as applicable. Design-Builder shall select the lift devices, and shall be responsible for their performance and for any damage resulting from the use of faulty or inferior devices. Lift devices shall not be visible on exposed faces of precast members. Provide a minimum four for each unit. Lifting devices shall be removable from units after erection, all holes and recesses shall be cleaned and filled with a cementitious repair mortar that matches the color and texture of the base precast or prestressed unit. Surface of the repair mortar shall be level with the surrounding surface of the precast or prestressed units.
- D. Cast-in openings larger than 10 inches in diameter or 10 inches square according to Shop Drawings. Smaller holes may be field cut by trades requiring them, as approved by MBTA.
- E. Reinforcement: Comply with recommendations in Concrete Reinforcing Steel Institute's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.
 - 1. Clean reinforcement of loose rust and mill scale, earth, and other materials that reduce or destroy the bond with concrete.
 - 2. Accurately position, support, and secure reinforcement against displacement by formwork, construction, or concrete-placement operations. Locate and support reinforcement by metal chairs, runners, bolsters, spacers, and hangers, as required.
 - 3. Place reinforcement to obtain at least the minimum coverage for concrete protection. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position while placing concrete. Set wire ties so ends are directed into concrete, not toward exposed concrete surfaces.
 - 4. Install welded wire fabric in lengths as long as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.
- F. Prestress tendons for precast structural concrete units by either pretensioning or posttensioning methods. Comply with Precast Concrete Institute MNL 116.
 - 1. Delay detensioning until concrete has reached at least 70% of its compressive strength as established by test cylinders cured under the same conditions as concrete.
 - 2. If concrete has been heat cured, detension while concrete is still warm and moist to avoid dimensional changes that may cause cracking or undesirable stresses.
 - 3. Detension pretensioned tendons either by gradually releasing tensioning jacks or by heat-cutting tendons, using a sequence and pattern to prevent shock or unbalanced loading.
- G. Mix concrete according to PCI MNL 116 and requirements in this Section. After concrete batching, no additional water may be added.
- H. Place concrete in a continuous operation to prevent seams or planes of weakness from forming in precast concrete units. Comply with requirements in PCI MNL 116 for measuring, mixing, transporting, and placing concrete.

- I. Thoroughly consolidate placed concrete by internal and external vibration without dislocating or damaging reinforcement and built-in items. Use equipment and procedures complying with PCI MNL 116.
- J. Comply with ACI 306.1 procedures for cold-weather concrete placement.
- K. Comply with ACI 305R recommendations for hot-weather concrete placement.
- L. Identify pickup points of precast concrete units and orientation in structure with permanent markings, complying with markings indicated on Shop Drawings. Imprint casting date on each precast concrete unit on a surface that will not show in finished structure.
- M. Cure concrete, according to requirements in PCI MNL 116, by moisture retention without heat or by accelerated heat curing using low-pressure live steam or radiant heat and moisture.
- N. Product Tolerances: Fabricate precast structural concrete units straight and true to size and shape with exposed edges and corners precise and true so each finished unit complies with PCI MNL 116 product tolerances.
- O. Finish formed surfaces of precast structural concrete as indicated for each type of unit, and as follows:
 - 1. Commercial Finish: Remove fins and large protrusions and fill large holes. Rub or grind ragged edges. Faces are to be true, well-defined surfaces.
- P. Screed finish unformed surfaces. Strike off and consolidate concrete with vibrating screeds to a uniform finish. Hand screed at projections.
 - 1. Apply scratch finish to precast concrete units that will receive concrete topping after installation. After initial strikeoff, transversely scarify surface to provide ridges approximately 1/4 inch deep.
- Q. Recess prestressing tendons a minimum of 1/2 inch, fill recesses with grout, and apply a sack finish to vertical ends of precast concrete units.

2.11 HOLLOW-CORE SLAB UNITS

- A. Type: Precast, prestressed concrete units with open, hollow cores running the full length of the slab units.
- B. Furnish units free of voids and honeycombs.
- C. Provide standard finish to precast concrete units.
- D. Reinforce units to resist transportation and erection stresses.
- E. Coordinate with other trades for installation of cast-in items.
- F. Include cast-in weld plates where required.
- G. Provide solid, monolithic, precast concrete slab units forming an integral part of hollow-core slab unit system. Design and fabricate solid units to dimensions and details indicated for hollow-core slab units.

- H. Provide headers of cast-in-place concrete or structural-steel shapes for openings larger than one slab width according to hollow-core slab unit fabricator's written recommendations.

2.12 LONG-SPAN UNITS

- A. Type: Plant-fabricated, precast, prestressed concrete long-span units.
- B. Furnish units free of voids and honeycombs.
- C. Provide standard finish to precast concrete units, unless otherwise indicated.
 - 1. If designed as composite members, broom or rake top finish of precast concrete units for bonding with concrete floor topping.
 - 2. If used as roof members, provide smooth, float top finish to precast concrete units.
- D. Reinforce units to resist transportation and erection stresses.
- E. Include cast-in weld plates where required.
- F. Coordinate with other trades for installation of cast-in items.

2.13 STRUCTURAL FRAMING UNITS

- A. Type: Precast, prestressed structural concrete framing units.
- B. Furnish units free of voids and honeycombs.
- C. Provide standard finish to precast concrete units.
- D. Reinforce units to resist transportation and erection stresses.
- E. Include cast-in weld plates where required.
- F. Coordinate with other trades for installation of cast-in items.

2.14 SOURCE QUALITY CONTROL

- A. Design-Builder shall engage an independent testing agency to evaluate precast structural concrete fabricator's quality-control and testing methods.
 - 1. Allow testing agency access to material storage areas, concrete production equipment, concrete placement, and curing facilities. Cooperate with testing agency and provide samples of materials and concrete mixes as may be requested for additional testing and evaluation.
 - 2. Notification Point - Notify MBTA at least 3 days in advance of testing. Testing may be witnessed by the MBTA.
- B. Quality-Control Testing: Test and inspect precast concrete according to PCI MNL 116 requirements.
- C. Strength of precast concrete units will be considered deficient if units fail to comply with PCI MNL 116 requirements, including the following:
 - 1. Units fail to comply with compressive-strength test requirements.
 - 2. Reinforcement and prestressed tendons of units do not comply with fabrication requirements.

3. Concrete curing and protection of units against extremes in temperature fail to comply with requirements.
 4. Units are damaged during handling and erecting.
- D. Testing: If there is evidence that the strength of precast concrete units may be deficient or may not comply with PCI MNL 116 requirements, Design-Builder shall employ an independent testing agency to obtain, prepare, and test cores drilled from hardened concrete to determine compressive strength according to ASTM C 42.
1. A minimum of three representative cores will be taken from units of suspect strength, from locations directed by MBTA.
 2. Cores will be tested, after immersion in water, in a wet condition per ACI 301.
 3. Strength of concrete for each series of 3 cores will be considered satisfactory if the average compressive strength is equal to at least 85% of the 28-day design compressive strength and no single core is less than 75% of the 28-day design compressive strength.
 4. Test results will be made in writing on the same day that tests are performed, with copies to MBTA, Design-Builder, and precast concrete fabricator. Test reports will include the following:
 - a. Project identification name and number.
 - b. Date when tests were performed.
 - c. Name of precast concrete fabricator.
 - d. Name of concrete testing agency.
 - e. Identification letter, name, and type of precast concrete unit or units represented by core tests; design compressive strength; type of break; compressive strength at break, corrected for length-diameter ratio; and direction of applied load to core in relation to horizontal plane of concrete as placed.
- E. Patching: If core test results are satisfactory and precast concrete units comply with requirements, clean and dampen core holes and solidly fill with precast concrete mix that has no coarse aggregate, and finish to match adjacent precast concrete surfaces.
- F. Dimensional Tolerances: Units with dimensions smaller or larger than required and not complying with tolerance limits may be subject to additional testing.
1. Precast concrete units with dimensions larger than required will be rejected if the appearance or function of the structure is adversely affected or if larger dimensions interfere with other construction. Repair or remove and replace rejected units, as required, to comply with construction conditions.
- G. Defective Work: Precast concrete units that do not comply with requirements, including strength, manufacturing tolerances, and finishes, are unacceptable. Replace with precast concrete units that comply with requirements.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances, true and level bearing surfaces, and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Bearing Pads: Install bearing pads as precast concrete units are being erected. Set pads on true, level, and uniform bearing surfaces and maintain in correct position until precast concrete units are placed.
- B. Install precast structural concrete. Shore and brace precast concrete units to maintain location, stability, and alignment until permanent connections are installed.
- C. Welding: Perform welding in compliance with AWS D1.1 and AWS D1.4, with qualified welders using qualified welding procedures.
 - 1. Protect precast concrete units and bearing pads from damage by field welding or cutting operations and provide noncombustible shields as required.
 - 2. Repair damaged metal surfaces by cleaning and applying a coat of galvanized repair paint to galvanized surfaces.
 - 3. Repair damaged metal surfaces by cleaning and repriming damaged painted surfaces.
 - 4. Steel shims shall be tack welded to supporting bearing plates.
- D. Fasteners: Do not use drilled or powder-actuated fasteners for attaching accessory items to precast, prestressed concrete units unless approved by MBTA.
- E. Erection Tolerances: Install precast concrete units level, plumb, square, and true, without exceeding the recommended erection tolerances in PCI MNL 127, "Recommended Practice for Erection of Precast Concrete".
- F. Grouting Connections and Joints: After precast concrete units have been placed and secured, grout open spaces at keyways, connections, and joints as follows:
 - 1. Provide forms or other approved method to retain grout in place until hard enough to support itself. Pack spaces with stiff grout material, tamping until voids are completely filled. Place grout to finish smooth, level, and plumb with adjacent concrete surfaces. Keep grouted joints damp for not less than 24 hours after initial set. Promptly remove grout material from exposed surfaces before it hardens.
- G. Adhesive Anchors: The use of Adhesive/Epoxy Anchors Systems (including but not limited to bolts, rebar dowels) is prohibited by the MBTA.

3.3 FIELD QUALITY CONTROL

- A. Testing: Design-Builder shall engage a qualified independent testing and inspecting agency to perform field tests and inspections.
- B. Notification Point - Field welds and connections using high-strength bolts will be subject to tests and inspections. Notify the MBTA 24 hours in advance of high-strength bolting.
- C. Testing agency will report test results promptly and in writing to Design-Builder and MBTA.
- D. Remove and replace work that does not comply with specified requirements.
- E. Additional testing and inspection, at Design-Builder's expense, will be performed to determine compliance of corrected work with specified requirements.

3.4 CLEANING

- A. Clean exposed surfaces of precast concrete units after erection to remove weld marks, other markings, dirt, and stains.
 - 1. Wash and rinse according to precast concrete fabricator's written recommendations. Protect other work from staining or damage due to cleaning operations.
 - 2. Do not use cleaning materials or processes that could change the appearance of exposed concrete finishes.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 03460

NOISE BARRIER ASSEMBLIES

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This Section specifies the furnishing and installation of pre-fabricated absorptive acoustic barrier panels and attachment system. The Noise Barriers will resemble a Massachusetts Department of Transportation standard item. The Noise Barriers will be freestanding or mounted on retaining walls. They will typically involve Cast-in-Place Concrete Foundations (for freestanding noise barriers), Steel Columns, Base Plates, Anchor Bolts, Pre-fabricated Panels, Spray-On Applications to the Panel Surfaces for various Sound Absorption Materials, Transparent Panels of Acrylic Materials for the upper sections of walls, and other related items.

1.2 RELATED SECTIONS

- A. Other specification sections that relate to the work include, but are not limited to, the following:
1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 2. Section 02282 – HANDLING, TRANSPORTATION, AND DISPOSAL OF EXCAVATED MATERIALS
 3. Section 03300 – CAST-IN-PLACE CONCRETE
 4. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE
 5. Section 03600 – NON-SHRINK CONSTRUCTION GROUT
 6. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS
 7. Section 05500 – MISCELLANEOUS METALS
 8. Section 10443 – NOISE PANELS

1.3 REFERENCED DOCUMENTS

- A. The following Codes, Regulations, Referenced Standards, and Specifications apply to work included in this Section:
1. Codes and Standards:
 - a. ASTM E-90: Standard Test method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions.
 - b. ASTM C423: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.
 - c. ASTM E413: Classification for Rating Sound Insulation
 2. Acoustical Performance:
 - a. The acoustical panel manufacturer will be required to submit acoustical performance data in the form of up-to-date test reports from an independent testing laboratory indicating the panel system to be provided will have the required Sound Transmission

Class Rating. Tests shall be performed in accordance with ASTM E90 and ASTM E413.

- b. The acoustical panel manufacturer will be required to submit acoustical performance data in the form of up-to-date test reports from an independent testing laboratory indicating the panel system to be provided will have the required Sound Absorption Coefficients. Tests shall be performed in accordance with ASTM C423.

1.4 SUBMITTALS

- A. Submit the following for approval in compliance with Section 01300 - SUBMITTALS, and with the additional requirements as specified for each:
 1. Shop Drawings: Submit shop drawings and calculations showing layout, profiles, and product components, including precast concrete panels, acrylic panels, anchorage, accessories, finish colors, patterns and textures.
 - a. Shop drawings and calculations shall be performed, stamped, and sealed by a Professional Structural Engineer registered in the Commonwealth of Massachusetts.
 2. Pre-fabricated Panels (Units and Support) Manufacturer's specifications and other data: Indicate type of barrier, location, length, top elevation, bottom of footer elevation, cross-sections, foundation, and quantities. Show the complete layout plans and fabrication details for barrier units, and step-by-step erection instructions. Indicate unit locations, architectural details, support items, dimensions, openings, and relationship to adjacent materials. Barrier panels are designed per AASHTO Guide Specifications for Structural Design of Sound Barriers – 1989 with Interims through 2003.
 - a. Manufacturer's specifications and other data are needed to prove compliance with these specifications. Include specifications, standard details, certified product test results, installation instructions and general recommendations as applicable to materials and finishes for each component and for the total panel system.
 3. Samples: Submit selection and verification samples for finishes, colors, and textures. Sample materials minimum 4" x 12". Include any panel accessories as required.
 4. Quality Assurance Submittals: Submit the following:
 - a. Certificates: Product certificates and literature signed by the manufacturer certifying materials comply with specified performance characteristics and criteria, and physical requirements.
 - b. Manufacturer's Instructions: Manufacturer's printed installation and handling instructions.
 - c. Field Reports: Manufacturer's field reports supporting specified application.
 5. Closeout Submittals: Submit the following:
 - a. Operation and Maintenance Data: Include methods for maintaining installed products and precautions against cleaning materials and methods detrimental to finishes and performance.
 - b. Warranty documents as further specified.

- B. Submit Plan of Actions to be implemented in the event any Response Value for deformation, as specified in Table 03460-1, is reached.

**TABLE 03460-1
RESPONSE VALUES**

Monitoring Type	Value
<u>Lateral Deflection of Noise Barriers Supported by Earth</u>	
Top of column	1%
Mid-Point of exposed column	0.5%
<u>Vertical Deflection of Noise Barriers Supported by Earth</u>	
Top of column	1/2 inch
<u>Ground Surface Settlement</u>	
Top of Rail	1/4 inch

- C. Means and methods to advance through obstructions. In this case, as in all cases, review and approval of submittal by Engineer or MBTA does not relieve the Design Builder in any way from the responsibility to complete the construction.

1.5 PROJECT CONDITIONS

- A. Visit the site to review all details of the work and working conditions affecting Work under this Section and to verify dimensions in the field including potential interference from adjacent structures. Notify the Engineer in writing of any discrepancy before performing any work. The Design Builder is hereby notified that the job site is located adjacent to the active railroad and existing buildings.
- B. The Design Builder shall be responsible for implementing all necessary traffic control measures, which may include but not be limited to traffic cones, barriers, barrels, signs, flagmen, and police details.
- C. Provisions for Contingencies
1. Monitor the performance of components of the stand alone noise barrier, both for vertical and horizontal movement, at intervals specified herein.
 2. Implement contingency plans if Response Values specified in Table 03460-1 are reached.
 3. Have materials and equipment available to implement the accepted Plan of Action.
- D. Consult official records of existing utilities, both surface and subsurface, and their connections to be fully informed on all existing conditions and limitations as they apply to this work and its relation to other construction work. Proceed with caution in areas of utility facilities. Expose them by hand excavation or by other methods acceptable to the utility MBTA. Protect existing utilities to remain within and adjacent to the work area in accordance with the requirements of authorities having jurisdiction over same. The Design Builder is responsible for any damage to utilities caused by the

Design Builder's operations and shall restore them to equal or better operation at no additional cost to the MBTA.

1.6 WARRANTY

- A. Warrant pre-fabricated panels to be free from defective workmanship for one (1) year from date of Substantial Completion.
- B. Warrant factory applied finishes to be free from fading, chalking, or cracking for ten (10) years from date of Substantial Completion.

1.7 SUBSURFACE DATA

- A. Logs of subsurface explorations performed at the site are shown on the Contract Documents. Approximate locations of these subsurface explorations are shown on the Contract Plans.
- B. The aforementioned data is for general information and is accurate only at the particular locations and times the subsurface explorations were made. It is the Design Builder's responsibility to make interpretations and draw conclusions based on the character of materials to be encountered and the impact on his work based on his expert knowledge of the area and of earthwork techniques. The Design Builder shall review test pit and boring logs and locations and other pertinent data for the site. The Design Builder, at his own expense, may conduct additional subsurface explorations for his own information after obtaining the MBTA's permission.

1.8 QUALITY ASSURANCE

- A. The Design Builder shall provide written certification indicating that the equipment used for monitoring of deformation monitoring points (DMP) (as specified in Paragraph 3.2 herein) has been calibrated and maintained in accordance with the test equipment manufacturer's calibration requirements. The accuracy/precision of horizontal and vertical survey monitoring shall be to the nearest 0.01 feet.
- B. Full length temporary casing drilled to the elevation shown on the Design Builder's Approved Drawings may be required for all predrilled holes for noise barrier posts.

1.9 QUALIFICATIONS OF DESIGN BUILDER'S INSTRUMENTATION PERSONNEL

- A. The Design Builder shall have on his staff, or on the staff of a specialist instrumentation subcontractor, instrumentation/survey personnel who are responsible for furnishing, installing, and maintaining instrumentation/survey equipment, as well as obtaining and interpreting data from the instrumentation/survey equipment.
- B. The Design Builder's instrumentation/survey personnel shall have the following qualifications:
 - 1. A minimum of a Bachelor of Science Degree in Civil Engineering or related discipline.
 - 2. A minimum of 2 years' experience in the installation, monitoring, and interpretation of data from the types of monitoring equipment used to monitor deformation-monitoring points (as specified in Paragraph 3.2 herein).
- C. The Design Builder's instrumentation personnel shall:
 - 1. Be on site and supervise or perform installation of each monitoring point.

2. Perform deformation monitoring in accordance with the Project Specifications.
3. Interpret deformation-monitoring data.
4. Ensure that deformation-monitoring data is tabulated accurately and in a format consistent with the Project Specifications.
5. Forward monitoring data to the designated review parties in a timely manner.

PART 2 – PRODUCTS

2.1 GENERAL

- A. The Design Builder shall make his own arrangements to purchase the materials covered by this section of the specifications, including all necessary incidentals. The Design Builder, or the supplier as his agent, shall furnish the Engineer a Certificate of Compliance certifying that the applicable materials comply with this section of the specifications. Materials not conforming to this section of the specifications shall not be used without the written consent of the MBTA.

2.2 NOISE BARRIER PANELS

- A. Panels: Panels shall conform to Section 10443 – NOISE PANELS.
- B. Structural Design: Loadings for noise barrier walls are based on a design life of not less than 50 years and in accordance with AASHTO Guide Specifications for Structural Design of Sound Barriers – 1989 with Interims through 2003.

2.3 NOISE BARRIER POSTS

- A. Post Spacing: Posts should be spaced as shown on the Design Builder's Approved Drawings. See Section 05126 - STRUCTURAL STEEL FOR RETAINING WALLS for post assembly materials.
- B. Anchorages: See Section 03600 – NON-SHRINK CONSTRUCTION GROUT for grout under baseplates and Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS for baseplate and anchorage specifications.

2.4 PERFORMANCE

- A. Acoustical Performance and Durability shall conform to Section 10443 – NOISE PANELS
- B. Panels: Panels shall conform to Section 10443 – NOISE PANELS.
- C. Structural Requirements: Design of panels and system for this installation will withstand wind loading of 40 psf as required by AASHTO Guide Specifications for Structural Design of Sound Barriers – 1989 with Interims through 2003.

2.5 PANEL FABRICATION

- A. Panel Lifting Components shall be placed at the neutral axis of the completed panel to provide a vertical placement when setting the panel.

PART 3 – EXECUTION

3.1 GENERAL REQUIREMENTS

- A. Install the wall in accordance with the accepted working drawings, and in such a manner as to prevent movement, settlement, loss of ground, removal of fines from the adjacent ground, and damage to or movement of adjacent structures and utilities.
- B. Perform work from track side of the proposed wall unless temporary easements have been granted to minimize adjacent property impacts. Heavy equipment shall be placed on the track side of the proposed wall.
- C. Perform field welding by certified welders in accordance with American Welding Society Standards AWS D 1.1, "Structural Welding Code - Steel."
- D. Implement the Plan of Actions as submitted under Paragraph 1.4B, if Response Values as specified in Table 03460-1 are reached.
- E. Borings indicate below ground obstructions may be encountered. Such obstructions may include, but are not necessarily limited to, boulders, and various other demolition and construction debris. Noise barriers shall be installed through all material encountered to the depth required by the Design Builder's Approved Drawings. Installation equipment shall be capable of drilling through boulders, and any other obstructions, encountered during installation at no additional cost to MBTA.
- F. Temporary casings used for pre-drilling holes for noise barrier posts shall be installed where specified on the Design Builder's Approved Drawings to top weathered bedrock, as a minimum, using rotary drilling techniques over their full depth to limit potential vibration damage to adjacent structures and facilities. Potential vibration damage could result if the piles or casing were installed using driving or vibratory methods.
- G. Protection of Existing Adjacent Structures
 - 1. The Design Builder shall repair all damage to adjacent properties and restore the surfaces and finishes to the original state.
 - 2. If in the opinion of the Engineer the integrity of the adjacent railroad tracks, bridge, buildings, structures, or paved areas are jeopardized due to movement, the Design Builder shall immediately discontinue further excavation in the affected area and implement accepted Plan of Action to mitigate further movement. Mitigating measures shall remain in effect until such time that the Engineer evaluates the impact on the structure and may direct the Design Builder to perform any remedial work. The Design Builder shall submit proposed remedial measures to the Geotechnical Engineer for review and approval. Submittals shall include methods and names of subcontractors. The Design Builder shall proceed with remedial work upon acceptance by the Engineer. Mitigating measures shall be at no additional cost to the MBTA.

3.2 MONITORING OF EXCAVATION

- A. Monitoring Track Movement
 - 1. Before the start of excavation and wall installation, establish elevations along Top of Rail of nearest track spaced approximately every 20 feet along the walls.

2. Perform two baseline elevation surveys of the Top of Rail before the start of excavation/wall installation. Survey both vertical and lateral (into excavation) positions.
 3. Perform weekly survey of settlement monitoring points from the beginning of excavation until the structure is completely in place and fully backfilled.
- B. The Design Builder shall submit the results of the settlement point readings to the Engineer in draft form at the end of each working day. All monitoring data for track shall be reported to the MBTA and Engineer within twenty-four (24) hours of measurement in tabular format, allowing comparison of current data to previous data, including baseline, and showing a complete history of movement versus time.

3.3 INSTALLATION

- A. Install work in accordance with reviewed shop drawings and these specifications using only factory-trained personnel as required by the manufacturer and approved by the Engineer.
1. Ensure panel orientation of noise absorptive surface is toward noise source and right side up.
 2. Be sure panels are properly seated before installing next panel. Ensure that lower panels do not move horizontally when installing follow on panels.
- B. Special care shall be exercised to protect the sound absorptive wall components from damage during fabrication, shipment, handling, storage, and installation such that permanently exposed surfaces of any panel is not chipped, gouged or marred. Handle and erect units carefully so as to avoid damage to units. If surface defects occur to any permanently exposed surface it will be at the discretion of the Engineer weather to replace the panel. Any such panel that cannot be repaired to the satisfaction of the Engineer shall be replaced at no additional cost to MBTA. Replace any members damaged to the extent where their aesthetics or structural integrity is compromised.
- C. The installer shall identify any underground utility or overhead obstruction that could affect job site safety. The installer is responsible to correct any site conditions that would compromise site safety and cause an accident.
- D. Install panels to the elevations shown in the Design Builder's Approved Drawings. Use lifting devices or rigging designed to safely lift and position panels. No lifting devices shall be placed such that it would be visible in the permanent position of the panel. Lift and lower panels into the post flanges making sure the panel's absorptive side is facing the noise source if only one side is absorptive. Set, level, and center the bottom panel to the planned elevation using elastomeric bearing pads. Set and level intermediate panels using elastomeric bearing pads, making sure all panels are centered between posts and the panel-to-panel pattern is misaligned. Continue stacking panels up to the elevation specified in the Design Builder's Approved Drawings. If key ways are used do not place the top of the uppermost panel nor the bottom of the lowermost panel with a key.
- E. Connections between the panel and the posts should account for movement and expansion and contraction of the panels.
- F. Where transparent panels are to be placed on top of concrete panels, ensure that the panels fit together in a manner acceptable to the manufacturer of each piece. No top panel or acrylic panel shall be placed until a compatible connection is approved by the manufacture of each panel and by the Engineer.

3.4 ACCEPTANCE CRITERIA FOR NOISE WALLS

A. Vertical

1. Maximum variation from elevation shall be 1/2”.
2. Maximum variation from plumb shall be 1%.

B. Horizontal

There shall be no more than 1” out of plane tolerance along the wall measured at any 20 foot increment.

3.5 ACRYLIC PANEL PROTECTION

- A. Acrylic panels shall be unpackaged as close to the location of installation as possible.
- B. Protective coverings shall remain in place until the time of acceptance.
- C. Acrylic panels which are damaged shall be repaired by the manufacturer or replaced to the satisfaction of the MBTA.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 03600

NON-SHRINK CONSTRUCTION GROUT

PART 1 - GENERAL

1.1 GENERAL PROVISIONS

- A. Attention is directed to the GENERAL CONDITIONS, SUPPLEMENTARY CONDITIONS, AND GENERAL REQUIREMENTS, which are hereby made a part of this Specification Section.
- B. Related Work: Examine all documents and all Sections of the Specifications for requirements and provisions affecting the work of this Section.

1.2 WORK INCLUDED

- A. The work to be performed under this Section consists of:
 - 1. Furnishing, constructing, and installation of non-shrink construction grout as required for the construction activities.

1.3 SUBMITTALS

- A. The Design-Builder shall submit, to the MBTA the following:
 - 1. Materials data and certificate of compliance attesting to conformance of products to the requirements of this Section.
- B. Submit manufacturer's instructions for use of the proposed grout. Include mix proportions, consistency, temperature range, and working time for each grout mix to be used.

1.4 PRODUCT DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials in original, tightly sealed bags, clearly labeled with manufacturer's name, brand name and number, batch number of the material, and other product marking as required by ASTM C11 07, Section 15.
- B. Store and handle material according to manufacturer's recommendations.

PART 2 - MATERIALS

2.1 NON-SHRINK GROUT

- A. Provide grout that complies with ASTM C1107, Grade A, B or C.
- B. Provide grout with suitable consistency, working time, and temperature range for the working conditions.
- C. Unless otherwise required by design, the grout shall have a compressive strength of at least 3,500 psi in 7 days when tested in accordance with AASHTO T106, and a minimum of 8,000 psi at 28 days. Design-Builder shall coordinate between trades, so that appropriate grout strengths are supplied and used for the proposed work.

PART 3 - CONSTRUCTION METHODS

3.1 PREPARATION

- A. Remove substances such as dust, laitance, grease, curing compounds, impregnations, waxes, foreign particles, and disintegrated materials from surfaces where non-shrink grout is to be applied.
 - 1. Use mechanical abrasion on structural steel and reinforcing steel to remove loose material and expose sound metal.
 - 2. Clean coatings from concrete surfaces using a degreasing and etching chemical applied in accordance with the manufacturer's written instructions for the particular application.
- B. Construct appropriate forms to contain grout at the fluidity level at which it will be used. Saturate foundations and forms with water for a minimum of 24 hours prior to grouting. Remove all standing water and puddles prior to application of grout. Take special care to eliminate water from bolt holes and other cavities.

3.2 MIXING

- A. Mix with potable water according to manufacturer's printed instructions.

3.3 PLACEMENT

- A. Follow manufacturer's placement instructions and recommendations for the particular application.
- B. Place grout only from one side to avoid entrapping air. Provide adequate air vent holes in large placements. Work or flow grout into place, filling all cavities. Inspect vent holes to ensure proper filling.
- C. Place grout within time limit specified by manufacturer after addition of water to the batch.
- D. Cure the grout after placement as for concrete, using appropriate methods as specified in Section 03300, CAST-IN-PLACE CONCRETE.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 03601

POST INSTALLED ANCHORS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Provide post-installed anchors as required for the design, as specified herein, and as needed for a complete and proper installation.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 03300 – CAST-IN-PLACE CONCRETE
 - 2. Section 03371 – SHOTCRETE
 - 3. Section 03410 – PLANT PRECAST STRUCTURAL CONCRETE
 - 4. Section 03460 – NOISE BARRIER ASSEMBLIES
 - 5. Section 03600 – NON-SHRINK CONSTRUCTION GROUT
 - 6. Section 03930 – CONCRETE REHABILITATION AND REPAIR

1.2 SUBMITTALS

- A. Provide manufacturers product data with recommended design values and physical characteristics for all post-installed anchors to be used in this project.
- B. The Design-Builder shall submit to the MBTA for review and approval, the methods and procedures for anchor bolt installation including drilling, installing and anchor bolt testing, including equipment and materials proposed for the work. The method and equipment used to drill the anchor bolt holes and the diameter of the drilled hole shall, at a minimum, conform to the recommendations of the manufacturer and shall also be submitted to the MBTA for approval.

1.3 QUALITY ASSURANCE

- A. General: Use adequate numbers of skilled workmen who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work of this Section.
- B. Single source responsibility: To ensure consistent quality of anchorage, obtain anchors from a single manufacturer.
- C. Installer Qualifications: Post-installed anchors shall be installed by the Design-Builder utilizing personnel and suppliers with a minimum of five years' experience performing similar installations.
- D. Installer Training: Conduct thorough training with the manufacturer or the manufacturer's representative for the installer. Training shall consist of a review of the complete installation process for post-installed anchors including the following:
 - 1. Hole drilling procedure.

2. Hole preparation and cleaning technique.
 3. Adhesive injection technique and dispenser training/maintenance.
 4. Anchor element type, material, diameter, and length.
 5. Proof loading/torqueing.
 6. Other procedures and techniques as necessary.
- E. Certifications: Unless otherwise authorized by the MBTA, anchors shall have one of the following certifications:
1. ACI 355.2 Evaluation Report.
 2. ICC-ES Evaluation Report indicating conformance with applicable ICC-ES AC193 or ICC-ES AC308.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. General: Deliver, store and handle anchors in accordance with manufacturer's recommendation.
- B. Deliver products in original, unopened packages with manufacturer's labels identifying products legible and intact.
- C. Store materials inside, under cover and in a manner to keep them dry, protected from the weather, surface contamination, and corrosion damage.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Fasteners and Anchors:
 1. Bolts and Studs: ASTM A307; ASTM A449 where "high strength" is required by design.
 2. Carbon and Alloy Steel Nuts: ASTM A563.
 3. Carbon Steel Washers: ASTM F436.
 4. Carbon Steel Threaded Rod: ASTM A36; or ASTM A193 Grade B7; or ISO 898 Class 5.8.
 5. Wedge Anchors: ASTM A510; or ASTM A108.
 6. Stainless Steel Bolts, Hex Cap Screws, and Studs: ASTM F593.
 7. Stainless Steel Nuts: ASTM F594.
 8. Zinc Plating: ASTM B633.
 9. Hot-Dip Galvanizing: ASTM A153.
 10. Metric Anchor Bolts, Screws, and Studs: ISO 898 Part 1.
 11. Metric Anchor Nuts: EN 24033.
 12. Metric Anchor Stainless Steel Bolts, Screws, and Studs: ISO 3506 Part 1.
 13. Metric Anchor Stainless Steel Nuts: ISO 3506 Part 2.

14. Reinforcing Dowels: ASTM A615
- B. Wedge Anchors: Wedge type, torque-controlled, with impact section to prevent thread damage complete with required nuts and washers. Provide anchors with length identification markings conforming to ICC ES AC01 or ICC ES AC193. Type and size as indicated on Drawings.
1. Exterior Use: As required by design, provide stainless steel anchors. Stainless steel anchors shall be AISI [Type 304] [and] [Type 316] stainless steel provided with stainless steel nuts and washers of matching alloy group and minimum proof stress equal to or greater than the specified minimum full-size tensile strength of the externally threaded fastener. Stainless steel nuts shall conform to ASTM F594 unless otherwise specified. Avoid installing stainless steel anchors in contact with galvanically dissimilar metals.
 2. Where anchor manufacturer is not indicated, subject to compliance with requirements and acceptance by the MBTA, provide the following:
 - a. Hilti Kwik Bolt 3, ICC ESR-1385.
 - b. Hilti Kwik Bolt TZ, ICC ESR-1917 (carbon steel and AISI Type 304 Stainless Steel).
- C. Heavy Duty Metric Sleeve Anchors: Torque-controlled, exhibiting follow-up expansion under load, with provision for rotation prevention during installation. Type and size as indicated on Drawings.
1. Exterior Use: As required by design, provide stainless steel anchors. Stainless steel anchors shall be manufactured from materials conforming to ISO 3506 Part 1 and having corrosion resistance equivalent to AISI [Type 304] [and] [Type 316] stainless steel. Stainless steel anchors shall be provided with stainless steel nuts and washers of matching alloy group and minimum proof stress equal to or greater than the specified minimum full-size tensile strength of the externally threaded fastener. All nuts shall conform to ISO 3506 Part 2 unless otherwise specified. Avoid installing stainless steel anchors in contact with galvanically dissimilar metals.
 2. Where anchor manufacturer is not indicated, subject to compliance with requirements and acceptance by the MBTA, provide the following:
 - a. Hilti HSL, HSLG, or HSLB, ICBO ER-3987.
 - b. Hilti HSL-3, HSL-3-G, or HSL-3-B, ICC ESR-1545 (carbon steel).
- D. Heavy Duty Metric Undercut Anchors: Bearing-type. Installed anchor shall have a minimum tension bearing area in the concrete, measured as the horizontal projection of the bearing surface, not less than two times the net tensile area of the anchor bolt. The installed anchor shall exhibit a form fit between the bearing elements and the undercut in the concrete. Type and size as indicated on Drawings.
1. Exterior Use: As required by design, provide sherardized or stainless steel anchors. Sherardized anchors shall be manufactured from materials conforming to ISO 898 Part 1 and having corrosion resistance equivalent to ASTM A153 with sherardized dry diffusion zinc coating (50 μ m min.). Stainless steel anchors shall be manufactured from materials conforming to ISO 3506 Part 1 and having corrosion resistance equivalent to AISI [Type 316] stainless steel. Stainless steel anchors shall be provided with stainless steel nuts and washers of matching alloy group and minimum proof stress equal to or greater than the specified minimum full-size tensile strength of the externally threaded fastener. All nuts shall conform to ISO 3506 Part 2 unless otherwise specified. Avoid installing stainless steel

anchors in contact with galvanically dissimilar metals.

2. Where anchor manufacturer is not indicated, subject to compliance with requirements and acceptance by the MBTA, provide the following:
 - a. Hilti HDA, ICC ER-5608 and ICC ESR-1546.
- E. Cartridge Injection Adhesive Anchors: Threaded steel rod, inserts or reinforcing dowels, complete with nuts, washers, polymer or hybrid mortar adhesive injection system, and manufacturer's installation instructions. Type and size as indicated on Drawings.
1. Exterior Use: As required by design, provide stainless steel anchors. Stainless steel anchors shall be AISI [Type 304] [and] [Type 316] stainless steel provided with stainless steel nuts and washers of matching alloy group and minimum proof stress equal to or greater than the specified minimum full-size tensile strength of the externally threaded fastener. All nuts shall conform to ASTM F594 unless otherwise specified. Avoid installing stainless steel anchors in contact with galvanically dissimilar metals.
 2. Reinforcing dowels shall be A615 Grade 60.
 3. Where anchor manufacturer is not indicated, subject to compliance with requirements and acceptance by the MBTA, provide the following:
 - a. Hilti HAS threaded rods or HIT-TZ rods with HIT HY-150 / HIT ICE Adhesive Anchorage System for anchorage to concrete or grouted masonry, ICC ER-5193, ICC ESR-1562.
 - b. Hilti HAS threaded rods with RE 500 Injection Adhesive Anchoring System for anchorage to concrete, ICC ESR-1682.
- F. Capsule Anchors: Threaded steel rod, inserts and reinforcing dowels with 45 degree chisel point, complete with nuts, washers, glass or foil capsule anchor system containing polyvinyl or urethane methacrylate-based resin and accelerator, and manufacturer's installation instructions. Type and size as indicated on Drawings.
1. Exterior Use: As required by design, provide chisel-pointed stainless steel anchors. Stainless steel anchors shall be AISI [Type 304] [and] [Type 316] stainless steel provided with stainless steel nuts and washers of matching alloy group and minimum proof stress equal to or greater than the specified minimum full-size tensile strength of the externally threaded fastener. All nuts shall conform to ASTM F594 unless otherwise specified. Avoid installing stainless steel anchors in contact with galvanically dissimilar metals.
 2. Reinforcing dowels shall be A615 Grade 60, with 45-degree chisel-points at embedded end.
 3. Where anchor manufacturer is not indicated, subject to compliance with requirements and acceptance by the MBTA, provide the following:
 - a. Hilti HVA Adhesive System with HVU capsules, ICC ER-5369.

PART 3 - EXECUTION

3.1 SURFACE CONDITIONS

- A. Examine the areas and conditions under which work of this Section will be performed. Correct conditions detrimental to timely and proper completion of the Work. Do not proceed until unsatisfactory conditions are corrected.
- B. Remove and replace misplaced or malfunctioning anchors. Fill empty anchor holes and patch failed anchor locations with high-strength non-shrink, nonmetallic grout. Anchors that fail to meet proof load or installation torque requirements shall be regarded as malfunctioning.

3.2 INSTALLATION

A. Drilled-In Anchors:

1. Drill holes with rotary impact hammer drills using carbide-tipped bits and core drills using diamond core bits. Drill bits shall be of diameters as specified by the anchor manufacturer. Unless otherwise shown on the Drawings, all holes shall be drilled perpendicular to the concrete surface.
 - a. Cored Holes: Where anchors are to be installed in cored holes, use core bits with matched tolerances as specified by the manufacturer. HIT HY-150 and HIT ICE shall not be installed in core drilled holes.
 - b. Embedded Items: Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Exercise care in coring or drilling to avoid damaging existing reinforcing or embedded items. Notify the MBTA if reinforcing steel or other embedded items are encountered during drilling. Take precautions as necessary to avoid damaging prestressing tendons, electrical and telecommunications conduit, and gas lines.
 - c. Base Material Strength: Unless otherwise specified, do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
2. Perform anchor installation in accordance with manufacturer instructions.
3. Wedge Anchors, Heavy-Duty Sleeve Anchors, and Undercut Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in part to be fastened. Set anchors to manufacturer's recommended torque, using a torque wrench. Following attainment of 10% of the specified torque, 100% of the specified torque shall be reached within 7 or fewer complete turns of the nut. If the specified torque is not achieved within the required number of turns, the anchor shall be removed and replaced unless otherwise directed by the MBTA.
4. Cartridge Injection Adhesive Anchors: Clean all holes per manufacturer instructions to remove loose material and drilling dust prior to installation of adhesive. Holes do not need to be cleaned for HIT-TZ Rods with HY-150 in accordance with ICC ESR-1562. Holes may be dry, damp or wet. Inject adhesive into holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive. Follow manufacturer recommendations to ensure proper mixing of adhesive components. Sufficient adhesive shall be injected in the hole to ensure that the annular gap is filled to the surface. Remove excess adhesive from the surface. Shim anchors with suitable device to center the anchor in the hole. Do not disturb or load anchors before manufacturer specified cure time has elapsed.

5. Capsule Anchors: Perform drilling and setting operations in accordance with manufacturer instructions. Clean all holes to remove loose material and drilling dust prior to installation of adhesive. Remove water from drilled holes in such a manner as to achieve a surface dry condition. Capsule anchors shall be installed with equipment conforming to manufacturer recommendations. Do not disturb or load anchors before manufacturer specified cure time has elapsed.
6. Observe manufacturer recommendations with respect to installation temperatures for cartridge injection adhesive anchors and capsule anchors.

3.3 TESTING

- A. Perform job testing as specified herein. Proof load 30% of each type and size of post installed anchor required on this project by an independent testing laboratory. Adhesive anchors and capsule anchors shall not be torque tested unless otherwise directed by the MBTA.
- B. Minimum anchor embedment, proof load and torque shall be as shown on the Drawings.
 1. All tests shall be performed in the presence of the inspector of record.
 2. Test anchors, as follows:
 - a. 10% of Sill plate bolts
 - b. 50% of equipment anchorage bolts
 - c. 100% of all other structural anchors
 - d. If any anchor fails to achieve the specified torque or proof load, all anchors of the same category not previously tested shall be tested until 20 consecutive anchors pass the test requirements. The initial testing frequency shall then be resumed. The cost of additional testing shall be borne by the Design-Builder.
 3. Apply proof test load to Wedge and Sleeve anchors without removing the nut if possible. If not, remove nut and install a threaded coupling to the same tightness of the original nut using a torque wrench and apply the test load.
 4. Reaction loads from test fixtures may be applied close to the anchor being tested, provided the anchor is restrained from withdrawing by the fixture(s).
 5. Test equipment (including torque wrenches) is to be calibrated by an approved testing laboratory in accordance with standard recognized procedures.
 6. Alternate torques test procedures and test values for shell type anchors may be submitted to the enforcement agency for review and approval on a case by case basis when test procedures are submitted and approved by the enforcement agency.
 7. The following criteria apply for the acceptance of installed anchors:
 - a. **HYDRAULIC RAM METHOD:** The anchor shall have no observable movement at the applicable test load. For Wedge type anchors, a practical way to determine movement is that the washer under the nut becomes loose.
 - b. **TORQUE WRENCH METHOD:** The applicable test torque shall be reached within one- half (1/2) turn of the nut.
 8. If the Manufacturer's recommended installation torque is less than the test torque noted in the table, the manufacturer's recommended installation torque shall be used in lieu of the tabulated values.
 9. Use the post-installed anchors only where shown on drawings.

10. Post-installed anchors shall be listed in a current evaluation report issued by ICC including, but not limited to, the following:
 - a. HILTI KB-TZ(ESR 1917)
 - b. SIMPSON STRONG-BOLT (ESR-1771)
 - c. SIMPSON TITEN HD (ESR-1056)

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 03930

CONCRETE REHABILITATION AND REPAIR

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Removal of deteriorated concrete and reinforcement and subsequent replacement and patching.
 - 2. Epoxy crack injection.
 - 3. Cleaning and restoration of existing (old) concrete surfaces.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 07190 – WATER REPELLENTS; clear penetrating and film-forming water repellents applied to concrete.
 - 2. Section 03300 – CAST-IN-PLACE CONCRETE
 - 3. Section 03371 - SHOTCRETE

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include material descriptions, chemical composition, physical properties, test data, and mixing, preparation, and application instructions.
- B. Formwork and Shoring Drawings: Prepared by or under the supervision of a qualified professional engineer working for the Design-Builder, detailing formwork and temporary shoring and supports. Include schedule and sequence for erection and removal relative to removal of deteriorated concrete and reinforcement and subsequent repair and reinforcement.
- C. Samples: Cured Samples of patching materials.
- D. Qualification Data: For installers.
- E. Material Certificates: For each type of product indicated, signed by manufacturers.
- F. Rehabilitation Program: For each phase of rehabilitation process, including protection of surrounding materials and Project site during operations. Describe in detail materials, methods, equipment, and sequence of operations to be used for each phase of the Work.
 - 1. If alternative materials and methods to those indicated are proposed for any phase of rehabilitation work, submit substitution request and provide a written description of proposed materials and methods, including evidence of successful use on other comparable projects, and a testing program to demonstrate their effectiveness for this Project.

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: Installer that employs workers trained and approved by manufacturer.

- B. **Manufacturer Qualifications:** Manufacturer that employs factory-trained representatives who are available for consultation and Project-site inspection.
- C. **Source Limitations:** Obtain each type of material through one source from a single manufacturer.
- D. **Hold Point - Mockups:** Build mockups for concrete removal and patching, floor joint repair and epoxy crack injection to demonstrate aesthetic effects and set quality standards for materials and execution.
 - 1. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials to Project site in manufacturer's original and unopened containers, labeled with type and name of products and manufacturers.
- B. Comply with manufacturer's written instructions for minimum and maximum temperature requirements and other conditions for storage.
- C. Store cementitious materials off the ground, under cover, and in a dry location.
- D. Store aggregates, covered and in a dry location, where grading and other required characteristics can be maintained and contamination avoided.

1.5 PROJECT CONDITIONS

- A. **Environmental Limitations for Epoxies:** Do not apply when air and substrate temperatures are outside limits permitted by manufacturer. During hot weather, cool epoxy components before mixing, store mixed products in shade, and cool unused mixed products to retard setting. Do not apply to wet substrates unless approved by manufacturer.
 - 1. Use only Class A epoxies when substrate temperatures are below or are expected to go below 40 deg F within 8 hours.
 - 2. Use only Class A or B epoxies when substrate temperatures are below or are expected to go below 60 deg F within 8 hours.
 - 3. Use only Class C epoxies when substrate temperatures are above and are expected to stay above 60 deg F for 8 hours.
- B. **Cold-Weather Requirements for Cementitious Materials:** Comply with the following procedures:
 - 1. When air temperature is below 40 deg F, heat patching material ingredients and existing concrete to produce temperatures between 40 and 90 deg F.
 - 2. When mean daily air temperature is between 25 and 40 deg F, cover completed Work with weather-resistant insulating blankets for 48 hours after repair or provide enclosure and heat to maintain temperatures above 32 deg F within the enclosure for 48 hours after repair.
 - 3. When mean daily air temperature is below 25 deg F, provide enclosure and heat to maintain temperatures above 32 deg F within the enclosure for 48 hours after repair.

- C. Hot-Weather Requirements for Cementitious Materials: Protect repair work when temperature and humidity conditions produce excessive evaporation of water from patching materials. Provide artificial shade and wind breaks, and use cooled materials as required. Do not apply to substrates with temperatures of 90 deg F and above.

PART 2 -PRODUCTS

2.1 BONDING AGENTS

- A. Epoxy-Modified, Cementitious Bonding and Anticorrosion Agent: Product that consists of water-insensitive epoxy adhesive, Portland Cement, and water-based solution of corrosion-inhibiting chemicals that forms a protective film on steel reinforcement.
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Euclid Chemical Company (The); Corr-Bond.
 - b. Sika Corporation; Armatec 110 EpoCem.
 - c. Sonneborn, Div. of ChemRex; Sonoprep.
 - d. Tamms Industries, Inc.; Duralprep A.C.
- B. Epoxy Bonding Agent: ASTM C 881/C 881M, Type II.
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anti-Hydro International, Inc.; Poly-Epoxy Bonding #100.
 - b. Euclid Chemical Company (The); Euco #452 Epoxy System.
 - c. Sika Corporation; Sikadur 35, Hi-Mod LV.
 - d. Sonneborn, Div. of ChemRex; Epogel or Epogrip.
 - e. Tamms Industries, Inc.; Duralbond.
 - f. ThoRoc, Div. of ChemRex; Epoxy Adhesive 24LPL.
- C. Mortar Scrub-Coat: One part Portland Cement complying with ASTM C 150, Type I, II, or III and one part fine aggregate complying with ASTM C 144, except 100% passing a No. 16 sieve.

2.2 PATCHING MORTAR

- A. Patching Mortar, General:
 - 1. Unless otherwise indicated, use any of the products specified in this Article.
 - 2. Overhead Patching Mortar: For overhead repairs, use patching mortar recommended by manufacturer for overhead use and as specified in this Article.
 - 3. Coarse Aggregate for Adding to Patching Mortar: Washed aggregate complying with ASTM C 33, Size No. 8, Class 5S. Add only as permitted by patching mortar manufacturer.
- B. Cementitious Patching Mortar: Packaged, dry mix complying with ASTM C 928.
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:

- a. Cementitious Patching Mortar:
 - 1. Sika Corporation; Sikarepair 223.
 - 2. Sonneborn, Div. of ChemRex; Deep Pour Mortar.
 - 3. ThoRoc, Div. of ChemRex; LA Repair Mortar.
- b. Cementitious Patching Mortar, Rapid Setting:
 - 1. Meadows, W. R. Inc.; Sealtight Meadow-Patch 20.
 - 2. Sika Corporation; Sikaset Roadway Patch.
 - 3. Sonneborn, Div. of ChemRex; Road Patch.
 - 4. Tamms Industries, Inc.; Speed Crete 2028.
 - 5. ThoRoc, Div. of ChemRex; 10-61 Rapid Mortar.

2.3 CONCRETE

- A. Concrete Materials and Admixtures: Comply with Division 3 Section 03300 "CAST-IN-PLACE CONCRETE".
- B. Steel and Fiber Reinforcement and Reinforcement Accessories: Comply with Division 3 Section 03300 "CAST-IN-PLACE CONCRETE".
- C. Form-Facing Materials: Comply with Division 3 Section 03300 "CAST-IN-PLACE CONCRETE".
- D. Shotcrete: Comply with Division 3 Section 03371 "SHOTCRETE".
- E. Preplaced Aggregate: Washed aggregate complying with ASTM C 33, Class 5S, with 100% passing a 1-1/2-inch sieve, 95% to 100% passing a 1-inch sieve, 40% to 80% passing a 3/4- inch sieve, 0% to 15% passing a 1/2-inch sieve, and 0% to 2% passing a 3/8-inch sieve.
- F. Fine Aggregate for Grout Used with Preplaced Aggregate: Fine aggregate complying with ASTM C 33, but with 100% passing a No. 8 sieve, 95% to 100% passing a No. 16 sieve, 55% to 80% passing a No. 30 sieve, 30% to 55% passing a No. 50 sieve, 10% to 30% passing a No. 100 sieve, 0% to 10% passing a No. 200 sieve, and having a fineness modulus of 1.30 to 2.10.
- G. Grout Fluidifier for Grout Used with Preplaced Aggregate: ASTM C 937.
- H. Portland Cement for Grout Used with Preplaced Aggregate: ASTM C 150.
- I. Pozzolans for Grout Used with Preplaced Aggregate: ASTM C 618.

2.4 MISCELLANEOUS MATERIALS

- A. Epoxy Joint Filler: 2-component, semirigid, 100% solids, epoxy resin with a Type A Shore durometer hardness of at least 80 per ASTM D 2240.
- B. Epoxy Crack Injection Adhesive: ASTM C 881/C 881M.
Capping Adhesive: Product manufactured for use with crack injection adhesive by same manufacturer.

- C. Corrosion-Inhibiting Treatment Materials: Water-based solution of alkaline corrosion-inhibiting chemicals that penetrates concrete by diffusion and forms a protective film on steel reinforcement.
- D. Steel Plates, Shapes, and Bars: ASTM A 36/A 36M.
 - 1. After fabricating, prepare surfaces to comply with SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning".
 - 2. After preparation, apply two-coat high-performance coating system consisting of organic zinc-rich primer, complying with SSPC-Paint 20 or SSPC-Paint 29 and topcoat of high-build, urethane or epoxy coating recommended by manufacturer for application over specified zinc-rich primer. Comply with coating manufacturer's written directions and with requirements in SSPC-PA 1, "Paint Application Specification No. 1: Shop, Field, and Maintenance Painting of Steel", for shop painting.
- E. Bolts, Nuts, and Washers: Carbon steel; ASTM A 307, Grade A, for bolts; ASTM A 563, Grade A, for nuts; and ASTM F 436 for washers; hot-dip or mechanically zinc coated.
- F. Postinstalled Anchors: Chemical or expansion anchors, made from stainless-steel components complying with ASTM F 593 and ASTM F 594, Alloy Group 1 or 2 for bolts and nuts; ASTM A 666 or ASTM A 276, Type 304 or 316, for anchors, with capability to sustain, without failure, a load equal to four times the load imposed, as determined by testing per ASTM E 488, conducted by a qualified independent testing agency.

2.5 MIXES

- A. Mix products, in clean containers, according to manufacturer's written instructions.
 - 1. Add clean silica sand and coarse aggregates to products only as recommended by manufacturer.
 - 2. Do not add water, thinners, or additives unless recommended by manufacturer.
 - 3. When practical, use manufacturer's premeasured packages to ensure that materials are mixed in proper proportions. When premeasured packages are not used, measure ingredients using graduated measuring containers; do not estimate quantities or use shovel or trowel as unit of measure. Only use full, unopened bags.
 - 4. Do not mix more materials than can be used within recommended open time. Discard materials that have begun to set.
- B. Mortar Scrub-Coat: Mix with enough water to provide consistency of thick cream.
- C. Dry-Pack Mortar: Mix with just enough liquid to form damp cohesive mixture that can be squeezed by hand into a ball but is not plastic.
- D. Concrete: Comply with Division 3 Section 03300 "CAST-IN-PLACE CONCRETE".
- E. Shotcrete: Comply with Division 3 Section 03371 "SHOTCRETE".
- F. Grout for Use with Preplaced Aggregate: Proportion according to ASTM C 938. Add grout fluidifier to mixing water followed by cementitious materials and then fine aggregate.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Notify MBTA seven days in advance of dates when areas of deteriorated or delaminated concrete and deteriorated reinforcing bars will be located.
- B. Locate areas of deteriorated or delaminated concrete using hammer or chain drag sounding and mark boundaries. Mark areas for removal by simplifying and squaring off boundaries as directed by MBTA. At columns and walls make boundaries level and plumb, unless otherwise indicated.
- C. Locate at least three reinforcing bars using a pachometer, and drill test holes to determine depth of cover. Calibrate pachometer, using depth of cover measurements, and verify depth of cover in removal areas using pachometer.
- D. All deteriorated concrete areas shown on the contract plans shall be sounded. The deteriorated areas shall be marked and work shall not proceed until approval is given by the MBTA.

3.2 PREPARATION

- A. Protect people, motor vehicles, equipment, surrounding construction, Project site, plants, trees, shrubs, other vegetation and surrounding buildings from injury resulting from concrete rehabilitation work.
 - 1. Erect and maintain temporary protective covers over pedestrian walkways and at points of entrance and exit for people and vehicles, unless such areas are made inaccessible during the course of concrete rehabilitation work. Construct covers of tightly fitted, 3/4-inch exterior-grade plywood supported at 16 inches o.c. and covered with asphalt roll roofing.
 - 2. Protect adjacent equipment and surfaces by covering them with heavy polyethylene film and waterproof masking tape or a liquid strippable masking agent. If practical, remove items, store, and reinstall after potentially damaging operations are complete.
 - 3. Neutralize and collect alkaline and acid wastes according to requirements of the MBTA, and dispose of by legal means off MBTA's property.
 - 4. Dispose of runoff from wet operations by legal means and in a manner that prevents soil erosion, undermining of paving and foundations, damage to landscaping, and water penetration into building interiors.
- B. Shoring: Install temporary supports as required before beginning concrete removal.
- C. Concrete Removal:
 - 1. Saw-cut perimeter of areas indicated for removal to a depth of at least 1/2 inch. Make cuts perpendicular to concrete surfaces and no deeper than cover on reinforcement.
 - 2. Remove deteriorated and delaminated concrete by breaking up and dislodging from reinforcement.
 - 3. Remove additional concrete, if necessary, to provide a depth of removal of at least 1/2 inch over entire removal area.
 - 4. Where half or more of the perimeter of reinforcing bar is exposed, bond between reinforcing bar and surrounding concrete is broken, or reinforcing bar is corroded, remove concrete from entire perimeter of bar and to provide at least a 3/4-inch clearance around bar.
 - 5. Test areas where concrete has been removed by tapping with hammer, and remove additional

concrete until unsound and disbonded concrete is completely removed.

6. Provide fractured aggregate surfaces with a profile of at least 1/8 inch that is approximately perpendicular or parallel to original concrete surfaces. At columns and walls, make top and bottom surfaces level, unless otherwise directed.
 7. Thoroughly clean removal areas of loose concrete, dust, and debris.
- D. Reinforcing Bar Preparation: Remove loose and flaking rust from reinforcing bars by abrasive blast cleaning until only tightly bonded light rust remains.
1. Where section loss of reinforcing bar is more than 25%, or 20% in 2 or more adjacent bars, cut bars and remove and replace as directed by MBTA. Remove additional concrete as necessary to provide at least 3/4-inch clearance at existing and replacement bars. Splice replacement bars to existing bars according to ACI 318, by lapping, welding, or using mechanical couplings.
- E. Surface Preparation for Corrosion-Inhibiting Treatment: Clean concrete by low-pressure water cleaning, detergent scrubbing or sand blasting to remove dirt, oils, films, and other materials detrimental to treatment application. Allow surface to dry before applying corrosion-inhibiting treatment.

3.3 APPLICATION

- A. General: Comply with manufacturer's written instructions and recommendations for application of products, including surface preparation.
- B. Epoxy-Modified, Cementitious Bonding and Anticorrosion Agent: Apply to reinforcing bars and concrete by stiff brush or hopper spray according to manufacturer's written instructions. Apply to reinforcing bars in two coats, allowing first coat to dry two to three hours before applying second coat. Allow to dry before placing patching mortar or concrete.
- C. Epoxy Bonding Agent: Apply to reinforcing bars and concrete by brush, roller, or spray according to manufacturer's written instructions, leaving no pinholes or other uncoated areas. Apply to reinforcing bars in at least two coats, allowing first coat to dry before applying second coat. Apply patching mortar or concrete while epoxy is still tacky. If epoxy dries, recoat before placing patching mortar or concrete.
- D. Latex Bonding Agent, Type II: Mix with Portland Cement and scrub into concrete surface according to manufacturer's written instructions. Apply patching mortar or concrete while bonding agent is still wet. If bonding agent dries, recoat before placing patching mortar or concrete.
- E. Latex Bonding Agent, Type I: Apply to concrete by brush roller or spray. Allow to dry before placing patching mortar or concrete.
- F. Mortar Scrub-Coat: Dampen repair area and surrounding concrete 6 inches beyond repair area. Remove standing water and apply scrub-coat with a brush, scrubbing it into surface and thoroughly coating repair area. If scrub-coat dries, recoat before applying patching mortar or concrete.
- G. Patching Mortar: Unless otherwise recommended by manufacturer, apply as follows:
1. Wet substrate thoroughly and then remove standing water. Scrub a slurry of neat patching mortar mixed with latex bonding agent into substrate, filling pores and voids.

2. Place patching mortar by troweling toward edges of patch to force intimate contact with edge surfaces. For large patches, fill edges first and then work toward center, always troweling toward edges of patch. At fully exposed reinforcing bars, force patching mortar to fill space behind bars by compacting with trowel from sides of bars.
 3. For vertical patching, place material in lifts of not more than 2 inches nor less than 1/8inch. Do not feather edge.
 4. For overhead patching, place material in lifts of not more than 1-1/2 inches nor less than 1/8 inch. Do not feather edge.
 5. After each lift is placed, consolidate material and screed surface.
 6. Where multiple lifts are used, score surface of lifts to provide a rough surface for application of subsequent lifts. Allow each lift to reach final set before placing subsequent lifts.
 7. Allow surfaces of lifts that are to remain exposed to become firm and then finish to a smooth surface with a broom or burlap drag.
 8. Wet-cure cementitious patching materials, including polymer-modified, cementitious patching materials, for not less than seven days by water-fog spray or water-saturated absorptive cover.
- H. Dry-Pack Mortar: Use for deep cavities and where indicated. Unless otherwise recommended by manufacturer, apply as follows:
1. Provide forms where necessary to confine patch to required shape.
 2. Wet substrate and forms thoroughly and then remove standing water.
 3. Place dry-pack mortar into cavity by hand, and compact into place with a hardwood drive stick and mallet or hammer. Do not place more material at a time than can be properly compacted.
Continue placing and compacting until patch is approximately level with surrounding surface.
 4. After cavity is filled and patch is compacted, trowel surface to match profile and finish of surrounding concrete. A thin coat of patching mortar may be troweled into the surface of patch to help obtain required finish.
 5. Wet-cure patch for not less than seven days by water-fog spray or water-saturated absorptive cover.
- I. Concrete: Place according to Division 3 Section 03300 "CAST-IN-PLACE CONCRETE" and as follows:
1. Apply bonding agent to reinforcement and concrete substrate.
 2. Use vibrators to consolidate concrete as it is placed.
 3. At unformed surfaces, screed concrete to produce a surface that when finished with patching mortar will match required profile and surrounding concrete.
 4. Where indicated place concrete by form and pump method.
 - a. Design and construct forms to resist pumping pressure in addition to weight of wet concrete. Seal joints and seams in forms and junctions of forms with existing concrete.
 - b. Pump concrete into place, releasing air from forms as concrete is introduced. When formed space is full, close air vents and pressurize to 14 psi.
 5. Wet-cure concrete for not less than seven days by leaving forms in place or keeping surfaces

continuously wet by water-fog spray or water-saturated absorptive cover.

6. Fill placement cavities with dry-pack mortar and repair voids with patching mortar. Finish to match surrounding concrete.
- J. Shotcrete: Place according to Division 3 Section 03371 "SHOTCRETE" and as follows:
1. Apply bonding agent to reinforcement and concrete substrate.
 2. Screed and finish shotcrete to produce a surface matching required profile and surrounding concrete.
- K. Grouted Preplaced Aggregate Concrete: Use for column and wall repairs. Place as follows:
1. Design and construct forms to resist pumping pressure in addition to weight of wet grout. Seal joints and seams in forms and junctions of forms with existing concrete.
 2. Apply bonding agent to reinforcement and concrete substrate.
 3. Place aggregate in forms, consolidating aggregate as it is placed. Pack aggregate into upper areas of forms to achieve intimate contact with concrete surfaces.
 4. Fill forms with water to thoroughly dampen aggregate and substrates. Drain water from forms before placing grout.
 5. Pump grout into place at bottom of preplaced aggregate, forcing grout upward. Release air from forms at top as grout is introduced. When formed space is full and grout flows from air vents, close vents and pressurize to 14 psi.
 6. Wet-cure concrete for not less than seven days by leaving forms in place or keeping surfaces continuously wet by water-fog spray or water-saturated absorptive cover.
 7. Repair voids with patching mortar and finish to match surrounding concrete.
- L. Epoxy Crack Injection: Comply with manufacturer's written instructions and the following:
1. Clean areas to receive capping adhesive of oil, dirt, and other substances that would interfere with bond, and clean cracks with oil-free compressed air or low-pressure water to remove loose particles.
 2. Place injection ports as recommended by epoxy manufacturer, spacing no farther apart than thickness of member being injected. Seal injection ports in place with capping adhesive.
 3. Seal cracks at exposed surfaces with a ribbon of capping adhesive at least 1/4 inch thick by 1 inch wider than crack.
 4. Inject cracks wider than 0.003 inch to a depth of 8 inches or to a width of less than 0.003 inch, whichever is less.
 5. Inject epoxy adhesive, beginning at widest part of crack and working toward narrower parts. Inject adhesive into ports to refusal, capping adjacent ports when they extrude epoxy. Cap injected ports and inject through adjacent ports until crack is filled.
 6. After epoxy adhesive has set, remove injection ports and grind surfaces smooth.
- M. Corrosion-Inhibiting Treatment: Apply by brush, roller, or airless spray in two coats at manufacturer's recommended application rate. Remove film of excess treatment by high-pressure washing before patching treated concrete.

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: Design-Builder shall engage a qualified testing agency to sample materials and perform tests as follows:
1. Patching Mortar, Packaged Mixes: Randomly selected samples tested according to ASTM C 928.
 2. Concrete: As specified in Division 3 Section "CAST-IN-PLACE CONCRETE".
 3. Shotcrete: As specified in Division 3 Section "SHOTCRETE".
 4. Grouted Preplaced Aggregate: Tested for compressive strength of grout according to ASTM C 942.
 - a. Testing Frequency: One sample for each 25 cu. yd. of grout or fraction thereof, but not less than one sample for each day's work.
 5. Joint Filler: Core drilled samples to verify proper installation.
 - a. Testing Frequency: One sample for each 100 feet of joint filled.
 - b. Where samples are taken, fill holes with joint filler.
 6. Epoxy Crack Injection: Core drilled samples to verify proper installation.
 - a. Testing Frequency: 3 samples from mockup and 1 sample for each 100 feet of crack injected.
 - b. Where samples are taken, fill holes with epoxy mortar.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 04800

MASONRY

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Concrete masonry units.
 2. Architectural Precast Concrete Trim units.
 3. Mortar and grout.
 4. Reinforcing steel, masonry joint reinforcement, ties and anchors
 5. Masonry-cell insulation.
 6. Furnish dovetail slots for masonry anchors to concrete trade for installation.
 7. Installation of items furnished by others for installation in masonry including but not limited to lintels, miscellaneous metal and iron sleeves, anchors and plate to be built into masonry walls, through-wall flashings, built-in flashings, anchors and inserts for signage, elevator rail bracket inserts, access doors in masonry openings, grilles in interior masonry walls, pipe and duct sleeves for placement into masonry openings.
- B. Related Work:
1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 2. Section 07920 - JOINT SEALANTS; sealing control and expansion joints in unit masonry.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For the following:
1. Masonry Units: Show sizes, profiles, coursing, and locations of special shapes.
 2. Precast Concrete Trim Units: Show sizes, profiles, and locations of each trim unit required.
 3. Reinforcing Steel: Detail bending and placement of unit masonry reinforcing bars. Comply with ACI 315, "Details and Detailing of Concrete Reinforcement."
- C. Samples for Verification: For each type and color of the following:
1. Exposed concrete masonry units.
 2. Precast Concrete Trim Units
 3. Pigmented mortar. Make Samples using same sand and mortar ingredients to be used on Project. Label Samples to indicate types and amounts of pigments used.
 4. Weep holes/vents.
 5. Accessories embedded in masonry.
- D. Qualification Data: For testing agency.

- E. Material Certificates: Include statements of material properties indicating compliance with requirements including compliance with standards and type designations within standards. Provide for each type and size of the following:
 - 1. Masonry units.
 - a. Include material test reports substantiating compliance with requirements.
 - b. For masonry units used in structural masonry, include data and calculations establishing average net-area compressive strength of units.
 - 2. Cementitious materials. Include brand, type, and name of manufacturer.
 - 3. Preblended, dry mortar mixes. Include description of type and proportions of ingredients.
 - 4. Grout mixes. Include description of type and proportions of ingredients.
 - 5. Reinforcing bars.
 - 6. Joint reinforcement.
 - 7. Anchors, ties, and metal accessories.
- F. Mix Designs: For each type of mortar and grout. Include description of type and proportions of ingredients.
 - 1. Include test reports, per ASTM C 780 for mortar mixes required to comply with property specification.
 - 2. Include test reports, per ASTM C 1019 for grout mixes required to comply with compressive strength requirement.
- G. Tests Results: For each type of test including mortar, grout and prism tests, for approval by the Engineer.
- H. Cold-Weather Procedures: Detailed description of methods, materials, and equipment to be used to comply with cold-weather requirements.
- I. UL Certificate of Compliance for fire rated concrete masonry units.

1.3 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency qualified according to ASTM C 1093 for testing indicated, as documented according to ASTM E 548.
- B. Source Limitations for Masonry Units: Obtain exposed masonry units of a uniform texture and color, or a uniform blend within the ranges accepted for these characteristics, through one source from a single manufacturer for each product required.
- C. Source Limitations for Mortar Materials: Obtain mortar ingredients of a uniform quality, including color for exposed masonry, from a single manufacturer for each cementitious component and from one source or producer for each aggregate.
- D. Preconstruction Testing Service: The Contractor will engage a qualified independent testing agency to perform preconstruction testing indicated below. Payment for these services will be made by the

Contractor. Retesting of materials that fail to meet specified requirements shall be done at Contractor's expense.

1. Prism Test: For each type of construction required, per ASTM C 1314; strength as specified.
- E. Fire-Resistance Ratings: Where indicated, provide materials and construction identical to those of assemblies with fire-resistance ratings determined per ASTM E 119 by a testing and inspecting agency, by equivalent concrete masonry thickness, or by other means, as acceptable to authorities having jurisdiction. All fire rated Concrete Masonry Units shall meet the requirements of UL-618, Standards of Concrete Masonry Units. Concrete Masonry Units to be used for the construction of 2-Hour, 3-Hour and 4-Hour Fire Rated Walls shall be clearly marked by manufacturer. The manufacturer shall clearly mark all concrete masonry units in each cube with the appropriated UL designation of 2-Hour, 3-Hour or 4-Hour.
- F. Hold Point - Sample Panels: Build sample panels to verify selections made under sample submittals and to demonstrate aesthetic effects.
1. Build sample panels for typical exterior and interior walls in sizes approximately 48 inches long by 48 inches high by full thickness.
 2. Clean one-half of exposed faces of panels with masonry cleaner indicated.
 3. Protect approved sample panels from the elements with weather-resistant membrane.
 4. Approval of sample panels is for color, texture, and blending of masonry units; relationship of mortar and sealant colors to masonry unit colors; tooling of joints; aesthetic qualities of workmanship; and other material and construction qualities specifically approved by Architect in writing.
 - a. Approval of sample panels does not constitute approval of deviations from the Contract Documents contained in sample panels unless such deviations are specifically approved by Architect in writing.
 - b. The standard for the work during construction shall be the same as demonstrated on approved panels.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Store masonry units on elevated platforms in a dry location. If units are not stored in an enclosed location, cover tops and sides of stacks with waterproof sheeting, securely tied. If units become wet, do not install until they are dry.
- B. Store cementitious materials on elevated platforms, under cover, and in a dry location. Do not use cementitious materials that have become damp.
- C. Store aggregates where grading and other required characteristics can be maintained and contamination avoided.
- D. Deliver preblended, dry mortar mix in moisture-resistant containers designed for lifting and emptying into dispensing silo. Store preblended, dry mortar mix in delivery containers on elevated platforms, under cover, and in a dry location or in a metal dispensing silo with weatherproof cover.
- E. Store masonry accessories, including metal items, to prevent corrosion and accumulation of dirt

1.5 PROJECT CONDITIONS

- A. Protection of Masonry: During construction, cover tops of walls, projections, and sills with waterproof sheeting at end of each day's work. Cover partially completed masonry when construction is not in progress.
1. Extend cover a minimum of 24 inches down both sides and hold cover securely in place.
 2. Where 1 wythe of multiwythe masonry walls is completed in advance of other wythes, secure cover a minimum of 24 inches down face next to unconstructed wythe and hold cover in place.
- B. Do not apply uniform floor or roof loads for at least 12 hours and concentrated loads for at least 3 days after building masonry walls or columns.
- C. Stain Prevention: Prevent grout, mortar, and soil from staining the face of masonry to be left exposed or painted. Immediately remove grout, mortar, and soil that come in contact with such masonry.
1. Protect base of walls from rain-splashed mud and from mortar splatter by spreading coverings on ground and over wall surface.
 2. Protect sills, ledges, and projections from mortar droppings.
 3. Protect surfaces of window and door frames, as well as similar products with painted and integral finishes, from mortar droppings.
 4. Turn scaffold boards near the wall on edge at the end of each day to prevent rain from splashing mortar and dirt onto completed masonry.
- D. Cold-Weather Requirements: Do not use frozen materials or materials mixed or coated with ice or frost. Do not build on frozen substrates. Remove and replace unit masonry damaged by frost or by freezing conditions. Comply with cold-weather construction requirements contained in ACI 530.1/ASCE 6/TMS 602.
1. Cold-Weather Cleaning: Use liquid cleaning methods only when air temperature is 40 deg F and above and will remain so until masonry has dried, but not less than 7 days after completing cleaning.
- E. Hot-Weather Requirements: Comply with hot-weather construction requirements contained in ACI 530.1/ASCE 6/TMS 602.

PART 2 -PRODUCTS

2.1 CONCRETE MASONRY UNITS (CMUs)

- A. Concrete Masonry Units: ASTM C 90, normal weight unless indicated otherwise manufactured to dimensions 3/8 inch less than nominal dimensions.
- B. Shapes: Provide standard shapes indicated and as required for building configuration. Provide special shapes for lintels, corners, jambs, sashes, movement joints, headers, bonding, and other special conditions.

1. Integral Water Repellent: Provide units made with integral water repellent for units exposed to the exterior Integral Water Repellent: Liquid polymeric, integral water-repellent admixture that does not reduce flexural bond strength. Units made with integral water repellent, when tested as a wall assembly made with mortar containing integral water-repellent manufacturer's mortar additive according to ASTM E 514, with test period extended to 24 hours, show no visible water or leaks on the back of test specimen. Available products include:
 - a. Addiment Incorporated; Block Plus W-10.
 - b. Grace Construction Products, a unit of W. R. Grace & Co. - Conn.; Dry-Block.
 - c. Master Builders, Inc.; Rheopel.
 - d. Or approved equal.
- C. Decorative CMUs: ASTM C 90, normal weight.
1. Pattern and Texture:
 - a. Standard pattern, polished ground-face finish.
 2. Colors: As selected by Architect from manufacturer's full range.

2.2 PRECAST CONCRETE TRIM UNITS

- A. Precast concrete trim locations include but are not limited to:
1. at masonry construction exterior walls: window sills, base course and parapet caps
 2. at elevator hoistways: curbs
- B. Aggregate: ASTM C33, fine and coarse, type of stone selected to achieve desired finish and texture.
- C. Reinforcement: ASTM C615, Grade 40 or 60, new billet steel bars with min. 2 in. cover when placed.
- D. Cast with suitable wash on exposed top surfaces, raised fillet at back of sills, drips on lower outer edge of projecting pieces.
- E. Tests: ACI 704 for average 3 specimens per test.
- F. Compressive Strength: Min. 2500 psi.
- G. Anchors: Type 302 or 304 stainless-steel.

2.3 MORTAR AND GROUT MATERIALS

- A. Portland Cement: ASTM C 150, Type I or II, except Type III may be used for cold-weather construction. Provide natural color or white cement as required to produce mortar color indicated.
- B. Hydrated Lime: ASTM C 207, Type S.
- C. Mortar Pigments: Natural and synthetic iron oxides and chromium oxides, compounded for use in mortar mixes. Use only pigments with a record of satisfactory performance in masonry mortar.

1. Available Products:
 - a. Bayer Corporation, Industrial Chemicals Div.; Bayferrox Iron Oxide Pigments.
 - b. Davis Colors; True Tone Mortar Colors.
 - c. Solomon Grind-Chem Services, Inc.; SGS Mortar Colors.
 - d. Or approved equal.
- D. Aggregate for Mortar: ASTM C 144. For mortar that is exposed to view, use washed aggregate consisting of natural sand or crushed stone.
- E. Aggregate for Grout: ASTM C 404.
- F. Water: Potable.

2.4 REINFORCEMENT

- A. Uncoated Steel Reinforcing Bars: ASTM A 615/A 615M or ASTM A 996/A 996M, Grade 60.
- B. Masonry Joint Reinforcement, General: ASTM A 951.
 1. Interior Walls: Mill-galvanized, carbon steel.
 2. Exterior Walls: Hot-dip galvanized, carbon steel.
 3. Wire Size and Spacing: As required by Code.
 4. Provide in lengths of not less than 10 feet, with prefabricated corner and tee units.
- C. Masonry Joint Reinforcement for Multiwythe Masonry:
 1. Ladder type with 1 side rod at each face shell of hollow masonry units more than 4 inches in width, plus 1 side rod at each wythe of masonry 4 inches or less in width.

2.5 TIES AND ANCHORS

- A. Materials: Provide ties and anchors specified in subsequent paragraphs that are made from materials that comply with subparagraphs below, unless otherwise indicated.
 1. Mill-Galvanized, Carbon-Steel Wire: ASTM A 82; with ASTM A 641/A 641M, Class 1 coating.
 2. Hot-Dip Galvanized, Carbon-Steel Wire: ASTM A 82; with ASTM A 153/A 153M, Class B-2 coating.
 3. Stainless-Steel Wire: ASTM A 580/A 580M, Type 316.
 4. Galvanized Steel Sheet: ASTM A 653/A 653M, Commercial Steel, G60 zinc coating.
 5. Steel Plates, Shapes, and Bars: ASTM A 36/A 36M.
- B. Stainless Steel bars: ASTM A 276 or ASTM A 666, Type 304.

- C. Adjustable Anchors for Connecting to Structure: Provide anchors that allow vertical or horizontal adjustment but resist tension and compression forces perpendicular to plane of wall.
 - 1. Anchor Section for Welding to Steel Frame: Crimped 1/4-inch-diameter, hot-dip galvanized steel. Mill-galvanized wire may be used at interior walls, unless otherwise indicated.
- D. Partition Top Anchors: 0.097-inch-thick metal plate with 3/8-inch-diameter metal rod 6 inches long welded to plate and with closed-end plastic tube fitted over rod that allows rod to move in and out of tube. Fabricate from steel, hot-dip galvanized after fabrication.
- E. Adjustable Masonry-Veneer Anchors:
 - 1. General: Provide anchors that allow vertical adjustment but resist tension and compression forces perpendicular to plane of wall, for attachment over sheathing to wood or metal studs, with structural performance capable of withstanding a 100-lb of load in both tension and compression without deforming or developing play in excess of 0.05 inch. Flat metal anchors are not acceptable.
 - 2. Contractor's Option: Unless otherwise indicated, provide any of the following types of anchors.
 - 3. Screw-Attached, Masonry-Veneer Anchors: Units consisting of a wire tie and a metal anchor section.
 - a. Anchor Section: Zinc-alloy barrel section with flanged head with eye and corrosion-resistant, self-drilling screw. Eye designed to receive wire tie and to serve as head for drilling fastener into framing. Barrel length to suit sheathing thickness, allowing screw to seat directly against framing with flanged head covering hole in sheathing.
 - b. Wire Ties: Triangular-, rectangular-, or T-shaped wire ties fabricated from 0.188-inch-diameter, hot-dip galvanized steel wire.

2.6 MISCELLANEOUS ANCHORS

- A. Anchor Bolts: L-shaped steel bolts complying with ASTM A 307, Grade A; with ASTM A 563 hex nuts and, where indicated, flat washers; hot-dip galvanized to comply with ASTM A 153/A 153M, Class C; of dimensions indicated.

2.7 EMBEDDED FLASHING MATERIALS

- A. Metal Flashings: Furnished under Section 07620.

2.8 MISCELLANEOUS MASONRY ACCESSORIES

- A. Compressible Filler: Premolded filler strips complying with ASTM D 1056, Grade 2A1; compressible up to 35 percent; of width and thickness indicated; formulated from neoprene.
- B. Preformed Control-Joint Gaskets: Made from styrene-butadiene-rubber compound, complying with ASTM D 2000, Designation M2AA-805 designed to fit standard sash block and to maintain lateral stability in masonry wall; size and configuration as indicated.
- C. Bond-Breaker Strips: Asphalt-saturated, organic roofing felt complying with ASTM D 226, Type I (No. 15 asphalt felt).
- D. Weep/Vent Products: Free-draining mesh; made from polyethylene strands, full height and width of

head joint and depth 1/8 inch less than depth of outer wythe; in color selected from manufacturer's standard.

- E. Cavity Drainage Material: Free-draining mesh, made from polymer strands that will not degrade within the wall cavity. Provide strips, full-depth of cavity and 10 inches wide, with dovetail shaped notches 7 inches deep that prevent mesh from being clogged with mortar droppings or equivalent. Available products:

1. Advanced Building Products Inc.; Mortar Break II.
2. Archovations, Inc.; CavClear Masonry Mat.
3. Dayton Superior Corporation, Dur-O-Wal Division; Polytite MortarStop.
4. Mortar Net USA, Ltd.; Mortar Net.
5. Or approved equal.

2.9 MASONRY CLEANERS

- A. Proprietary Acidic Cleaner: Manufacturer's standard-strength cleaner designed for removing mortar/grout stains, efflorescence, and other new construction stains from new masonry without discoloring or damaging masonry surfaces. Use product expressly approved for intended use by cleaner manufacturer and manufacturer of masonry units being cleaned.

1. Available Manufacturers:
 - a. Diedrich Technologies, Inc.
 - b. EaCo Chem, Inc.
 - c. ProSoCo, Inc.
 - d. Or approved equal.

2.10 MORTAR AND GROUT MIXES

- A. General: Do not use admixtures, including pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds, or other admixtures, unless otherwise indicated.

1. Do not use calcium chloride in mortar or grout.
2. Limit cementitious materials in mortar to Portland cement [mortar cement] and lime.

- B. Mortar for Unit Masonry: Comply with ASTM C 270, Proportion Specification. Provide the following types of mortar for applications stated unless another type is indicated or needed to provide required compressive strength of masonry.

1. For masonry below grade or in contact with earth, use Type M, minimum strength 2,500 psi.
2. For reinforced masonry and all glass block, use Type S, minimum strength 1,800 psi.
3. For exterior, above-grade, load-bearing and non-load-bearing walls and parapet walls; for interior load-bearing walls; for interior non-load-bearing partitions; and for other applications where another type is not indicated, use Type N, minimum strength 75 psi.

- C. Pigmented Mortar: Use colored cement product. Pigments shall not exceed 10 percent of Portland cement by weight.
- D. Grout for Unit Masonry: Comply with ASTM C 476.
 - 1. Use grout of type indicated or, if not otherwise indicated, of type (fine or coarse) that will comply with Table 1.15.1 in ACI 530.1/ASCE 6/TMS 602 for dimensions of grout spaces and pour height.
 - 2. Provide grout with a slump of 8 to 11 inches as measured according to ASTM C 143/C 143M.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of work.
 - 1. For the record, prepare written report, endorsed by Installer, listing conditions detrimental to performance of work.
 - 2. Verify that foundations are within tolerances specified.
- B. Before installation, examine rough-in and built-in construction for piping systems to verify actual locations of piping connections.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. Thickness: Build cavity and composite walls and other masonry construction to full thickness shown. Build single-wythe walls to actual widths of masonry units, using units of widths indicated.
- B. Build chases and recesses to accommodate items specified in this and other Sections.
- C. Leave openings for equipment to be installed before completing masonry. After installing equipment, complete masonry to match the construction immediately adjacent to opening.
- D. Use full-size units without cutting if possible. If cutting is required to provide a continuous pattern or to fit adjoining construction, cut units with motor-driven saws; provide clean, sharp, unchipped edges. Allow units to dry before laying unless wetting of units is specified. Install cut units with cut surfaces and, where possible, cut edges concealed. Do not use units cut to less than one-half size.
- E. Do not install concrete masonry units with more than 5 percent damage to the face.
- F. Select and arrange units for exposed unit masonry to produce a uniform blend of colors and textures. Mix units from several pallets or cubes as they are placed.
- G. Comply with construction tolerances in ACI 530.1/ASCE 6/TMS 602 and with the following:
 - 1. For conspicuous vertical lines, such as external corners, door jambs, reveals, and expansion

and control joints, do not vary from plumb by more than 1/8 inch in 10 feet, 1/4 inch in 20 feet, and 1/2 inch maximum over entire height.

2. For vertical alignment of exposed head joints, do not vary from plumb by more than 1/4 inch in 10 feet, and 1/2 inch maximum over entire height.
 3. For conspicuous horizontal lines, such as lintels, sills, parapets, and reveals, do not vary from level by more than 1/8 inch in 10 feet, 1/4 inch in 20 feet, and 1/2 inch maximum over entire length.
 4. For exposed bed joints, do not vary from thickness indicated by more than plus or minus 1/8 inch, with a maximum thickness limited to 1/2 inch. Do not vary from bed-joint thickness of adjacent courses by more than 1/8 inch.
 5. For exposed head joints, do not vary from thickness indicated by more than plus or minus 1/8 inch. Do not vary from adjacent bed-joint and head-joint thicknesses by more than 1/8 inch.
 6. For faces of adjacent exposed masonry units, do not vary from flush alignment by more than 1/16 inch except due to warpage of masonry units within tolerances specified for warpage of units.
- H. Do not retemper mortar.
- I. Masonry Cell Insulation: Loose-fill Perlite complying with ASTM C 549, Type II (surface treated for water repellency and limited moisture absorption) or Type IV (surface treated for water repellency and to limit dust generation)

3.3 LAYING MASONRY WALLS

- A. Lay out walls in advance for accurate spacing of surface bond patterns with uniform joint thicknesses and for accurate location of openings, movement-type joints, returns, and offsets. Avoid using less-than-half-size units, particularly at corners, jambs, and, where possible, at other locations.
- B. Bond Pattern for Exposed Masonry: Unless otherwise indicated, lay exposed masonry in bond pattern indicated on Drawings; do not use units with less than nominal 4-inch horizontal face dimensions at corners or jambs. Prior to installation review bond pattern with Engineer.
- C. Stopping and Resuming Work: Stop work by racking back units in each course from those in course below; do not tooth. When resuming work, clean masonry surfaces that are to receive mortar, remove loose masonry units and mortar, and wet brick if required before laying fresh masonry.
- D. Built-in Work: As construction progresses, build in items specified in this and other Sections. Fill in solidly with masonry around built-in items.
- E. Fill space between steel frames and masonry solidly with mortar, unless otherwise indicated.
- F. Fill cores in hollow concrete masonry units with grout 24 inches under bearing plates, beams, lintels, posts, and similar items, unless otherwise indicated.
- G. Build non-load-bearing interior partitions full height of story to underside of solid floor or roof structure above, unless otherwise indicated.

1. Install compressible filler in joint between top of partition and underside of structure above.
2. Fasten partition top anchors to structure above and build into top of partition. Grout cells of CMUs solidly around plastic tubes of anchors and push tubes down into grout to provide 1/2-inch clearance between end of anchor rod and end of tube. Space anchors 48 inches o.c., unless otherwise indicated.
3. Wedge non-load-bearing partitions against structure above with small pieces of tile, slate, or metal. Fill joint with mortar after dead-load deflection of structure above approaches final position.
4. At fire-rated partitions, treat joint between top of partition and underside of structure above to comply with Division 7 Section "Firestopping".

3.4 MORTAR BEDDING AND JOINTING

- A. Lay hollow concrete masonry units as follows:
 1. With face shells fully bedded in mortar and with head joints of depth equal to bed joints.
 2. With webs fully bedded in mortar in all courses of piers, columns, and pilasters.
 3. With webs fully bedded in mortar in grouted masonry, including starting course on footings.
 4. With entire units, including areas under cells, fully bedded in mortar at starting course on footings where cells are not grouted.
- B. Lay solid masonry units with completely filled bed and head joints; butter ends with sufficient mortar to fill head joints and shove into place. Do not deeply furrow bed joints or slush head joints.
- C. Tool exposed joints slightly concave when thumbprint hard, using a jointer larger than joint thickness, unless otherwise indicated.
 1. At repurposed granite ashlar veneer retaining walls, horizontal joints shall be racked and vertical joints shall be flush.
- D. Cut joints flush for masonry walls to receive plaster or other direct-applied finishes (other than paint), unless otherwise indicated.

3.5 INSTALLING GLASS BLOCK WITH MORTAR

- A. Apply a heavy coat of asphalt emulsion to sill and adhere expansion strips to jambs and heads with asphalt emulsion. Allow asphalt emulsion to dry before placing mortar. Trim expansion strips to width required to fit glass block and to full lengths of heads and jambs.
- B. Set glass block with completely filled bed and head joints, with no furrowing, accurately spaced and coordinated with other construction. Maintain 1/4-inch exposed joint widths unless otherwise indicated.
- C. Install panel reinforcement in horizontal joints at spacing indicated and continuously from end to end of panels; comply with the following requirements:
 1. Vertical Spacing of Panel Reinforcement for Exterior Panels: Every other course but not more than 16 inches o.c., starting with first course above sill.
 2. Vertical Spacing of Panel Reinforcement for Interior Panels: Not more than 16 inches o.c.
 3. Do not bridge expansion joints with panel reinforcement.

4. Place panel reinforcement in joints immediately above and below all openings within glass unit masonry assemblies.
 5. Lap panel reinforcement not less than 6 inches if more than one length is necessary.
 6. Embed panel reinforcement in mortar bed by placing lower half of mortar bed first, pressing panel reinforcement into place and covering with upper half of mortar bed.
- D. Install panel anchors at locations indicated and in same horizontal joints where panel reinforcement occurs. Extend panel anchors at least 12 inches into joints, and bend within expansion joints at edges of panels and across the head. Attach panel anchors as indicated.
1. For in-place unit masonry assemblies and concrete, attach panel anchors with 1/4-inch- diameter bolt-size, postinstalled anchors, two per panel anchor.
- E. Use rubber mallet to tap units into position. Do not use steel tools, and do not allow units to come into contact with metal accessories and frames.
- F. Use plastic spacers or temporary wedges in mortar joints to produce uniform joint widths and to prevent mortar from being squeezed out of joints.
- G. Keep expansion joints free of mortar.
- H. Rake out joints indicated to be pointed to a uniform depth sufficient to accommodate pointing material, but not less than joint width.
1. Point joints at both faces of exterior panels with mortar.
- I. Point joints with mortar by filling raked joints and voids. Place and compact pointing mortar in layers not more than 3/8 inch thick. Compact each layer thoroughly and allow to become thumbprint hard before applying next layer.
1. Tool exposed joints slightly concave when pointing mortar is thumbprint hard. Use a smooth plastic jointer larger than joint width.
- J. Install sealant at jambs, heads, mullions and other locations indicated. Prepare joints, including installation of primer and bond-breaker tape or cylindrical sealant backing, and apply elastomeric sealants to comply with requirements in Section 07920 - JOINT SEALANTS.
- K. Construction Tolerances: Set glass block to comply with the following tolerances:
1. Variation from Plumb: For vertical lines and surfaces, do not exceed 1/4 inch in 10 feet or more.
 2. Variation from Level: For bed joints, and other conspicuous lines, do not exceed 1/8 inch in 10 feet, or more.
 3. Variation of Location in Plan: For location of elements in plan do not vary from that indicated by more than plus or minus 1/4 inch.
 4. Variation in Mortar-Joint Thickness: Do not vary from joint thickness indicated by more than plus or minus 1/16 inch.
 5. For faces of adjacent exposed units, do not vary from flush alignment by more than 1/16 inch.

3.6 CAVITY WALLS

- A. Bond wythes of cavity walls together using one of the following methods:
 - 1. Masonry Joint Reinforcement: Installed in horizontal mortar joints. Where one wythe is of clay masonry and the other of concrete masonry, use adjustable (two-piece) type reinforcement with continuous horizontal wire in facing wythe attached to ties to allow for differential movement regardless of whether bed joints align.
 - 2. Masonry Veneer Anchors: Comply with requirements for anchoring masonry veneers.
- B. Bond wythes of cavity walls together using bonding system indicated on Drawings.
- C. Keep cavities clean of mortar droppings and other materials during construction. Bevel beds away from cavity, to minimize mortar protrusions into cavity. Do not attempt to trowel or remove mortar fins protruding into cavity.
- D. Coordinate and allow access for air and vapor barrier membrane and insulation installed in cavity under Section 07190 - Air and Vapor Barrier System.

3.7 MASONRY JOINT REINFORCEMENT

- A. General: Install entire length of longitudinal side rods in mortar with a minimum cover of 5/8 inch on exterior side of walls, 1/2 inch elsewhere. Lap reinforcement a minimum of 6 inches. Space reinforcement not more than 16 inches o.c.
- B. Interrupt joint reinforcement at control and expansion joints, unless otherwise indicated.
- C. Provide continuity at wall intersections by using prefabricated T-shaped units.
- D. Provide continuity at corners by using prefabricated L-shaped units.

3.8 ANCHORING MASONRY TO STRUCTURAL MEMBERS

- A. Anchor masonry to structural members where masonry abuts or faces structural members to comply with the following:
 - 1. Provide an open space not less than 1 inch in width between masonry and structural member, unless otherwise indicated. Keep open space free of mortar and other rigid materials.
 - 2. Anchor masonry to structural members with anchors embedded in masonry joints and attached to structure.
 - 3. Space anchors as indicated, but not more than 24 inches o.c. vertically and 36 inches o.c. horizontally.

3.9 ANCHORING MASONRY VENEERS

- A. Anchor masonry veneers with masonry-veneer anchors to comply with the following requirements:
 - 1. Fasten screw-attached anchors through insulation and sheathing to wall framing and to concrete and masonry backup as applicable with metal fasteners of type indicated.
 - 2. Embed tie sections in masonry joints. Provide air space indicated on the Drawings between back of masonry veneer and face of insulation.

3. Locate anchor sections to allow maximum vertical differential movement of ties up and down.
4. Space anchors as required by Code.

3.10 CONTROL AND EXPANSION JOINTS

- A. General: Install control and expansion joint materials in unit masonry as masonry progresses. Do not allow materials to span control and expansion joints without provision to allow for in-plane wall or partition movement.
- B. Form control joints in concrete masonry using one of the following methods:
 1. Fit bond-breaker strips into hollow contour in ends of concrete masonry units on one side of control joint. Fill resultant core with grout and rake out joints in exposed faces for application of sealant.
 2. Install preformed control-joint gaskets designed to fit standard sash block.
 3. Install interlocking units designed for control joints. Install bond-breaker strips at joint. Keep head joints free and clear of mortar or rake out joint for application of sealant.
 4. Install temporary foam-plastic filler in head joints and remove filler when unit masonry is complete for application of sealant.
- C. Provide horizontal, pressure-relieving joints by either leaving an air space or inserting a compressible filler of width required for installing sealant and backer rod specified in Division 7 Section "Joint Sealants", but not less than 3/8 inch.
 1. Locate horizontal, pressure-relieving joints beneath shelf angles supporting masonry.

3.11 LINTELS

- A. Install steel lintels where indicated.
- B. Lintels shall comply with the Specification.
- C. Provide minimum bearing of 8 inches at each jamb, unless otherwise indicated.

3.12 FLASHING, WEEP HOLES, CAVITY DRAINAGE, AND VENTS

- A. General: Install embedded flashing and weep holes in masonry at shelf angles, lintels, ledges, other obstructions to downward flow of water in wall, and where indicated.
- B. Install flashing as follows, unless otherwise indicated:
 1. Prepare masonry surfaces so they are smooth and free from projections that could puncture flashing. Where flashing is within mortar joint, place through-wall flashing on sloping bed of mortar and cover with mortar. Before covering with mortar, seal penetrations in flashing with adhesive, sealant, or tape as recommended by flashing manufacturer.
 2. At multiwythe masonry walls, including cavity walls, extend flashing through outer Wythe, turned up a minimum of 8 inches, and 1-1/2 inches into the inner wythe. Form 1/4-inch hook in edge of flashing embedded in inner wythe.

3. At masonry-veneer walls, extend flashing through veneer, across air space behind veneer, and up face of sheathing at least 8 inches; with upper edge covered with elastomeric membrane, lapping at least 4 inches.
 4. At lintels and shelf angles, extend flashing a minimum of 6 inches into masonry at each end. At heads and sills, extend flashing 6 inches at ends and turn up not less than 2 inches to form end dams.
- C. Install reglets and nailers for flashing and other related construction where they are shown to be built into masonry.
- D. Install weep holes in head joints in exterior wythes of first course of masonry immediately above embedded flashing and as follows:
1. Use open head joints to form weep holes.
 2. Space weep holes 24 inches o.c., unless otherwise indicated.
- E. Place cavity drainage material in cavities to comply with configuration requirements for cavity drainage material in Part 2 "Miscellaneous Masonry Accessories" Article.
- F. Install vents in head joints in exterior wythes at spacing indicated.

3.13 MASONRY CELL INSULATION

- A. Pour loose-fill insulation into cavities to fill void spaces. Maintain inspection ports to show presence of fill at extremities of each pour area. Close the ports after filling has been confirmed. Limit the fall of fill to one story high, but not more than 20 feet.

3.14 REINFORCED UNIT MASONRY INSTALLATION

- A. Temporary Formwork and Shores: Construct formwork and shores as needed to support reinforced masonry elements during construction.
1. Construct formwork to provide shape, line, and dimensions of completed masonry as indicated.
Make forms sufficiently tight to prevent leakage of mortar and grout. Brace, tie, and support forms to maintain position and shape during construction and curing of reinforced masonry.
 2. Do not remove forms and shores until reinforced masonry members have hardened sufficiently to carry their own weight and other temporary loads that may be placed on them during construction.
- B. Placing Reinforcement: Comply with requirements in ACI 530.1/ASCE 6/TMS 602.
- C. Grouting: Do not place grout until entire height of masonry to be grouted has attained enough strength to resist grout pressure. Comply with requirements in ACI 530.1/ASCE 6/TMS 602 for cleanouts and for grout placement, including minimum grout space and maximum pour height.

3.15 FIELD QUALITY CONTROL

- A. Inspectors: The Contractor shall engage qualified independent inspectors to perform inspections and prepare reports. Allow inspectors access to scaffolding and work areas, as needed to perform

inspections. Place grout only after inspectors have verified compliance of grout spaces and grades, sizes, and locations of reinforcement.

- B. Testing Agency: The Contractor shall engage a qualified independent testing and inspecting agency to perform field tests and inspections indicated below and prepare test reports. Retesting of materials failing to comply with specified requirements shall be done at Contractor's expense.
- C. Testing Frequency: One set of tests for each 5000 sq. ft. of wall area or portion thereof. Test types as determined by the independent testing and inspection agency.

3.16 REPAIRING, POINTING, AND CLEANING

- A. Remove and replace masonry units that are loose, chipped, broken, stained, or otherwise damaged or that do not match adjoining units. Install new units to match adjoining units; install in fresh mortar, pointed to eliminate evidence of replacement.
- B. Pointing: During the tooling of joints, enlarge voids and holes, except weep holes, and completely fill with mortar. Point up joints, including corners, openings, and adjacent construction, to provide a neat, uniform appearance. Prepare joints for sealant application, where indicated.
- C. In-Progress Cleaning: Clean unit masonry as work progresses by dry brushing to remove mortar fins and smears before tooling joints.
- D. Final Cleaning: After mortar is thoroughly set and cured, clean exposed masonry as follows:
 - 1. Remove large mortar particles by hand with wooden paddles and nonmetallic scrape hoes or chisels.
 - 2. Test cleaning methods on sample wall panel; leave one-half of panel uncleaned for comparison purposes. Obtain Engineer's approval of sample cleaning before proceeding with cleaning of masonry.
 - 3. Protect adjacent stone and nonmasonry surfaces from contact with cleaner by covering them with liquid strippable masking agent or polyethylene film and waterproof masking tape.
 - 4. Wet wall surfaces with water before applying cleaners; remove cleaners promptly by rinsing surfaces thoroughly with clear water.
 - 5. Clean concrete masonry by cleaning method indicated in NCMA TEK 8-2A applicable to type of stain on exposed surfaces.

3.17 MASONRY WASTE DISPOSAL

- A. Salvageable Materials: Unless otherwise indicated, excess masonry materials are Contractor's property. At completion of unit masonry work, remove from Project site.
- B. Waste Disposal as Fill Material: Dispose of clean masonry waste, including excess or soil-contaminated sand, waste mortar, and broken masonry units, by crushing and mixing with fill material as fill is placed.
 - 1. Crush masonry waste to less than 4 inches in each dimension.
 - 2. Mix masonry waste with at least two parts of specified fill material for each part of masonry waste. Fill material is specified in Division 2 Section "Earthwork".
 - 3. Do not dispose of masonry waste as fill within 18 inches of finished grade.

- C. Excess Masonry Waste: Remove excess clean masonry waste that cannot be used as fill, as described above, and other masonry waste, and legally dispose of off the Site.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05041

HOT-DIP GALVANIZING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items:
1. Hot-dip galvanizing for all station structural and station miscellaneous steel items shown on the Contract Plans and/or designated in the specification to be galvanized.
 2. Hot-dip galvanizing and painting for all station structural steel and all station galvanized steel items.
- B. Related Work:
1. Section 03300 – CAST-IN-PLACE CONCRETE
 2. Section 05120 – STRUCTURAL STEEL FOR STATIONS AND BUILDINGS
 3. Section 05310 – STEEL DECK
 4. Section 05500 – MISCELLANEOUS METALS
 5. Section 05511 – METAL STAIRS
 6. Section 05700 – DECORATIVE METAL
 7. Section 05720 – METAL RAILINGS AND GATES
 8. Section 09900 – PAINTING for field painting of items that are not hot-dip galvanized.

1.2 QUALITY ASSURANCE

- A. Definitions:
1. Hot-Dip Galvanizing: The dipping of steel members and assemblies into an alloy of molten zinc and nickel for lasting long-term protection.
- B. Reference Standard:
1. American Galvanizers Association Inc. (AGA): Publication entitled "Inspection Of Hot-Dip Galvanized Steel Products."
 2. American Society for Testing and Materials (ASTM):
 - A123 Zinc (Hot Dip Galvanized) Coatings on Products Fabricated from Rolled and Forged Steel Shapes and Hardware
 - A153 Zinc Coating (Hot-Dip) on Iron and Steel Hardware
 - A143 Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedures for Detecting Embrittlement

- A384 Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
- A385 Providing High Quality Zinc Coatings (Hot-Dip)
- A767 Standard Spec for Zinc Coating (Hot-Dip) Steel Bars for Concrete Reinforcement
- A780 Repair of Damaged Hot-Dip Galvanized Coating
- D6386 Standard practice for preparation of zinc (hot dip galvanized) coated iron and steel products and hardware surfaces for painting.

- C. Galvanizer shall have a minimum of 15 years experience performing hot dip galvanizing and painting fabricated iron and steel assemblies of similar scope and complexity.
- D. Mock Up: Refer to Specification Section 01420 - Mock-Ups and Section 05120 – Structural Steel.
 - 1. Contractor shall provide galvanized, primed and finish painted steel mockup from galvanizing plant using galvanizing process and painting procedures. Mockup shall contain both a mechanical connection and welded connection to demonstrate in field patch process. Mockup shall be damaged and repaired using galvanizer's repair process and ASTM procedures. The mockup shall require the approval of both the Architect and the Engineer. In regard to the approval of the mock up and for all galvanized finishes, for matters of aesthetics and finishes, the Architect shall have authority. For structural matters, the Engineer shall have final authority. The mockup can be incorporated into the final work with the approval of both the Engineer and Architect.

1.3 SUBMITTAL

A. Certification

- 1. Furnish Notarized Certificate of Compliance with ASTM Standard and specifications herein listed. Each Certificate will be signed by the Galvanizer. The certificate will provide a detailed description of all material. Certification shall state the steel materials that have been coated and that the total coating system is in conformance with these Specifications.
- 2. Submit Manufacturer's literature for zinc-rich repair compound.
- 3. Coordination Drawings: To safeguard against warpage or distortion, Contractor shall furnish, to the galvanizer, steel fabricator's shop drawings of non-standard fabrications, tubular fabrications, fabrications involving any dimension which exceeds the size of the galvanizer's kettle, and fabrications involving materials of different thickness.

1.4 PRE-AWARD INSPECTION

- A. Contractor's galvanizing plant shall be inspected by Architect, Engineer and/or an independent third party inspection service including shop environmental controls, shop layout, equipment and coating procedure to ensure compliance with specifications. The Contractor shall verify by site visit that the galvanizer's coating and painting facility complies with the environmental conditions required by the above performance standards.

1.5 PRE-APPLICATION CONFERENCE

- A. Arrange a pre-construction conference meeting to be attended by interested parties including MBTA, Galvanizer Contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

1.6 GALVANIZER'S STAMP

- A. All galvanized material, shall be marked with a galvanizer's stamp indicating the name of the galvanizer, the weight or thickness of the galvanizing and the applicable ASTM specification numbers. Locate stamp where not visible to public view.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Steel:
 - 1. Steel for Galvanizing: Geometrically suitable for galvanizing as specified in ASTM A384 and A385.
 - 2. Chemical Suitability Galvanizing: Steel should contain carbon below 0.25 percent, phosphorous below 0.05 percent, and manganese below 1.35 percent.
- B. Nickel-Zinc for Galvanizing: Conform to ASTM B6 as specified in ASTM A123, using special high grade zinc, with the addition to the bath of a predetermined amount of nickel, minimum 0.05 percent by weight, to reduce the effect of high silicon steel.
- C. Paint:
 - 1. Polyamide epoxy primer. Sherwin Williams – or approved equal.
 - 2. Finish coat: Hi-Solids Polyurethane. Sherwin Williams – or approved equal. Basis of bid price shall assume a minimum of 15 paint colors to be identified by architect during submittal process.
 - 3. Clear coat: Diamond Clad Polyurethane. Sherwin Williams – or approved equal.

PART 3 - EXECUTION

3.1 GALVANIZING

- A. All metal items shown on the Contract Plans and designated in the specifications shall be hot-dip galvanized after fabrication in accordance with ASTM A123, A153, A767 or A385 as the case may be, to a thickness equivalent to two (2) ounces per square foot minimum.
- B. Safeguard against embrittlement in conformance with ASTM A143.
- C. Warpage or Distortion prevention:

1. To safeguard against warpage or distortion of steel member, in conformance with ASTM A384, Contractor shall submit shop drawings of non-standard fabrications, all tubular fabrications, all fabrications involving at dimension which exceed the size of the galvanizer's kettle, and any fabrication involving materials of different thicknesses.
 2. Engineer shall provide these drawings to the galvanizer before fabrication to determine the suitability of the material for galvanizing.
- D. Galvanize bolts, nuts, washers, iron and steel hardware components in accordance with ASTM A 153.
- E. Fabrication shall include all shop operations such as shearing, punching bending, forming and welding. Units shall be fabricated complete or in the largest practical sections before galvanizing.

3.2 REPAIR OF DAMAGED SURFACES

- A. Repair damaged galvanized surface in accordance with ASTM A780.
- B. Dry Film thickness: Min. 6 mils of organic zinc-rich repair compound.
- C. If steel requires re-priming and painting, steel final finish shall be indistinguishable from surrounding steel, and other similarly finished units. Finish approval by the Architect.

3.3 PAINTING OF GALVANIZED SURFACES

- A. All steel exposed to public view shall be painted except retaining wall soldier pile steel.
- B. Do not quench or apply post galvanizing treatment that may interfere with paint adhesion.
- C. Apply primer, at the galvanizer's plant, within twelve hours of galvanizing.
- D. Prepare all galvanized surfaces to be primed by abrasion, to achieve maximum paint adherence.
1. Deform, but do not remove, the outermost zinc layer.
 2. Prepare HDG for painting, following ASTM D 6386, using either sweep blasting or power tool.
- E. Apply primer.
1. Temperature of the steel to be primed shall be 70 degrees.
 2. Relative humidity of the room used for applying primer shall be 50%.
 3. Primer shall meet or exceed the following performance criteria:
 - a. Abrasion: ASTM D 4060, CS17 wheel, 1000 gram load <200 mg loss.
 - b. Adhesion: ASTM D 4541, 1050 psi.
 - c. Humidity resistance: ASTM D 4585, 2000 hours passes, no cracking or delamination.
 - d. Salt Spray (fog): ASTM B 117, 5600 hours passes, no cracking or delamination.
- F. Apply Finish Coat:
1. Finish coat shall meet or exceed the following performance criteria:
 - a. Abrasion: ASTM D 4060, CS17 Wheel, 1,000 gram load, <87.1 mg loss.

- b. Adhesion: ASTM D 4541, 1050 psi.
- c. Corrosion Weathering: ASTM D 5894, 21 cycles, rating 10 per ASTM D714 for blistering rating 9, per ASTM D610 for rusting.
- d. Surface burning Characteristics: ASTM E 84, Flame Spread Index 0, Smoke Development Index 0.
- e. Salt Spray (Fog): ASTM B 117, 9000 hours rating 10 per ASTM D714 for blistering rating 9, per ASTM D610 for rusting.

G. Apply Clearcoat over finish coat:

- 1. Clearcoat shall meet or exceed the following performance criteria:
 - a. Abrasion: ASTM D 4060, CS17 Wheel, 1,000 gram load <55 mg loss.
 - b. Adhesion: ASTM D 4541, 1050 psi.
 - c. Graffiti Resistance: After drying for seven days, no staining from acrylic, epoxy, epoxyester and alkyd spray paints, ballpoint pen, crayons, magic marker, black shoe polish, and lipstick.
 - d. Corrosion Weathering: ASTM D 5894, 9 cycles, passes, no blistering, cracking, rusting, or delamination..
 - e. Exterior Exposure: 5 years at 45 degrees South, no blistering, cracking, or chalking; 85% gloss retention <4 MacAdam unit color change.
 - f. Salt Spray (Fog): ASTM B 117, 3000 hours passes, no cracking or delamination.
 - g. Flexibility: ASTM D 522, 180 degree bend, 1/8 inch cylindrical mandrel, passes.
 - h. Hardness: ASTM D 3363 (Pencil) HB.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05120

STRUCTURAL STEEL FOR STATIONS AND BUILDINGS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Structural steel.
- B. Items To Be Installed Only: Install the following items as furnished by the designated Sections:
 - 1. Section 04800 - MASONRY: Anchor sections of adjustable masonry anchors for connecting to structural frame.
- C. Items To Be Furnished Only: Furnish the following items for installation by the designated Sections
 - 1. Section 03300 - CAST-IN-PLACE CONCRETE: Lintels, sleeves, anchors, inserts, embedded wall plates, loose leveling plates and similar items.
- D. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03600 – NON-SHRINK CONSTRUCTION GROUT
 - 3. Section 05041 – HOT DIP GALVANIZING
 - 4. Section 05122 – STRUCTURAL STEEL FOR RAIL STRUCTURES
 - 5. Section 05123 – STRUCTURAL STEEL FOR ROADWAY BRIDGES
 - 6. Section 05210 – STEEL JOISTS
 - 7. Section 05310 – STEEL DECK
 - 8. Section 05500 – MISCELLANEOUS METALS
 - 9. Section 16125 – CATENARY POLES
 - 10. Section 09900 – PAINTING

1.2 DEFINITIONS

- A. Structural Steel: Elements of structural-steel frame, as classified by AISC's "Code of Standard Practice for Steel Buildings and Bridges", that support design loads.
- B. Exposed Steel: All steel exposed to view or within public spaces. Steel hidden by ceilings within public spaces is not considered exposed steel.

1.3 PERFORMANCE REQUIREMENTS

- A. Connections: Provide details of connections required by the Contract Documents to be selected or completed by the structural-steel fabricator to withstand loads indicated and comply with other information and restrictions indicated.

1. Select and complete connections using the American Institute of Steel Construction's (AISC) "Manual of Steel Construction, Load and Resistance Factor Design", Part 9.
2. Engineering Responsibility: Fabricator's responsibilities include using a qualified Professional Engineer registered in the Commonwealth of Massachusetts to prepare structural analysis data for structural-steel connections.
3. All field connections shall be bolted connections, unless noted otherwise.
4. All welded steel shall comply with the American Welding Society (AWS) D1.1, "Structural Welding Code--Steel", unless noted otherwise.

1.4 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: Submit shop and erection drawings showing location and fabrication of structural-steel components.
 1. Include details of cuts, connections, splices, camber, holes, and other pertinent data.
 2. Include embedment drawings.
 3. Indicate welds by standard AWS symbols, distinguishing between shop and field welds, and show size, length and type of each weld.
 4. Indicate welding sequences as required by AWS.
 5. Indicate type, size and length of bolts, distinguishing between shop and field bolts, and bolts with threads excluded from shear plane. Identify pre-tensioned and slip-critical high-strength bolted connections.
 6. For structural-steel connections indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer responsible for their preparation. Refer to structural drawings for connection design requirements.
- C. Welding Certificates: Certificate from AWS indicating certification in type of welding required for each welder and welding operator.
- D. Welding Records and Data:
 1. Before welding, submit the procedure which will be used for qualifying welders and welding procedures. For procedures other than those pre-qualified in accordance with AWS D1.1, submit a copy of procedure qualification test records.
 2. Submit certified copy of qualification test records for each welder, welding operator, and tacker who will be employed in the work.
 3. Where field welding has been required for specific connections, submit descriptive data for field welding equipment.
 4. Submit all Non-Destructive Examination (NDE) records (radiographs, ultrasonic, magnetic particle) and visual inspection reports upon completion or when otherwise requested by the Engineer.
- E. Qualification Data: For installer, fabricator, professional engineer, testing agency, welding inspectors, NDE inspectors and galvanizer. Submit two weeks prior to starting work.

- F. Mill Test Reports: Signed by manufacturers certifying that the following products comply with requirements:
1. Structural steel including chemical and physical properties.
 2. Bolts, nuts, and washers including mechanical properties and chemical analysis.
 3. Direct-tension indicators.
 4. Tension-control, high-strength bolt-nut-washer assemblies.
 5. Shear stud connectors.
- G. Calculations: Submit "Job Standards" for each connection type. The "Job Standards" shall show by calculation the design capacities of each connection. Moment connection calculations shall include calculations for providing stiffener plates and web doubler plates for the columns in accordance with the drawings. Submitting such calculations does not relieve the engineer producing calculations in any way as to the accuracy or compliance to codes of the submitted calculations. Calculations shall be stamped by a professional structural engineer registered in the Commonwealth of Massachusetts.

1.5 QUALITY ASSURANCE

- A. Fabricator Qualifications: A qualified fabricator who participates in the AISC Quality Certification Program and is certified for: Steel Building Structures (STD); or Simple Steel Bridge Structures (SBD); or Major Steel Bridges (CBR) as applicable
- B. Installer Qualifications: A qualified installer with previous experience in installing structural steel.
- C. Welding: Qualify procedures and personnel according to AWS D1.1, "Structural Welding Code--Steel"
- D. Comply with applicable provisions of the following specifications and documents:
1. AISC's "Code of Standard Practice for Steel Buildings and Bridges"
 2. AISC's "Seismic Provisions for Structural Steel Buildings" and "Supplement No. 2"
 3. AISC's "Specification for Structural Steel Buildings--Allowable Stress Design and Plastic Design" and "Load and Resistance Factor Design Specification for Structural Steel Buildings"
 4. AISC's "Specification for the Design of Steel Hollow Structural Sections"
 5. AISC's "Specification for Allowable Stress Design of Single-Angle Members" and "Specification for Load and Resistance Factor Design of Single-Angle Members"
 6. RCSC's "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts"
- E. Tests and Inspection
1. The Contractor will test and inspect high-strength bolted connections and welded connections and prepare test reports. Specialty tests shall be performed at no expense to the Authority by an independent testing laboratory approved by the Engineer. Costs of specialty tests shall be borne by the Contractor. Test reports shall be submitted to the Engineer for approval.
 2. The Engineer reserves the right to inspect high-strength bolted connections and weld connections. Provide access to places where structural steel work is being fabricated or erected so that required inspection and testing can be accomplished at no change in Contract Price. At times, inspection may require moving or handling of steel to permit proper inspection. Notify Materials Testing Laboratory not less than 48 hours prior to start of fabrication.

3. The Engineer may inspect structural steel at the plant before shipment; however, the Engineer reserves the right, at any time before final acceptance, to reject material not complying with specified requirements.
 4. All waterproof welds shall be performed by welders experienced and qualified in waterproof welding procedures. Waterproof welds shall be subject to inspection, nondestructive examination, and documentation.
 5. Correct deficiencies in structural steel work that inspections and laboratory test reports have indicated to be not in compliance with requirements at the Contractor's expense. Perform additional tests, at no expense to the Authority, as may be necessary to reconfirm any non-compliance of the original work, and as may be necessary to show compliance of corrected work.
 6. Specialty Tests: Nondestructive examination of welds in accordance with provisions of AWS D1.1 and ASTM Standards noted shall be made in accordance with the following schedule:
 - a. Ultrasonic Examination, per ASTM E164: Complete joint penetration groove butt welds not accessible for radiographic examination shall be subjected to ultrasonic testing. The extent shall be the same as noted for radiographic examination. Ultrasonic examination shall be made 48 to 72 hours after welding at locations on weldments or welded joints subject to high restraint as indicated in order to check for lamellar tearing. 100% of complete joint penetration welds shall be tested.
 - b. Magnetic Particle Examination, per ASTM E709, field and shop:
 - 1) 100% of partial penetration groove welds shall be tested.
 - c. Penetrant Examination, per ASTM E165: Shall be used for detecting discontinuities that are open to the surface use as appropriate.
 7. Visual Examination: All welds whether otherwise examined or not shall be visually examined and faulty joints shall be marked for correction.
 8. When any testing, examination or inspection reveals faulty welds, all joints of the same type shall be checked at no expense to the Authority until the integrity of the weld is assured before resuming examination.
 9. After faulty welds have been corrected or repaired, they shall each be re-examined at no expense to the Authority in the manner specified for the original joint.
 10. It is intended that inspections shall be performed to permit an orderly flow of completed material from the shop. Work with the Engineer to establish a schedule that will permit this.
 11. Test result information shall be forwarded to the Engineer immediately after test results are available stating the acceptance or rejection of fabricated pieces in order that the repairs and re-inspection may be made as soon as possible.
- F. Pre-Installation Conference: Contractor shall schedule a meeting to be attended by Contractor, Engineer, fabricator and galvanizer. Agenda shall include the following: Project schedule, source for each fabrication, coordination between fabricator and galvanizer and adjacent Work, finish of surfaces, application of coatings, submittals, and approvals.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Store materials to permit easy access for inspection and identification. Keep steel members off ground and spaced by using pallets, dunnage, or other supports and spacers. Protect steel members and packaged materials from erosion and deterioration.
 - 1. Store fasteners in a protected place. Clean and re-lubricate bolts and nuts that become dry before use.
 - 2. Do not store materials on structure in a manner that might cause distortion, damage, or overload to members or supporting structures. Repair or replace damaged materials or structures as directed.
 - 3. Do not handle structural steel until paint has thoroughly dried.

1.7 COORDINATION

- A. Furnish anchorage items to be embedded in or attached to other construction without delaying the Work. Provide setting diagrams, sheet metal templates, instructions and directions for installation.

1.8 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 STRUCTURAL-STEEL MATERIALS

- A. Channels, M-Shapes, S-Shapes, W-Shapes: ASTM A 572, Grade 50.
- B. Angles: ASTM A 36
- C. Plate and Bar: ASTM A 572/A 572M, Grade 50.
- D. Cold-Formed Hollow Structural Sections: ASTM A 500, Grade B, structural tubing.
- E. Steel Pipe: ASTM A 53, Type E or S, Grade B.
- F. Medium-Strength Steel Castings: ASTM A 27, Grade 65-35 carbon steel.
- G. High-Strength Steel Castings: ASTM A 148, Grade 80-50, carbon or alloy steel.
- H. Welding Electrodes: Comply with AWS requirements.

2.2 COATINGS

- A. All steel except steel to receive fireproofing shall be galvanized and painted. Refer to section 05041 "Hot-Dipped Galvanizing."

2.3 BOLTS, CONNECTORS, AND ANCHORS

- A. High-Strength Bolts, Nuts, and Washers: ASTM A 325, Type 1, heavy hex steel structural bolts; ASTM A 563, Grade C, heavy hex carbon-steel nuts; and ASTM F 436 hardened carbon-steel washers.
 - 1. Finish: Hot-dip zinc coating, ASTM A 153, Class C. Field paint to match steel member. Refer to Section 09900- Painting.
- B. Tension-Control, High-Strength Bolt-Nut-Washer Assemblies: ASTM F 1852, Type 1, steel structural bolts with splined ends; ASTM A 563 heavy hex carbon-steel nuts; and ASTM F 436 hardened carbon-steel washers. Finish, mechanically deposited zinc coating, ASTM B 695, Class 50.
- C. Anchor Rods: ASTM F 1554, grade as applicable, hot-dip zinc coating, ASTM A 153, Class C.
- D. Threaded Rods: ASTM A 193, grade as applicable, hot-dip zinc coating, ASTM A 153, Class C.
- E. Eye Bolts and Nuts: ASTM A 108, Grade 1030, cold-finished carbon steel.
- F. Sleeve Nuts: ASTM A 108, Grade 1018, cold-finished carbon steel.

2.4 MISCELLANEOUS MATERIALS

- A. Galvanizing Repair Paint: Coatings meeting requirements of ASTM A 780.
- B. Paint: Primer, Intermediate and Finish Coat. Refer to Section 09900 – PAINTING.
- C. Nonmetallic, Shrinkage-Resistant Grout: ASTM C 1107, factory-packaged, nonmetallic aggregate grout, noncorrosive, nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

2.5 FABRICATION

- A. Structural Steel: Fabricate and assemble in shop to greatest extent possible. Detail assemblies to minimize handling and to expedite erection. Fabricate according to AISC's "Code of Standard Practice for Steel Buildings and Bridges" except as modified herein and AISC's "Specification for Structural Steel Buildings--Allowable Stress Design and Plastic Design".
 - 1. Camber structural-steel members where indicated.
 - 2. Identify high-strength structural steel according to ASTM A 6/ A 6M and maintain markings until structural steel has been erected unless noted otherwise.
 - 3. Mark and match-mark materials for field assembly unless noted otherwise.
 - 4. Complete structural-steel assemblies, including welding of units, before starting shop-priming operations.
 - 5. Cap hollow structural sections with 3/8-inch cap plates, unless noted otherwise. For hollow structural sections to be hot dip galvanized provide vent holes and plastic plugs to match finish paint to the greatest extent possible.
- B. Thermal Cutting: Perform thermal cutting by machine to greatest extent possible. Plane thermally cut edges to be welded to comply with requirements in AWS D1.1.

- C. Bolt Holes: Cut, drill, or punch standard bolt holes perpendicular to metal surfaces not more than 1/16" larger than the connector diameter. Finishing: Accurately finish ends of columns and other members transmitting bearing loads.
- D. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1 and manufacturer's written instructions.
- E. Holes: Provide holes required for securing other work to structural steel and for passage of other work through steel framing members.
 - 1. Cut, drill, or punch holes perpendicular to steel surfaces. Do not thermally cut bolt holes or enlarge holes by burning.
 - 2. Base-Plate Holes: Cut, drill, mechanically thermal cut, or punch holes perpendicular to steel surfaces.
 - 3. Weld threaded nuts to framing and other specialty items indicated to receive other work.
- F. Curved Members: Fabricate indicated members to curved shape by rolling to final shape in fabrication shop.
 - 1. Distortion of webs, stems, outstanding flanges, and legs of angles shall not be visible from a distance of 20 feet (6 m) under any lighting conditions.
 - 2. Tolerances for walls of hollow steel sections after rolling shall be approximately 1/2 inch (13 mm).

2.6 CONNECTIONS

- A. High-Strength Bolts: Install high-strength bolts according to RCSC's "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts" for type of bolt and type of joint specified.
- B. Weld Connections: Comply with AWS D1.1 for welding procedure specifications, tolerances, appearance, and quality of welds and for methods used in correcting welding work. Complete welds in accordance with the Contract Drawings.
 - 1. Comply with AISC's "Code of Standard Practice for Steel Buildings and Bridges" for bearing, adequacy of temporary connections, alignment, and removal of paint on surfaces adjacent to field welds.
 - 2. Remove backing bars or runoff tabs, back gouge, and grind steel smooth.
 - 3. Assemble and weld built-up sections by methods that will maintain true alignment of axes without exceeding tolerances of AISC's "Code of Standard Practice for Steel Buildings and Bridges" for mill material
 - 4. Insufficient welds shall be rejected and corrected until required profiles are met.
 - 5. Verify that weld sizes, fabrication sequence, and equipment used for exposed structural steel will limit distortions to allowable tolerances. Prevent weld show-through on exposed steel surfaces.
 - a. Grind butt welds flush.
 - b. Grind or fill exposed fillet welds to smooth profile. Dress exposed welds.
 - c. Re-profile all steel surfaces (using needle guns or other profiling methods) that have been welded and ground smooth to assure proper adhesion of primers and topcoats.

- d. Prime with a zinc-rich primer as required in 2.6.B, and apply finish coat and clear top coat as required in section 05041 Hot-Dip Galvanizing. The color of finish coat shall match that of the shop-applied finish coat.
- 6. No intermittent welds will be permitted for steel connections to be coated, unless noted otherwise.
- C. Minimum connections shall comply with appropriate tables headed "Framed Beam Connections" shown in the AISC "Manual of Steel Construction". Seated connection may be used only when they do not interfere with architectural features.
- D. For non-composite beams, the connections used shall be adequate to provide for the reaction due to the maximum uniformly distributed load that the beam is capable of carrying for its span, based on the allowable unit stresses, except where higher reactions are shown.
- E. For composite beams, connections shall be adequate to provide for reactions shown on the drawings. Where reactions are not indicated on drawings, the following criteria for connections shall be followed: For composite beams the shear connection shall be adequate to provide for twice the reaction due to the maximum uniformly distributed load that the non-composite beam section is capable of carrying for its span, and for composite girders the connection capacity shall be 1.5 times the reaction due to the maximum uniformly distributed load that the non-composite girder section is capable of carrying for its span.
- F. For ordinary moment frames, the connection shall be adequate to provide for the values of the moments as shown on drawings, in addition to the shear connections as specified above. If the value of the moment is not indicated on the drawings, the connection shall be adequate to resist the moment capacity of the framing beams for ordinary moment frames. Stiffener plates and web doubler plates for columns shall be provided for the above mentioned criteria. For ductile moment resisting frames, as shown on the drawings, comply with all AISC Seismic Provisions and the Commonwealth of Massachusetts State Building Code.

2.7 STEEL PRIMERS AND FINISHES

- A. Preparation for Shop Priming: Prepare uncoated ferrous-metal surfaces to comply with minimum requirements indicated below for The Society for Protective Coatings (SSPC) surface preparation specifications and environmental exposure conditions of installed metal fabrications:
 - 1. Exteriors (SSPC Zone 1B) and Items Indicated to Receive Zinc-Rich Primer: SSPC-SP 10/NACE No. 2, "Near White Metal Blast Cleaning"
 - 2. Interiors (SSPC Zone 1A): SSPC-SP 6, "Commercial Blast Cleaning"
 - 3. Apply shop primer to uncoated surfaces of metal fabrications, except those with galvanized finishes and those to be field welded, embedded in concrete or masonry, unless otherwise indicated. Extend priming of partially embedded members to a depth of 2 inches.
 - 4. Comply with SSPC-PA 1, "Paint Application Specification No. 1: Shop, Field, and Maintenance Painting of Steel" for shop painting.
 - 5. Comply with SSPC-PA 2, "Measurement of Dry Coating Thickness with magnetic Gages"
- B. Zinc-Rich Primer: Urethane zinc rich primer compatible with topcoat Specified in Section 09900. Provide primer with a VOC content of 340 g/L (2.8 lb/gal.) or less per OTC ozone standards. Provide Tnemec Series 394 or Ameron 5105 or equal by DuPont or Carboline for exposed steel to be fireproofed, or Tnemec Series 901K97 Series or 90-97 or Ameron 68HS or equal by DuPont or Carboline for exposed steel to be finish painted at 3.0 mils DFT.

- C. Primer for Exposed Steel to Receive Multi-Coat Shop-Applied Coating: Tnemec Series 901K97 or 90-97 urethane zinc rich primer at 3.0 to 3.5 mils DFT, topcoated in shop with Tnemec Series V73 Endura-Shield, or use Ameron Series 68HS Primer at 3.0 to 5.0 mils DFT topcoated in shop with Ameron's Amercoat 450H, or use or equal primers and finish coats from DuPont or Carboline.
- D. Galvanizing: All Steel, except steel to be fireproofed shall be Hot-dip galvanized & painted, see section 05041- Hot-Dip Galvanizing. All steel to be Hot-dip galvanized & painted shall be primed and/or painted by the galvanizer in his own facility within 12 hours of galvanizing and force cured in a booth capable of maintaining 130° F.
- E. Steel erected in the field that requires repainting shall use touch up kit provided by the galvanizing shop and in accordance with the project specifications. Finish shall match exactly the shop finish and shall be approved by the Architect.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify elevations of concrete- and masonry-bearing surfaces and locations of anchor rods, bearing plates, and other embedments, with steel erector present, for compliance with requirements. Elevations shall be verified by a surveyor licensed in the Commonwealth of Massachusetts.
- B. Proceed with installation of rejected pieces only after unsatisfactory conditions have been corrected to Architect's satisfaction.

3.2 PREPARATION

- A. Provide temporary shores, guys, braces, and other supports during erection to keep structural steel secure, plumb, and in alignment against temporary construction loads and loads equal in intensity to design loads. Protect painted surfaces from abrasions. Remove temporary supports when permanent structural steel, connections, and bracing are in place, unless otherwise indicated. Do not remove temporary shoring supporting composite deck construction until cast-in-place concrete has attained its design compressive strength.

3.3 ERECTION

- A. Set structural steel accurately in locations and to elevations indicated and according to AISC's "Code of Standard Practice for Steel Buildings and Bridges".
- B. Base and Bearing Plates: Clean concrete- and masonry-bearing surfaces of bond-reducing materials, and roughen surfaces prior to setting base and bearing plates. Clean bottom surface of base and bearing plates.
 - 1. Set base and bearing plates for structural members on wedges, shims, or setting nuts as required.
 - 2. Weld plate washers to top of base plate.
 - 3. Snug-tighten or pretension anchor rods as applicable after supported members have been positioned and plumbed. Do not remove wedges or shims but, if protruding, cut off flush with edge of base or bearing plate before packing with grout.
 - 4. Promptly pack grout solidly between bearing surfaces and base or bearing plates so no voids remain. Neatly finish exposed surfaces; protect grout and allow to cure. Comply with manufacturer's written installation instructions for shrinkage-resistant grouts.

- C. Maintain erection tolerances of structural steel within AISC's "Code of Standard Practice for Steel Buildings and Bridges"
- D. Align and adjust various members forming part of complete frame or structure before permanently fastening. Before assembly, clean bearing surfaces and other surfaces that will be in permanent contact with members. Perform necessary adjustments to compensate for discrepancies in elevations and alignment.
 - 1. Level and plumb individual members of structure.
 - 2. Make allowances for difference between temperature at time of erection and mean temperature when structure is completed and in service.
- E. Splice members only where indicated.
- F. Remove erection bolts on welded exposed structural steel; fill holes with plug welds; and grind smooth at exposed surfaces.
- G. Do not use thermal cutting during erection unless approved by Engineer. Finish thermally cut sections within smoothness limits in AWS D1.1 and to Architect's satisfaction in the case of Exposed Steel.
- H. Do not enlarge unfair holes in members by burning or using drift pins. Ream holes that must be enlarged to admit bolts after getting approval from Engineer.
- I. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1 and manufacturer's written instructions.

3.4 FIELD CONNECTIONS

- A. Connections shall comply with requirements specified in Part 2 – Products

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified independent testing and inspecting agency to inspect field welds and high-strength bolted connections.
- B. Bolted Connections: All bolted connections shall be inspected in accordance with RCSC's "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts". When using bolted connections prime with "slip critical class B" primer as specified in this Section. All surfaces of bolted or bearing connections may be primed. When welding, hold back primer a minimum of 2 inches each side of weld.
- C. Welded Connections: Field welds will be visually inspected according to AWS D1.1. In addition to visual inspection, specialty tests will be performed in accordance with AWS D1.1 and at the frequency stated in Article 1.5.E.5
- D. In addition to visual inspection, test and inspect field-welded shear connectors according to requirements in AWS D1.1 for stud welding and as follows:
 - 1. Perform bend tests if visual inspections reveal either a less-than- continuous 360-degree flash or welding repairs to any shear connector.
 - 2. Conduct tests on additional shear connectors if weld fracture occurs on shear connectors already tested, according to requirements in AWS D1.1.

- E. Correct deficiencies in Work that test reports and inspections indicate do not comply with the Contract Documents.
- F. Architect will examine Exposed Steel in place to determine acceptability relating to aesthetic effect. The Architect will have final approval of installed structural Exposed Steel to view.

3.6 REPAIRS AND PROTECTION

- A. Avoid bending, twisting, marking or otherwise distorting the Structural Steel during fabrication or erection.
- B. Remove welded tabs that were used for attaching temporary bracing and safety cabling and that are exposed to view in the completed Work. Grind steel smooth.
- C. Repair damaged galvanized coatings on galvanized items with galvanized repair paint according to ASTM A 780 and manufacturer's written instructions.
- D. Touchup Painting: Comply with Hot Dip Galvanizing Specification Section 05041. Immediately after erection, clean field welds, bolted connections, and abraded areas of shop paint, and paint exposed areas with zinc rich primer, and with the same finish coat and clear-coat as used for shop painting to comply with SSPC-PA 1 for touching up shop-painted surfaces. Touchup Painting shall be invisible from surrounding steel as approved by Architect.
 - 1. Clean and prepare surfaces by SSPC-SP 2 hand-tool cleaning or SSPC-SP 3 power-tool cleaning.
 - 2. Apply a compatible primer of same type as shop primer used on adjacent surfaces.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05123

STRUCTURAL STEEL FOR ROADWAY BRIDGES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. The furnishing and installation of Structural Steel for Roadway Bridges.
 2. Structural Steel Elements will be used at Roadway Bridges for Girders, Diaphragms and Cross Frames, Utility Supports and Hangers, and other related uses.
- B. Related Work:
1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 2. Section 05124 – BRIDGE RAILS.
 3. Section 05125 – BRIDGE BEARINGS.
 4. Section 05420 – TEMPORARY STEEL UTILITY BRIDGES.
 5. Section 05810 – EXPANSION JOINT COVER ASSEMBLIES.
 6. Section 07911 – EXPANSION JOINT ASSEMBLIES.
- C. For all Structural Steel requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 960.
1. For Roadway Bridge Structural Steel submittal requirements, including, but not limited to shop drawings, working drawings, Requests For Information, Non Conformance and testing reports, refer to Section 01300 – SUBMITTALS of the Contract Specifications.
 2. Per Division 1 of the Contract Specifications, the Contractor is responsible for all sampling and testing as outlined in their approved Quality Management Plan and Testing Plan. The Contractor is also responsible for all costs related to the sampling, testing, and related work.
 3. Replace all references to Measurement and Payment with Sub-section 4.1 below.

PART 2 – PRODUCTS

- A. Not used.

PART 3 – EXECUTION

3.1 STAFFING OF OFFICE AND INSPECTION OF WORK

- A. The Contractor shall hire an independent testing agency (ITA) responsible for maintaining an office staffed with personnel adequate in number, training and experience to perform the work required under this contract. The office shall also be staffed with a full-time, qualified technical

representative who shall be responsible for the proper management, control and performance of the operational functioning of this Contract throughout the period of time covered by the Contract.

- B. Prior to the beginning of work, the ITA shall submit the names, resumes and geographic locations of all personnel to be assigned to do the work. The ITA shall provide at each and every inspection location sufficient personnel to carry out the work. The Engineer shall be the sole judge of what constitutes sufficient personnel to carry out the work.
- C. Only approved inspectors may work on assignments for the ITA.
- D. The services stipulated by the Contract shall be duly performed by the ITA's own employees and/or approved sub consultants.
- E. It shall be the responsibility of the ITA to provide each Inspector with the applicable tools, specifications of AASHTO, AWS, ASTM and any other Specification and/or Code necessary for the proper inspection of the work. The Department will furnish the ITA with such additional plans, detailed drawings, and any additional directions that may be necessary for the proper prosecution of the work.

3.2 QUALIFICATIONS OF PERSONNEL

- A. The minimum qualifications required of the personnel who will be serving as shop or field inspectors will be as follows:

- 1. Individuals shall possess experience in the inspection of structural steel and miscellaneous metals used in the fabrication of bridge components. This experience shall include work performed for State agencies and authorities. The following minimum years of experience in fabrication is required:

Project Type	Min. Years' Experience
Miscellaneous (incl. Joints, lighting and sign supports)	1
Rolled Beam Bridges	1
Welded Girders (I- and Box- section)	2
Complex Structures (i.e., trusses)	3
Fracture Critical Members	3

- B. Individuals shall be knowledgeable in all aspects of fabrication including welding, bolting, painting and nondestructive test methods.
- C. Individuals shall be certified welding inspectors in accordance with the American Welding Society's Standard for Qualification and Certification of Welding Inspectors (AWS QC1).
- D. Individuals involved in paint inspection shall have as a minimum NACE Session I certification, completed FHWA Bridge Coating Inspection Course No.130079 or received other formal training subject to the approval of the E.
- E. Individuals involved in timber inspection shall have at a minimum 5 years of timber inspection experience.
- F. Individuals shall have a working knowledge of the various codes and standards used in fabrication including the AASHTO/AWS D1.5 Bridge Welding Code, AWS D1.1 Structural Welding Code, and AASHTO LRFD Bridge Design Specifications and AASHTO LRFD Bridge

Construction Specifications.

- G. For initial plant audits, the individual shall have a minimum of 10 years' experience in the above-mentioned qualifications. The individual shall also be a registered Professional Engineer or approved by the MassDOT Department to perform the audits.
- H. The minimum qualifications required of the personnel who will be performing nondestructive testing will be as follows:
 - 1. Individuals shall, at a minimum be certified as a Level II technician by the American Society for Nondestructive Testing, Recommended Practice SNT-TC-1A. These individuals shall be certified by a Level III technician who shall have attained certification by examination. In addition to meeting the requirements above, those individuals performing ultrasonic testing shall be qualified by a written examination and performance test administered by the Engineer. The Engineer at his/her discretion may accept other properly documented certifications and tests.
- I. The laboratory that will be performing the chemical and physical tests shall be nationally accredited.
- J. The Engineer shall be the sole judge of the competency of each inspector, and any employee of the ITA deemed to be incompetent or unsatisfactory shall be replaced when so directed.

3.3 DOCUMENTATION

- A. Familiarization with Requirements
 - 1. Become familiar with applicable portions of the Contract documents covering the work to be inspected. Study the documents and specifications before fabrication commences to provide ample opportunity to coordinate with the Engineer.
 - 2. Have thorough knowledge of the following references:
 - a. Applicable current standard specifications, supplements, special provisions, and addenda,
 - b. Approved shop drawings. Checking of shop drawings for accuracy or error is not a requirement of the inspection contract. However, if the Inspector notes errors or inaccuracies in the shop drawings, he/she should immediately notify the Engineer.
 - c. Applicable provisions of the *AREMA Manual for Railway Engineering*, if required for the project,
 - d. AASHTO/AWS D1.5, *Bridge Welding Code*,
 - e. Fabricator's QCP.
 - 3. Be familiar with the following references:
 - a. AWS D1.1, *Structural Welding Code*,
 - b. AWS A2.4, *Symbols for Welding and Nondestructive Testing*,
 - c. AWS A3.0, *Standard Welding Terms and Definitions*,
 - d. Applicable ASTM or AASHTO specifications,
 - e. Applicable coating test methods,
 - f. Applicable SSPC Specifications,

- g. Prefabrication meeting minutes, if any.

B. Required Documents

1. Acquire the following documents:
 - a. MTRs for material used in fabrication,
 - b. List of qualified welders, welding operators, and tack welders,
 - c. Approved WPSs,
 - d. Approved PQRs,
 - e. Copy of approved nondestructive testing procedures,
 - f. List of qualified NDE technicians for the project,
 - g. NDE reports for all work on this project that have been inspected and accepted by NDE.

C. Mill Test Reports (MTRs)

1. Verify use of proper materials by checking a copy of the MTRs when the material arrives and by monitoring heat numbers during fabrication until the material is joined into a piece-marked item. Identify by heat numbers the material proposed to be used. Certified Mill Analysis Reports shall be checked for conformance to the Standard Specifications and Project Special Provisions. Initial all test reports that have been checked and identified. Witness the transfer of all heat numbers by the Fabricator to pieces that are cut from material that will become a main member or member component.
2. Prior to any fabrication, the Inspector shall have at hand certified copies of mill tests and shall check the following:
 - a. Product description (specifications, grade, H or P testing frequency),
 - b. Chemistry,
 - c. Physical test results, including Charpy V-Notch when applicable,
 - d. Applicable “Buy America” certification requirements,
 - e. Heat number,
 - f. Certification signature (Quality Control Department and Notary, when required)
3. Do not accept material if the Fabricator cannot furnish appropriate certifications to establish compliance with the required material properties and “Buy America” requirements, if required in the Contract.
4. Verify that the fabricator is maintaining a record of heat number for identification for main members.
5. Accept structural steel based on MTRs. Miscellaneous hardware or other associated products may be accepted based on certifications of compliance.

3.4 SHOP INSPECTION

- A. The QAI must verify that fabricated steel bridge members meet Contract requirements by performing the functions listed in this section.

B. Inspection of Raw Materials

1. Steel bridge material specifications require conformance with applicable requirements of AASHTO M 160 (ASTM A 6). These specifications cover common requirements for hot-rolled plates, shapes, sheet piling and bars, and are also used for material acceptance inspection and repairing certain surface defects.
2. Check materials for surface defects and discontinuities, both initially and as material is being worked. Check rolled sections and steel castings for dimensions, straightness, twist, fins, scabs, and rolling defects, prior to fabrication. Monitor steel plate during cutting for internal defects or other problems.
3. No material shall be accepted from shop stock without permission of the Engineer, and where such stock material is permitted to be used, quality must be checked by reliable test records (properly identified). Material must be free from rust, pitting or other surface defects.

C. Inspection of Fabricated Members

1. During fabrication the QAI should monitor and spot-check that the work performed by the fabricator meets the contract requirements, including, as a minimum, the following:
 - a. Straightness. No unauthorized corrections made by welding or manual thermal cutting,
 - b. Camber operations. Check and record the camber and the length, center to center of bearings, of all beams and girders. When it is necessary to straighten or camber by heating, the Inspector shall be present. The procedure for heat straightening or cambering shall have prior approval of the Engineer,
 - c. Size and quality of punches and dies,
 - d. Proper setup and securing of drilling or reaming templates,
 - e. Bolt hole location, edge distance, and diameter,
 - f. Cylindrical and perpendicular bolt holes,
 - g. Absence of burrs, tears, and chips in bolt holes,
 - h. Thickness of plates, clearances, fitup accuracy, alignment of holes, and proper size of sections at field connections,
 - i. Shop assembly of girders or other parts required for reaming or drilling of field splice holes: positioning, securing, match marking members and splice plates, splice plate orientation (flange splice plates rolling direction parallel to flanges), fills in assembly, and all plies in contact when assembled,
 - j. Flatness of flanges at bearing areas,
 - k. Bearing plates and bearing assemblies, including rockers and shoes for structural steel and expansion joints,
 - l. Proper surface finish and protection of machined surfaces,
 - m. Contact condition of milled bearing surfaces,
 - n. Camber blocking during girder assembly, prior to drilling and QAI acceptance for disassembly records of final sweep or camber,
 - o. Inspection and installation of fasteners in the shop,
 - p. Location of stiffeners and connection plates,
 - q. Match-marking of assembled members,
 - r. Preparation of match-mark diagrams,
 - s. Control and use of heat and/or pressure to obtain or correct sweep and camber in accordance with shop's QCP, and avoidance of buckles, twists, kinks or other defects,

- t. Legibility and position of erection and shipping marks,
- u. No unacceptable twists, bends, kinks, or sweep in finished members,
- v. Proper number of pieces,
- w. Small parts properly packaged or otherwise secured against loss or damage in transit,
- x. Loose pieces fastened in place for shipment,
- y. Application of rust-preventive material when required, and covering to prevent contamination of painted surfaces.

D. Assembly

- 1. Periodically observe laydowns and shop assembly.
- 2. Verify the Fabricator's geometry control methods and measurements. For full or partial shop assemblies, receive the QCI's signed reports of measurements for the Owner's records. For full assemblies, photographs should also be included in the QAI's report.

E. Welding

- 1. Monitor these criteria prior to welding:
 - a. Appropriate equipment in acceptable condition and periodically calibrated per QCP,
 - b. Proper functioning of drying and baking ovens,
 - c. Qualified welders, welding operators, and tack welders,
 - d. Appropriate, approved WPS for detailed joint,
 - e. Joint details, including root face and opening, bevel angle, and alignment of parts within appropriate welding code tolerances,
 - f. Proper application of extension tabs (run-on and run-off),
 - g. Cleanliness of surfaces to be welded,
 - h. Proper condition and storage of welding consumables,
 - i. Size, quality and location of tack welds.
- 2. Monitor these consumable-handling criteria:
 - a. Storage, condition, and exposure times of welding consumables,
 - b. Re-drying and recycling limits.
- 3. Monitor these criteria during welding:
 - a. Following approved WPSs: amperage, voltage, speed of travel, electrode extension, shielding gas flowrate, and preheat, interpass, and/or post-heat temperatures within applicable welding code and WPS tolerances,
 - b. Workmanship of individual welders,
 - c. Use of proper repair procedures for fabrication errors, including, when required, the Engineer's approval,
 - d. Weld starts and stops, securing and removing run-on and run-off tabs, stopping short of snipes or plate edges, and ending without craters.
- 4. Monitor these final weld quality criteria:
 - a. Size, profile, and contour of fillet and groove welds,

- b. No defects in welds or parent metal,
 - c. Accurate interpretation by QCIs for the acceptance or rejection of welds,
 - d. Cleaning and backgouging of welds, including thorough removal of unsound metal and gouging contamination (copper, carbon).
5. Use of Approved Welding Consumables: Review the consumable manufacturer's certificate of conformance maintained by the Fabricator for all consumables used.
6. Nondestructive Evaluation (NDE)
- a. Review and approve the qualification documentation of those performing NDE for the Fabricator.
 - b. Verify that reports are complete and legible and affix his/her signature to those reports that indicate acceptable tested material.
 - c. For radiographic testing (RT), conduct the following activities:
 - 1. Witness inspection by this procedure during the entire period of testing.
 - 2. Interpret test results in accordance with Contract requirements,
 - 3. Verify that final edges may be properly interpreted. (If the plate will be cut after RT, the final edge may be within the plate on the RT film).
 - 4. Verify proper application of edge blocks (plate edge is final edge in structure).
 - 5. Verify that each radiograph represents a unique section or piece by comparing punch marks or other approved methods of marking the work and corresponding marks on the film.
 - 6. Submit report which shall show the following: date radiographs examined; source of radiation including type and size; distance; density; sensitivity; penetrometer size; shim; edge blocks; film including size, type and exposure time; name of radiographer; name of interpreter; name of Inspector; and name of shop representative examining radiographs. It shall indicate the number of radiographs found satisfactory and list those radiographs declared unacceptable.
 - 7. A diagrammatic sketch of radiograph locations shall be submitted with the report.
Such sketches shall show the heat numbers of each plate of major components and identification shall be such that the sketch may be readily oriented to the contract drawings.
 - 8. Deliver all radiographs including unsatisfactory radiographs, to the Bridge Section of MassDOT. All radiographs shall be delivered in suitable containers that are clearly marked to identify the project and the relative inspection reports. Each radiograph shall be wrapped in a suitable manner and marked to indicate radiograph number, beam or girder number and exact location on the beam or girder. A separate summary report as required by the Engineer shall be submitted with each transmittal or radiograph.
 - d. Witness inspection by ultrasonic testing (UT) for the entire test period. Ascertain that the equipment, procedure and technique are in conformance with the Massachusetts Department of Transportation, Highway Division Standards and all pertinent reference documents.
 - e. For magnetic particle testing (MT), conduct the following activities:

1. Be present and witness inspection by the procedure during the entire period of testing.
 2. Submit fabricators certification that the magnetic particle inspection was carried out on and completed satisfactorily in the presence of the MASSDOT Inspector. Submit report of their evaluation and corrective measures ordered. Re-examination, after re-welding, is required if welds are not satisfactory.
 3. A final separate summary report of Magnetic Particle Inspection shall be submitted. The report shall be signed by the fabricator and the inspector and shall contain sufficient information to identify the weld or base metal inspected.
- f. For liquid penetrant (PT), observe technique and interpret results. Submit a summary report of liquid penetrant inspection. The report shall contain sufficient information to identify the extent of the weld or base metal inspected.
7. Coatings
- a. When sampling:
 1. Witness sampling, including mixing or stirring if required for uniformity.
 2. Ensure that the required samples are delivered to MassDOT and conform to the current Massachusetts Department of Transportation, Highway Division Standard Specifications for Highways and Bridges and the Construction Contract Special Provisions.
 - b. Check to ensure that the paint system to be used is acceptable and on the NEPCOAT approved list.
 - c. If the coating samples are obtained directly from the manufacturer, and the batches are approved prior to shipment to the Fabricator or jobsite, verify that the batch numbers received are approved.
 - d. Prior to coating application, verify the following:
 1. Coating containers are properly marked with a batch number,
 2. Batches have been properly strained and mixed (note when pot life initiates),
 3. Check air temperature, humidity and dew point.
 - e. Report manufacturer, name and lot number of paint.
 - f. For coating application inspection, verify the following:
 1. Proper cleaning and surface preparation of base metal prior to coating,
 2. Application of coating in accordance with manufacturer and/or Contract requirements,
 3. Adequate curing of each coat,
 4. Thickness of coating, wet or dry, as specified for each system and type,
 5. Sufficient drying of coating prior to loading for shipment,
 6. Absence of dry spray, runs, sags and other defects,
 7. Proper coating of inaccessible and limited access areas,
 8. Proper treatment of faying surfaces.
8. Bolting

- a. Ensure bolting is in accordance with AASHTO and all MassDOT Specifications.
- b. Ensure faying surfaces are clean.
- c. Ensure the solid seating of all parts.
- d. Inspect for over reaming, burning and other defects.
- e. Verify proper calibration of wrenches and skidmore machines.
- f. Verify that all fasteners are properly stored, segregated and in good condition.
- g. Ensure that installation and verification testing procedures are properly followed.
- h. Witness the rotational capacity and verification testing.
- i. Review bolt certifications.

9. Final Inspection and Loading for Shipment

- a. When all work is complete, conduct a final visual examination of every member against the drawings for section, dimensions, connection locations, details, workmanship and coating.
- b. The QCI will provide copies of reports covering the materials to be shipped. Verify that all data is correct. The reports shall include the name and address of the Fabrication plant, the name of the co-signee, and the location of the project and date shipped, letters and numbers of cars or of trucks, the number of pieces in the load with lengths or dimensions and weights, together with other pertinent information as may be necessary.
- c. Randomly observe handling and loading of the work to verify that the methods and supports used will prevent significant damage during shipping.
- d. The Inspector shall verify that all members are identified and that these shop marks are in accordance with the shop drawings and are legible.
- e. A mark signifying the member has been inspected and accepted shall be plainly, legibly and indelibly placed at the fabricating shop near the erection mark on each member. The identification mark shall include the name or initials of the Inspection Agency and the inspector's identification number, placed in a manner to insure their preservation up to the time of erection.
- f. The inspector shall reject all assemblies that are not in strict conformance with the Contract documents and specifications.

3.5 INSPECTOR RECORDS AND REPORTS

- A. The ITA shall report to the Engineer such information as the Engineer may require in connection with the manufacture, handling, and shipment of the materials inspected. The information furnished shall include the location where the material is being fabricated, the municipality and roadway where the project is located, the Bridge Number, the MassDOT contract number of the project, daily summary of work done, and statements that the said materials conform to particular pertinent specifications as noted. If any of the above items are not included, the report will be returned for corrections. Payment will not be made until a corrected report is received.
- B. Maintain a narrative report for each project, as directed by the Owner. The report shall be maintained in an electronic log with automatic date and time recording. Record the Fabricator's activity on the work inspected, including both positive and negative comments, suggestions given to the Fabricator, and any agreements made. Make entries as soon possible after the events or conversations.
- C. Reports shall be made daily and submitted weekly. Include information about the status of the work performed, shop activities, and other events of interest to the Engineer. Examples of

attachments include: girder fabrication status records, NDT reports, paint thickness readings and camber reports. Number the reports consecutively until completion of the work, with the last report noted "final".

1. Make notes, emails, letters, faxes, reports, and memoranda clear and brief, and keep them on file.
 2. Do not make or release photographs or digital images without the Fabricator's approval.
 3. Documentation is not a substitute for appropriate dialogue with the Fabricator, but should provide a record of important discussions.
- D. Reports and associated documentation shall be stored and transmitted electronically. Selected firms will be required to supply inspection personnel with the appropriate technology (hardware and software) capable of storing and transmitting documents in the pdf format.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05124

BRIDGE RAILS

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. Metal Bridge Railings and Barriers to be used for permanent edge protection at Roadway Bridges, the Washington Street Railroad Bridge, including:
 - a. Type S3-TL4 Bridge Rail
 - b. Type 1 Protective Screen
 - c. Modified Type 1 Protective Screen
 - d. Type BR-2 Bridge Mounted Barrier
 2. Metal Bridge Railings and Barriers to be used for permanent edge protection at Green Line Viaducts, Structures, and Equipment Platform Structures.
 - a. Galvanized Metal Pipe Handrail / Guardrail.
- B. Related Work:
1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 2. Section 03300 – CAST-IN-PLACE CONCRETE.
 3. Section 03301 – CAST-IN-PLACE CONCRETE FOR ROADWAY BRIDGES.
 4. Section 03601 – POST INSTALLED ANCHORS.
 5. Section 05041 – HOT DIP GALVANIZING.
- C. For all Roadway Bridges and Washington Street Railroad Bridge, Bridge Rail requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 975.
1. For Roadway Bridges, Bridge Rail submittal requirements, including, but not limited to shop drawings, working drawings, Requests For Information, Non Conformance and testing reports, refer to Section 01300 – SUBMITTALS of the Contract Specifications.
 2. Per Division 1 of the Contract Specifications, the Contractor is responsible for all sampling and testing as outlined in their approved Quality Management Plan and Testing Plan. The Contractor is also responsible for all costs related to the sampling, testing, and related work.
 3. Replace all references to Measurement and Payment with the Sub-section 4.1 below.
- D. Performance requirements for Green Line Viaduct Structures:

1. General: In engineering handrails and guardrails to withstand structural loads indicated, determine allowable design working stresses of handrail and railing materials based on the following:
 - a. Metal Pipe Handrail/Guardrail Steel: AISC 360, "Specification for Structural Steel Buildings"
2. Structural Performance of Handrails and Guardrails: Provide handrails and guardrails capable of withstanding the following structural loads without exceeding allowable design working stresses of materials for handrails, railings, anchors, and connections:
 - a. Top Rail of Handrails/Guardrails: Capable of withstanding the following loads applied as indicated:
 1. Concentrated load of 200 lbf applied at any point and in any direction.
 2. Uniform load of 50 lbf/ft. applied horizontally and concurrently with uniform load of 100 lbf/ft. applied vertically downward.
 3. Concentrated and uniform loads above need not be assumed to act concurrently.
 - b. Intermediate Rails of Handrails/Guardrails Not Serving As Top Rails: Capable of withstanding the following loads applied as indicated:
 1. Concentrated load of 200 lbf applied at any point and in any direction.
 2. Uniform load of 50 lbf/ft vertically downward and concurrently with a uniform load of 50 lbf/ft. horizontally.
 3. Concentrated and uniform loads above need not be assumed to act concurrently.
 - c. Infill Area of Rails/Guards: Capable of withstanding a horizontal concentrated load of 200 lbf applied to 1 sq. ft. at any point in system, including panels, intermediate rails, balusters, or other elements composing infill area.
 1. Load above need not be assumed to act concurrently with loads on top rails in determining stress on Rails/guards.
 - d. Posts of Handrails/Guardrails shall be designed for a minimum single concentrated load of 200 lb. applied horizontally or vertically at any point along the post.
3. Submittals:
 - a. Shop Drawings: Show fabrication and installation of handrails and guardrails. Include plans, elevations, sections, component details, and attachments to other Work.
 - b. For installed handrails and guardrails indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer, registered in the Commonwealth of Massachusetts, responsible for their preparation.
 - c. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include lists of completed projects

with project names and addresses, names and addresses of architects and owners, and other information specified.

- d. Product Test Reports: From a qualified testing agency indicating products comply with requirements, based on comprehensive testing of current products.
4. Storage:
 - a. Store handrails and guardrails in a dry, well-ventilated, weather tight place.
 5. Quality Assurance:
 - a. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in the Commonwealth of Massachusetts and who is experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of handrails and guardrails that are similar to those indicated for this Project in material, design, and extent.
 - b. Testing Agency Qualifications: An independent testing agency with the experience and capability to conduct the testing indicated, as documented according to ASTM E 548.
 - c. Source Limitations: Obtain each type of handrail and guardrail through one source from a single manufacturer.
 6. Coordination:
 - a. Coordinate installation of anchorages for handrails and guardrails. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to Project site in time for installation.
 - b. Schedule installation so handrails and guardrails are mounted only on completed structures. Do not support temporarily by any means that does not satisfy structural performance requirements.
 7. Project Conditions:
 - a. Field Measurements: Verify handrail and guardrail dimensions by field measurements before fabrication and indicate measurements on Shop Drawings. Coordinate fabrication schedule with construction progress to avoid delaying the Work.
 1. Established Dimensions: Where field measurements cannot be made without delaying the Work, establish dimensions and proceed with fabricating handrails and guardrails without field measurements. Coordinate construction to ensure that actual dimensions correspond to established dimensions.

PART 2 – PRODUCTS

2.1 BRIDGE RAILS FOR WASHINGTON STREET BRIDGE

A. Not used.

2.2 BRIDGE RAILS AND BARRIERS FOR VIADUCTS AND OTHER GREEN LINE STRUCTURES

A. METALS

1. General: Provide metal free from pitting, seam marks, roller marks, stains, discolorations, and other imperfections where exposed to view on finished units.
2. Steel and Iron: Provide steel and iron in the form indicated, complying with the following requirements:
 - a. Steel Pipe: ASTM A 53; finish, type, and weight class as follows: Type F, or Type S, Grade A, standard weight (Schedule 40), unless another grade and weight are required by structural loads.
 - b. Steel Tubing: Cold-formed steel tubing, ASTM A 500, Grade A, unless another grade is required by structural loads.
 - c. Steel Plates, Shapes, and Bars: ASTM A 36.
 - d. Iron Castings: Malleable iron complying with ASTM A 47, Grade 32510.
 - e. Iron Castings: Gray iron complying with ASTM A 48, Class 30.
3. Brackets, Flanges, and Anchors: Cast or formed metal of same type of material and finish as supported rails, unless otherwise indicated.

B. WELDING, MATERIALS, FASTENERS, AND ANCHORS

1. Welding Electrodes and Filler Metal: Provide type and alloy of filler metal and electrodes as recommended by producer of metal to be welded and as required for color match, strength, and compatibility in fabricated items.
2. Fasteners for Anchoring Handrails and Railings to Other Construction: Select fasteners of type, grade, and class required to produce connections suitable for anchoring handrails and railings to other types of construction indicated and capable of withstanding design loads.
3. Fasteners for Interconnecting Handrail and Guardrail Components: Use fasteners fabricated from same basic metal as fastened metal, unless otherwise indicated. Do not use metals that are corrosive or incompatible with materials joined.
 - a. Provide concealed fasteners for interconnecting handrail and guardrail components and for attaching them to other work, unless exposed fasteners are unavoidable or are the standard fastening method for handrails and railings indicated.
 - b. Provide Phillips flat-head machine screws for exposed fasteners, unless otherwise indicated.
4. Post-installed Anchors: Comply with the requirements of Specification SECTION 03601

– POST INSTALLED ANCHORS. Use epoxy anchors for all attachments to structural items.

C. FINISH

1. Galvanize all steel handrail and guardrail components in accordance with ASTM A123, after fabrication is completed.

D. FABRICATION

1. General: Fabricate handrails and guardrails to comply with requirements indicated for design, dimensions, member sizes and spacing, details, finish, and anchorage, but not less than that required to support structural loads.
2. Assemble handrails and guardrails in the shop to greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation. Use connections that maintain structural value of joined pieces.
3. Form changes in direction of railing members as follows:
 - a. By flush radius bends unless otherwise indicated.
4. Form simple and compound curves by bending members in jigs to produce uniform curvature for each repetitive configuration required; maintain cylindrical cross section of member throughout entire bend without buckling, twisting, cracking, or otherwise deforming exposed surfaces of handrail and railing components.
5. Welded Connections: Fabricate handrails and guardrails for connecting members by welding.

Cope components at perpendicular and skew connections to provide close fit, or use fittings designed for this purpose. Weld connections continuously to comply with the following.

 - a. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals at each location. The configuration and dimensions of anchoring devices shall be appropriate for the configuration, dimensions, and materials of the supporting structure.
 - b. Obtain fusion without undercut or overlap.
 - c. Remove flux immediately.
 - d. At exposed connections, finish exposed surfaces smooth and blended so no roughness shows after finishing and welded surface matches contours of adjoining surfaces.
6. Brackets, Flanges, Fittings, and Anchors: Provide wall brackets, flanges, miscellaneous fittings, and anchors to interconnect handrail and railing members to other work, unless otherwise indicated.
7. Provide inserts and other anchorage devices for connecting handrails and guardrails to concrete or masonry work. Fabricate anchorage devices capable of withstanding loads

imposed by handrails and railings.

8. Shear and punch metals cleanly and accurately. Remove burrs from exposed cut edges.
9. Ease exposed edges to a radius of approximately 1/32 inch, unless otherwise indicated. Form bent-metal corners to smallest radius possible without causing grain separation or otherwise impairing the Work.
10. Cut, reinforce, drill, and tap components, as indicated, to receive finish hardware, screws, and similar items.
11. Provide weep holes or another means to drain entrapped water in hollow sections of handrail and railing members that are exposed to exterior or to moisture from condensation or other sources.
12. Close exposed ends of handrail and guardrails members with prefabricated end fittings.
13. Provide wall returns at ends of wall-mounted handrails, unless otherwise indicated. Close ends of returns at all locations.
14. Toe Boards: Where indicated, provide toe boards at handrails and guardrails around openings and at edge of open-sided platforms. Fabricate to dimensions and details indicated.

2.3 ACCEPTANCE SAMPLING AND DOCUMENTATION REQUIREMENTS FOR MASSDOT ROADWAY BRIDGES

- A. The following samples and documents must be submitted to the Program Manager per MassDOT Research and Materials assurance requirements:
 1. Sampling Frequency: A minimum of one from each source per bridge project.

PART 3 – EXECUTION

3.1 TESTING, INSTALLATION, AND INSPECTION OF BRIDGE RAILS FOR WASHINGTON STREET BRIDGE

Not used.

3.2 TESTING, INSTALLATION, AND INSPECTION OF BRIDGE RAILS FOR VIADUCTS AND OTHER GREEN LINE STRUCTURES

A. EXAMINATION

1. Examine concrete and steel surfaces to that are to receive anchors for support of the Handrail/Guardrail assemblies, to verify that locations of concealed reinforcements have been clearly marked for Installer. Locate reinforcements and mark locations if not already done.

B. INSTALLATION, GENERAL

1. Fit exposed connections together to form tight, hairline joints.

2. Perform cutting, drilling, and fitting required to install handrails and guardrails. Set handrails and guardrails accurately in location, alignment, and elevation; measured from established lines and levels and free from rack.
 - a. Do not weld, cut, or abrade surfaces of handrail and guardrail components that have been coated after fabrication and that are intended for field connection by mechanical or other means without further cutting or fitting.
 - b. Set posts plumb within a tolerance of 1/16 inch in 3 feet.
 - c. Align rails so variations from level for horizontal members and from parallel do not exceed 1/4 inch in 12 feet.
3. Adjust handrails and railings before anchoring to ensure matching alignment at abutting joints.
Space posts at interval indicated, but not less than that required by structural loads.
4. Fastening to In-Place Construction: Use epoxy anchorage devices and fasteners where necessary for securing handrails and guardrails and for properly transferring loads to in-place construction.

C. RAILING CONNECTIONS

1. Welded Shop Connections: Use fully welded shop joints for permanently connecting railing components, prior to galvanizing. Comply with requirements for welded connections in "Fabrication" Article.
2. Bolted Field Connections: Use mechanical means to make connections in the field, so as not to damage the galvanized coating.
3. Expansion Joints: Install expansion joints at locations indicated but not farther apart than required to accommodate thermal movement. At a minimum, expansion joints shall be installed at all bridge deck joint locations. Provide slip-joint internal sleeve extending 6 inches beyond joint on either side, fasten internal sleeve securely to one side, and locate joint within 6 inches of post.

D. ANCHORING POSTS

1. Anchor post to concrete surfaces with surface mounted circular or oval base plate. Base plate shall be shop welded to the post prior to galvanizing. Use post installed epoxy anchors as required to resist the design loads.
2. Anchor posts to metal surfaces with surface mounted circular or oval base plates. Base plate shall be shop welded to the post prior to galvanizing, and field bolted to supporting steel surfaces.

E. CLEANING

1. Immediately after erection, clean bolted connections, abraded areas, and exposed areas with same material showing through. Apply Engineer approved cold galvanizing compound to repair surfaces.

F. PROTECTION

1. Protect finishes of handrails and guardrails from damage during construction period with temporary protective coverings approved by railing manufacturer. Remove protective coverings at the time of Substantial Completion.
2. Restore finishes damaged during installation and construction period so no evidence remains of correction work. Return items that cannot be refinished in the field to the shop; make required alterations and refinish entire unit, or provide new units. The Engineer will be the sole judge of whether material can be restored or must be replaced.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05125

BRIDGE BEARINGS

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. The furnishing and installation of elastomeric bearings for Roadway Bridges.
 2. The furnishing and installation of disc and elastomeric bearings for the Washington Street Railroad Bridge.
 3. The furnishing and installation of bearings for Viaduct Structures.
- B. Related Work:
1. Section 03301 – CAST-IN-PLACE CONCRETE FOR ROADWAY BRIDGES.
- C. For all Roadway Bridge bearing requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section M9.14.5. The number and location of each type of bearing shall match the DB Entity's approved drawings. According to M9.14.5, MassDOT requires one bearing pad of each size and type for destructive testing in addition to those identified on the Design Documents.
1. For Bridge Bearing submittal requirements, including, but not limited to shop drawings, working drawings, Requests For Information, Non Conformance and testing reports, see Volume 2.
 2. The DB Entity is responsible for all sampling and testing as outlined in their approved Quality Management Plan and Testing Plan. The DB Entity is also responsible for all costs related to the sampling, testing, and related work.
- D. The following information pertains to the requirements for bearings of the Viaduct Structures:
1. Definition:
 - a. Load Range: A load range is a range of load capacities in which the highest capacity is no more than 2.0 times as large as the lowest.
 - b. Lot: A lot is a group of no more than 25 bearings of the same type (e.g. Elastomeric or Disc Bearings, and fixed, guided or floating), in the same load range.
 - c. Batch: A batch is a body of material in which the ingredients are uniformly blended together at one time.
 - d. Sample: A sample is a piece of material or a complete bearing which is tested in order to infer the properties of the batch of material or group of bearing elements from which it is taken. A sample shall consist of at least one bearing chosen randomly from each lot and material batch and shall comprise at least 10% of the lot.

E. Submittals for Washington Street Railroad Bridge and Viaduct Structures:

1. The DB Entity shall submit to the MBTA shop drawings and design calculations which are sufficiently detailed to permit proper review of the bearings. The drawings shall show all details of the bearings and of the materials proposed for use and must be approved by the MBTA before fabrication of the bearings begins. Such approval shall not relieve the DB Entity of any responsibility under the contract for the successful completion of the work. The drawings shall include, but not be limited to the following information:
 - a. Plan, elevations and sections including all nominal dimensions and material designations.
 - b. Vertical and horizontal load capacities, horizontal movement capacities and rotation capacities about two horizontal axes and one vertical axis.
 - c. Design calculations for all items designed by the bearing manufacturer.
 - d. Material designations and specifications.
 - e. A schedule of bearing offsets.
 - f. Shop coating requirements.
 - g. Any special installation requirements by the manufacturer.
2. Each bearing shall be marked in indelible ink or flexible paint. The marking shall consist of the location, orientation, order number, lot number, bearing identification number, and elastomer type and grade number, unless otherwise indicated. The marking shall be on a face which is visible after erection of the bridge.

F. Certification: the DB Entity/manufacturer shall supply certification data for all materials used. This shall consist of at least test reports for the bearing performance tests and for any forgings, castings or hardened material, mill certificates for all other steels used, and a certificate of compliance for the bearing as a whole, dowels or other accessories. If the manufacturer designed the bearing, he shall certify that each bearing satisfies the Contract Documents' requirements.

PART 2 – PRODUCTS

2.1 DISC AND ELASTOMERIC BEARINGS FOR RAILROAD BRIDGES

- A. The following information pertains to bearings for the Washington Street Railroad Bridge.
1. Description: Both Multi Rotational Disc bearings and Steel Reinforced Elastomeric bearings are to be provided for the Railroad Structure. Disc bearings both fixed and expansion shall be designed to the loads, rotations and displacements as indicated on the contract documents. Additionally, Disc and Steel Reinforced Elastomeric bearings shall be fabricated to the sizes and shapes as indicated in the details on the contract drawings, unless otherwise approved by the Engineer. Bearings of each type, either Disc or Elastomeric shall be supplied only by one manufacturer.

Fixed Multi Rotational Disc Bearings shall allow rotation but no longitudinal movement. Allowable transverse movement shall vary by girder by the amount shown on the Contract Documents.

Expansion (Guided) Multi Rotational Disc Bearings shall allow rotation and longitudinal movement in the bearing plane; allowable transverse movement shall vary by girder by the amount shown on the Contract Documents. To allow longitudinal movement, the upper steel bearing plate shall be faced with polytetrafluoroethylene (PTFE) sheet and support a sliding steel top bearing plate. The mating surface of the sliding steel top bearing plate shall be faced with polished stainless steel. Transverse movement in excess of the allowable amount shall be restricted with either a guide bar or keyway.

Fixed Steel Reinforced Elastomeric Bearings shall allow rotation but no longitudinal or transverse movement.

Expansion Steel Reinforced Elastomeric Bearings shall allow rotation and longitudinal movement in the bearing plane; transverse movement shall be restricted. To allow longitudinal movement, bearings are sized for the required shear deformation.

2. Materials

- a. Steel: All steel, except steel for guide bars and shear-restriction pins and sleeves shall conform to ASTM A709, Grade 50. Guide bars and shear-restriction devices shall be as detailed by the manufacturer, unless otherwise specified.

Stainless steel sliding surfaces shall conform to ASTM A167 or A240 Type 304, with portions in contact with PTFE polished to a No. 8 mirror finish. The minimum thickness of the stainless steel shall be shall be 0.050 inches. Welded stainless steel overlay produced using Type 309L electrodes.

- b. Elastomeric Disc (Disc Bearings): The elastomeric disc for disc bearings shall be Polyether Urethane conforming to the requirements of the Table below:

Physical Property	ASTM Test Method		Requirement	
Durometer Hardness - Shore D	D2240	45	55	65
Tensile Strength				
@ 100% Elongation	D412	1,500 psi	1,900 psi	2,300 psi
@ 200% Elongation	D412	2,800 psi	3,400 psi	4,000 psi
Tensile Strength	D412	4,000 psi	5,000 psi	6,000 psi
Ultimate Elongation (min.)	D412	350%	285%	220%
Compression Set	D395	40%	40%	40%

- c. Polytetrafluoroethylene (PTFE): PTFE sliding surfaces shall be virgin PTFE resin filled or unfilled PTFE sheets or PTFE fabric. PTFE resin shall be virgin material

(not reprocessed) meeting the requirements of ASTM D1457. Filler material, when used, shall be milled glass fibers, carbon or other inert filler materials.

Unfilled PTFE sheet shall be made of virgin PTFE resin and shall be in accordance with ASTM D3293, Type III, Grade I, Class C.

Filled PTFE sheet shall be made from virgin PTFE resin uniformly blended with inert filler material conforming to the following requirements:

Property	ASTM Method	15% Glass Fibers	25% Carbon
Tensile Strength (minimum)	D638M	2,000 psi	1,300 psi
Elongation (minimum)	D638M	150%	75%
Specific Gravity (minimum)	D792	2.20 ± 0.03	2.10 ± 0.03

Where the PTFE is to be epoxy bonded, the PTFE shall be etched by the sodium naphthalene or sodium ammonia etching process.

- d. Non-Shrink Grout: The non-shrink grout shall conform to the requirements of M.03.01- 12, and shall be flowable type capable of being pumped with a positive displacement pump through an opening 1/8” in diameter.
- e. Elastomeric (Steel Reinforced Elastomeric Bearings): The elastomeric compound shall be composed of 100% low temperature Grade 3 virgin crystallization resistant polychloroprene (neoprene), or cast polyurethane meeting the requirements of AREMA, Table 15-10-3. Material with a nominal hardness greater than 60 durometer shall not be used in reinforced bearings. Dimensions and design compressive load are indicated on the DB Entity’s approved drawings. All expansion bearings are subject to shear deformation. Shear Modulus, at 73 degrees Fahrenheit, shall fall between 130 psi and 200 psi, and have a maximum creep deflection at 25 years of 35%. Shear modulus tests shall be carried out using the apparatus and procedure described in annex A of ASTM D 4014. The vulcanized bond between reinforcement steel laminated bearings shall develop a minimum peel strength of 40 pound per inch. Peel strength tests shall be performed by ASTM D 429 Method B.
- f. Paint: Paint shall conform to the requirements indicate in the specifications and as provided on the DB Entity’s approved drawings for Structural Steel. All elements painted shall be shop painted.

3. Construction Methods

- a. Plans: Design calculations and detailed fabrication working drawings for the bearings shall include, but not be limited to, the following:
 - 1. Plan view and section elevations, providing all fabrication dimensions and required surface finishes.
 - 2. All ASTM, AREMA, and other material designations.
 - 3. Vertical and horizontal load capacity; rotation and movement capacity.

4. A schedule of all bearing offsets if required by the project.
5. Shop paint or coating requirements.

The design calculations shall be complete; verifying conformance of the bearing to provisions of this specification.

- b. Design Parameters – Notations: The symbols defined in the following notations are used in bearing design requirements presented subsequently in this Section:

DEFINITIONS

C	= exterior vertical clearance in inches between stationary and moving bearing parts.
D_d	= diameter in inches of elastomeric disc; disc bearing.
D_p	= diameter in inches of elastomeric disc; inside diameter in inches of pot.
D_s	= projected diameter in inches of loaded spherical segment.
G	= depth of pot bearing pot cavity in inches.
k	= depth of chamfer in inches on pot bearing piston.
L_h	= horizontal design load, in kips, on bearing.
L_v	= vertical design load in kips, on bearing.
R_s	= maximum design rotation of structure in radians, specified on the DB Entity's approved drawings, but not less than 0.02 radians.
R_c	= maximum construction tolerance rotation 0.005 radians unless otherwise specified on the DB Entity's approved drawings.
R_b	= minimum design rotation capacity of bearing in spherical surfaces.
R_{max}	= maximum radius in inches to prevent the unseating of spherical surfaces.
OD	= outside diameter in inches of the round pot base or the round disc base.
S	= side (outside dimension) in inches of a square pot base or square disc base.
t	= thickness in inches of elastomeric disc.
theta	= $\arctan(L_h \text{ max}/L_v \text{ min})$ radians.
W	= piston face width in inches of pot bearing.
Delta C	= compression deflection of elastomeric disc.
Bearing Proper	= The components of the bearing that are between the girder flange and the bearing base.

- c. General Requirements: Multi-rotational disc bearings shall be designed to accommodate the loads, forces and movements specified in the bearing schedule. Particular care shall be taken that all components of the bearings provide adequately for the horizontal loads and forces specified.

Maximum design stresses for all bearing components shall not exceed the allowable design stresses of the applicable issue of the AREMA Manual for Railway Engineering and the applicable sections of this specification.

Minimum rotation capacity (R_b) shall be the sum of $R_s + R_c$.

Minimum horizontal load capacity for fixed and guided bearings shall be as specified on the DB Entity's approved drawings but in no case less than 10% of the vertical dead load shown on the approved drawings. Expansion bearings shall be designed for additional movement capacity, in each direction, beyond the design movement indicated on the approved drawings. The additional movement capacity shall be 10% of the design movement or one inch, whichever is greater. Spacing between the guides of the bearing does not require this additional movement capacity.

An auxiliary plate shall be provided for all bearings as noted in the specification herein. The auxiliary plate shall be designed to fit between the bearing proper and the masonry plate. The auxiliary plate shall be engaged with the bearing proper by means of a properly designed shop weld, or by a "saucer-like" machined recess to snugly fit the base of the bearing. The purpose of the auxiliary plate is the following:

To provide a means of field installation adjustment and sufficient horizontal restraint for the base of the bearing proper without a field weld directly to the bearing where access is often difficult;

To simplify the future removal and replacement of the bearing assembly in the event maintenance is required;

To reduce the possibility of heat damage to critical bearing components during field welding installation.

Bearings shall be designed so that all rotational and sliding elements can be replaced with a minimum lifting not to exceed 1/2".

All specified machined surface finish tolerances shall be verified using a calibrated profilometer provided by the DB Entity and approved by the MBTA.

Overall bearing height if different from that shown on the DB Entity's approved drawings shall be accompanied by the necessary adjustment in the bearing pad elevation. Overall bearing height shall be not more than 3/16" greater than, nor zero (0) inch less than, detail dimension provided on the fabrication working drawings.

All finished bearing components shall be shop painted except for the following materials and surfaces: urethane, stainless steel, PTFE, inside surfaces of disc bearing in contact with urethane.

Welding shall conform to the requirements of AWS D1.1 Structural Welding Code.

1. Disc Bearings: Urethane disc: Urethane discs shall be of minimum thickness (t), where:

a. $t = [\Delta C + (R_s + R_c) \times D_d \times 0.5] \times e_{max}$

b. c = deflection due to total compressive load

- c. e_{max} = strain due to all effects except long term creep at maximum vertical stress, and shall be less than 15%.
 - d. The area of the disc shall be designed for an average stress not to exceed:
 - 1. 4000 psi for Polyether Urethane - 45 Durometer
 - 2. 5000 psi for Polyether Urethane - 55 Durometer
 - 3. 6000 psi for Polyether Urethane - 65 Durometer
 - e. Recesses in plates for discs shall have a tolerance of ± 0.030 " for all diameters. Inside surfaces facing disc shall be commercial shot blast finished in accordance with SSPC SP-6.
 - f. Limiting Ring: A limiting ring shall be provided by a welded ring, by machining a recess in the bearing plate, or by other limiting means. The depth of the limiting ring shall be equal to or greater than $D_d \times 0.014$. The inside diameter of the limiting ring shall be equal to $D_d \times 1.05$.
 - g. Plate Beneath Disc: The section thickness of the plate beneath the disc shall be:
 - 1. $D_d \times 0.06$ for bearings directly on concrete,
 - 2. $D_d \times 0.045$ for bearings directly on steel masonry plates,
 - 3. But in no case less than $\frac{3}{4}$ " on concrete and $\frac{1}{2}$ " on steel.
 - h. Vertical Clearance: Design of disc bearings shall provide vertical clearance, between rotating and non-rotating bearing parts no less than $\frac{1}{8}$ " at maximum rotation as follows:
 - 1. Bearings square in plan, $C = (R_b \times 0.7 \times S) + 0.12" + 2 \times \Delta C$
 - 2. Bearings round in plan, $C = (R_b \times OD/2) + 0.12" + 2 \times \Delta C$
 - i. Shear Mechanism: The shear restriction mechanism shall be designed to allow free rotation and withstand the specified horizontal forces. The mechanism shall be designed to withstand the design forces on the bearing without exceeding allowable shear of $0.33F_y$, bending stress of $0.55F_y$ and maximum bearing stress of $0.8F_y$. Shear resistance of the disc shall not be included. The shear mechanism shall be connected to the bearing plates by welding, machining out of the solid unless otherwise approved by the MBTA.
2. Non-Rotational Bearing Elements:
- a. PTFE: Sheet PTFE primary sliding surfaces, filled or unfilled, shall be designed for an average stress not to exceed 3,500 psi. The maximum edge stress shall be 5,000 psi at maximum combined rotation, vertical, and horizontal load. The stresses on the PTFE for Disc Bearings shall not exceed 75% of these values.

Sheet PTFE sliding surfaces shall be bonded by the bearing manufacturer under controlled conditions and in accordance with the requirements of the manufacturer of the approved adhesive system. After completion of bonding, the PTFE surface shall be smooth and free from bubbles. Filled PTFE surfaces shall be polished after bonding until smooth.

Sheet PTFE shall be a minimum of 1/8" thick, epoxy- bonded into a square-edge recess equal in depth to one half the thickness of the PTFE.

The maximum coefficient of friction for PTFE sheet shall be equal to or less than the following:

<u>PTFE Compressive Stress</u>	<u>Coefficient of Friction</u>
500 psi or less	0.08
500 to 2,000 psi	0.06
2,000 or more	0.04

- b. **Stainless Steel:** The stainless steel surface shall cover the mating surface in all operating positions plus one inch in each direction of movement.

Sheet stainless steel shall be 13 to 16 gage in thickness. It shall be connected to the substrate by a continuous weld around the entire perimeter. The sheet shall be in full contact with the substrate. Stainless steel sliding surfaces shall, preferably, be face down.

Stainless steel welded overlay shall be a minimum of 3/32" thick after welding, grinding and polishing and be produced using Type 309L electrodes.

Stainless steel sheet shall be seal-welded around the entire perimeter using techniques which ensure it remains in contact with the backing plate.

- c. **Guide Bars and Guide Keys:** Central Guide keys may be made integral by machining from the solid. Where a separate key or guide bar is used they shall be fitted in a keyway slot machined to give a press fit and bolted or welded to resist overturning. Guide bars may be made integral by machining from the solid or fabricated from bars welded, bolted and or recessed at the manufacturing option.

Guide bars and central guide keys shall be designed for the specified horizontal forces, but not for less than 10% of the vertical capacity of the bearing.

The sum of clearances between guided surfaces shall not exceed 1/8". Net contact area between guiding surfaces must remain constant throughout all operating positions.

All guide bars and guide keys shall be self-aligning. (i.e., guides in pot bearings must bear against piston components; guides in spherical bearings must bear against unfixed spherical components).

Guiding directly between fixed bearing components shall not be permitted. Stainless steel and PTFE are required on guiding surfaces. The compressive stress on PTFE shall not exceed the following average bearing stresses:

<u>Unfilled PTFE</u>	<u>Filled PTFE</u>
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All loads except seismic loads	3,500 psi	3,500 psi
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(PTFE on guiding surfaces need not be designed for seismic loading).

Edge load pressure due to all loads and rotation (except seismic) shall not exceed 5,000 psi for filled or unfilled PTFE.

PTFE on guiding surfaces shall be 3/16" minimum thickness, epoxy bonded into a square edged recess 3/32" deep in the substrate. In addition, the PTFE shall be mechanically fastened by a minimum of two screws into the substrate, located at a distance equal to twice the nominal screw diameter from the end of the PTFE strip. The top of the screws shall be recessed an amount not less than the minimum of one half the PTFE relief.

- d. Travel Stops: Travel stops if detailed on the approved drawings shall be capable of resisting the horizontal forces specified. The stops shall be set a 150% of the longitudinal movement or as directed on the approved drawings.
- e. Top Plate, Masonry Plate, and Auxiliary Plate: Where top plates and masonry plates bear on concrete the concrete bearing stress on the loaded area shall not exceed the limits specified in AREMA, Volume 2, Chapter 8.

Special consideration shall be given to the design of top plates (or plate to which sliding elements are attached) to assure that any bending forces imparted during field installation do not deflect the sliding surfaces. (The top plate, for example, may be subject to extreme bending forces during a retrofit installation as a result of vertical load conditions prior to the completion of field welding).

The auxiliary plate shall be located between the bearing proper and the masonry plate. The auxiliary plate shall be shop welded to the bearing proper, or shall have a "saucer-like" recess which shall snugly fit and restrain the bearing, and have adequate capacity to resist all required design forces. All field welds required for the anchoring of the lower bearing unit shall be limited to the interface between the masonry plate and auxiliary plate.

The auxiliary plate shall be designed for all required shear and bending forces. The auxiliary plate shall be adequately designed for all bending forces imparted by vertical design loads, discounting any contribution of the field weld between it and the masonry plate. The recess machined for the pot (or lower spherical element) shall be not less than ½" in depth. The recessed surface on which the bearing proper will bear shall be machined to a tolerance equal to 0.0005 x the diameter or width or recess. The minimum thickness of the auxiliary plate after machining of the recess shall be one (1) inch. Unless otherwise approved by the Engineer, the auxiliary plate shall extend a minimum of four (4) inches beyond the plan limit of the pot (or lower spherical element) in all plan directions, but not less than one (1) inch beyond the horizontal plan limits of bearing travel stops, if required, and other bearing components if any which limit access to required field welds.

- d. Fabrication Tolerances: The classes of tolerances are defined as follows:
1. Class A: 0.001 x nominal dimensions
 2. Class B: 0.002 x nominal dimensions
 3. Class C: 0.005 x nominal dimensions

Fabrication tolerances shall be in conformance with the following table:

Item	Thickness Tolerance (in.)	Dimension Tolerance (in.)	Flatness or out-of-round tolerance (in.)	Surface finish micro-in. (ms.)
Disc Bearings				
Overall dimensions	-0.0, +1/4	-0.0, +0.125	---	---
Shear-restricting element	---	-0.0, +0.005	Class A	63
Other machined parts	-0.0, +1/16	-0.0, +0.060	Class B	125
Urethane disc	-0.0, +1/16	-0.0, +0.125	Class B	125
Guides				
Contact surface	---	-0.0, +0.125	Class A	63
Distance between guides	---	-0.0, +0.030	---	---
Parallelism of guides (radians)	---	+0.005	---	---
Load Plates				
Overall dimensions	-1/16,+1/16	-1/4, +1/4	Class A	250
Bevel slope (radians)	+0.002	---	---	---

Load plate overall dimensions for flatness tolerance and surface finish shall apply only to the surfaces in contact with the bearing.

4. Basis of Design: D.S. Brown Versiflex HLMR Disc Bearing Assemblies.
 - a. Versiflex HLMR Disc Bearing Assemblies Fixed DF Series – 30%.
 - b. Versiflex HLMR Disc Bearing Assemblies Uni-Directional DMG Series – 10%.

2.2 BEARINGS FOR VIADUCT STRUCTURES

A. General:

1. Both Multi Rotational Disc bearings and Steel Reinforced Elastomeric bearings are to be provided for the Viaduct Structure. Disc bearings both fixed and expansion shall be design to the loads, rotations and displacements as indicated on the Contract Documents.

Additionally, Disc and Steel Reinforced Elastomeric bearings shall be fabricated to the sizes and shapes as indicated in the details on the contract drawings, unless otherwise approved by the Engineer. Bearings of each type, either Disc or Elastomeric shall be supplied by only one manufacturer.

2. Bearings shall be designed and constructed in accordance with the requirements of Division I, Section 14 Bearings and Division II, Section 18 Bearings, of the American Association of State Highway and Transportation Officials (AASHTO), Standard Specification for Highway Bridges 17th Edition. Steel Reinforced Elastomeric bearings have been designed in accordance with Method B of the AASHTO Standard.
3. Fixed Multi Rotational Disc Bearings shall allow rotation but no longitudinal or transverse movement.
4. Expansion (Guided) Multi Rotational Disc Bearings shall allow rotation and longitudinal movement in the bearing plane; transverse movement shall be restricted. To allow longitudinal movement, the upper steel bearing plate shall be faced with polytetrafluoroethylene (PTFE) sheet and support a sliding steel top bearing plate. The mating surface of the sliding steel top bearing plate shall be faced with polished stainless steel. Transverse movement shall be restricted with either a guide bar or keyway.
5. Fixed Steel Reinforced Elastomeric Bearings shall allow rotation but no longitudinal or transverse movement.
6. Expansion Steel Reinforced Elastomeric Bearings shall allow rotation and longitudinal movement in the bearing plane; transverse movement shall be restricted. To allow longitudinal movement, bearing are sized for the required shear deformation.

B. Materials – Viaduct Structure and Multi Rotational Bearings and Steel Reinforced Elastomeric Bearings.

1. Steel: All steel, shall conform to ASTM A709, Grade 50. Multi Rotational Disc Bearing Guide bars, load plates, uplift restraints and shear-restriction devices shall be as detailed by the manufacturer, unless otherwise specified or indicated. Steel for laminates of Elastomeric Bearings shall conform to ASTM A36.
2. Stainless steel sliding surfaces shall conform to ASTM A167 or A240 Type 304, with portions in contact with PTFE polished to a No. 8 mirror finish. The minimum thickness of the stainless steel shall be 0.050". Welded stainless steel overlay produced using Type 309L electrodes.
3. Elastomeric Disc (Disc Bearings): The rotational element of the disc bearing shall be made from an elastomeric compound with a hardness which lies between 45 and 65 on the Shore D scale. The elastomeric disc for disc bearings shall be Polyether Urethane conforming to the requirements of the AASHTO Table 18.4.7.1-1.
4. Polytetrafluoroethylene (PTFE): PTFE sliding surfaces shall be 100% new material and shall comply with ASTM D 4894 or D 4895. It shall satisfy the requirements of AASHTO Table 18.4.3.1-1. No reclaimed material shall be used. Finished PTFE sheet, strip and fabric shall be resistant to acids, alkalis, and petroleum products, stable at temperatures from - 360°F to + 500°F, nonflammable, and nonabsorbent of water.

- a. Filler material, when used in PTFE, shall be milled glass fiber, carbon fiber or other approved fiber. The filler shall not react chemically with the PTFE but shall adhere to it so that the two act compositely.
 - b. Finished PTFE sheet shall be made from virgin PTFE resin or virgin PTFE resin uniformly blended with approved filler. The maximum filler content shall be 15% for fiberglass and 25% for carbon fibers. The PTFE sheet shall satisfy the requirements of AASHTO Table 18.4.3.1-1. Values for intermediate filler contents may be obtained by interpolation.
 - c. Adhesive used for bonding sheet PTFE shall be an epoxy material satisfying the requirements of federal specification MMM-A-134, FEP film or equal, as approved by the MBTA.
 - d. Lubricant, if used, shall consist of a combination of solids which does not react chemically or electrolytically with the PTFE and its mating surface and shall remain stable in the environmental conditions expected at the bridge site.
5. Elastomeric (Steel Reinforced Elastomeric Bearings): The elastomeric compound shall be composed of 100% low temperature Grade 3 virgin crystallization resistant polychloroprene (neoprene) meeting the requirements of AASHTO M 251 and Division II, Section 18 of the AASHTO Standard Specifications for Highway Bridges, Table 18.4.5.1-1A. All bearings shall consist of 60 Shore A Durometer hardness, dimensions, design compressive load are indicated on the approved drawings. All expansion bearings are subject to shear deformation. Shear Modulus, at 73 degrees Fahrenheit, shall fall between 130 psi and 200 psi, and have a maximum creep deflection at 25 years of 35%. Shear modulus tests shall be carried out using the apparatus and procedure described in annex A of ASTM D 4014. The vulcanized bond between reinforcement steel laminated bearings shall develop a minimum peel strength of 40 pound per inch. Peel strength tests shall be performed by ASTM D 429 Method B.
 6. Bedding materials below bearing assemblies when indicated shall consist of common desilverized sheet lead, conforming to ASTM B 29. The sheets shall be of uniform thickness and shall be free from cracks, seams, slivers, scale, and other defects. Unless otherwise specified, lead sheet thickness shall be 1/8" plus or minus 0.03".

PART 3 – EXECUTION

3.1 TESTING, INSTALLATION, AND INSPECTION OF DISC AND ELASTOMERIC BEARINGS FOR RAILROAD BRIDGES

A. Testing

1. General: Tests shall be performed on test bearings as specified below to ensure the requirements of the specification have been met. Testing is to be performed at the manufacturer's plant.
Bearing with capabilities that exceed the manufacturer's testing capacity shall be tested at an approved testing laboratory. If suitable test equipment is not available in the United States, alternative testing/inspection procedures will be agreed between the Department and the manufacturer.

2. Sampling: Tests shall be performed on randomly selected samples from the production bearings. One bearing per "lot" shall be tested. A lot shall be defined as the smallest number of bearings as determined by the following criteria:
 - a. One lot shall not exceed a single contract or project quantity. One lot shall not exceed 25 bearings.
 - b. A lot shall consist of those bearings of the same type within a "Load Category". Bearing types shall be fixed type bearings or expansion type bearings. Guided and non-guided expansion bearings will be considered a single type.
 - c. One load category shall consist of bearings of differing vertical load capacity within a load range as outlined below:
 1. For bearings less than or equal to 1,000 kips capacity, the Load Category shall be based on a range of 500 kips.
 2. For bearings greater than 1,000 kips capacity but less than or equal to 3,000 kips capacity, the Load Category shall be based on range of 1,000 kips.
 3. For bearings in excess of 3,000 kips capacity the Load Category shall be based on a range of 2,000 kips.
3. Friction Test: A sample from each lot of expansion bearings shall be tested. Specially made bearings shall not be used; only actual bearings to be used in the project shall be tested.

The test method and equipment shall be approved by the MBTA and include the following requirements:

- a. The test must be arranged so that the static coefficient of friction on the first movement of the manufactured bearing can be determined.
 - b. The bearing surface shall be cleaned prior to testing.
 - c. The test shall be conducted at the maximum working stress for the PTFE surface with the test load applied for 12 hours prior to measuring the friction.
 - d. The first movement static and dynamic coefficients of friction shall be determined at a sliding speed of 1 inch per minute or less and shall not exceed the coefficient of friction stated on the Contract Documents.
 - e. The bearing specimen shall be subjected to a minimum of 100 movements of at least one inch of relative movement at a speed of less than 12 inches per minute. After cycling the static and dynamic coefficients of friction shall be determined again at a speed of less than one inch per minute and shall not exceed the coefficient of friction specified for the PTFE elsewhere in this special provision. The bearing shall show no visible sign of bond failure or other defects.
4. Proof Load Test: One bearing shall be tested from each production "lot" of fixed and expansion bearings. Load shall be applied to the test bearings equal to 150% of the rated design capacity of the bearing simultaneously rotated 0.02 radians or the design rotation, whichever is greater, for one hour. During the test or subsequently upon disassembly, the bearing shall show no sign of deformation or extrusion of elastomer or PTFE.
 5. PTFE Bond Test: Bearings with Sheet PTFE Primary Surfaces shall, at the option of the Engineer, have a 180 degree peel test performed on the primary PTFE sliding surface

using the ASTM D903 Test Method. Minimum peel strength shall be 20 lbs. per inch. One bearing from each production lot shall be tested.

Bearings with Fabric PTFE Primary Sliding Surfaces shall have the primary PTFE tested in shear. One bearing from each production lot shall be tested as follows:

- a. The component carrying the Fabric PTFE (or complete bearing at the option of the manufacturer) shall be subjected to the maximum vertical design load of the bearing and simultaneously but transversely, a load equal to 13% of the vertical design load for a period of one minute. Slip or creep shall not exceed 1/8" during the test.
- b. Only bearings from lots from which test specimens have passed all the above requirements will be approved for use in the structure.

Bearing assemblies shall be securely fixed together as units so that they may be shipped to the job site and stored without relative movement of the bearing parts or disassembly at any time. Bearings shall be wrapped in moisture resistant and dust resistant material to protect against shipping and job site conditions.

Care shall be taken to ensure that bearings at the job site are stored in a dry sheltered area free from dirt or dust until installation.

When bearings are to be inspected on site, they shall be inspected within one week of arrival and may not be disassembled except under the supervision of the manufacturer or his representative or with the written approval of the manufacturer. Following inspection, the wrapping shall be reapplied and the bearings kept clean until installation.

Removal of top plates of bearings for separate attachment to the structure is not permitted except under the direct supervision of the manufacturer and by approval of the MTBA.

B. Shipping and Packing:

1. Bearing assemblies shall be securely fixed together as units so that they may be shipped to the job site and stored without relative movement of the bearing parts or disassembly at any time. Bearings shall be wrapped in moisture resistant and dust resistant material to protect against shipping and job site conditions.

Care shall be taken to ensure that bearings at the job site are stored in a dry sheltered area free from dirt or dust until installation.

When bearings are to be inspected on site, they shall be inspected within one week of arrival and may not be disassembled except under the supervision of the manufacturer or his representative or with the written approval of the manufacturer. Following inspection, the wrapping shall be reapplied and the bearings kept clean until installation.

Removal of top plates of bearings for separate attachment to the structure is not permitted except under the direct supervision of the manufacturer and by approval of the MBTA.

C. Installation:

1. Bearings shall be evenly supported over their upper and lower surfaces under all erection and service conditions.

Bearings shall be lifted only by their underside or specially designed lifting lugs.

When installing bearings, extreme care shall be exercised to protect bearing surfaces from damage and contamination.

The bearing assembly shall be aligned with the superstructure as shown on the approved drawings. On guided bearings, special care must be taken to properly align the guiding mechanism with the designated expansion direction of the structure as shown on the Design Documents.

Bearing straps or retaining clamps shall be left in place as long as possible to ensure parts of bearings are not inadvertently displaced relative to each other. Care must be taken to remove straps or clamps before any normal structural movement takes place.

Offsets of upper and lower bearing parts shall be set as required by the approved drawings to compensate for loan deflection, temperature movement, and elastic shortening and creep of post-tensioned concrete superstructure as the case may be.

Bearings installed on a concrete substructure shall be installed over a preformed fabric pad, or shall bear upon non-shrink grout, as indicated on the Design Documents.

Where bearings are installed over a prefabricated pad on a concrete bearing pad, the concrete bearing pad surface shall be prepared to the correct elevation and finished to the following flatness tolerance:

For bearings seats up to 30" in length or width.....1/16".
For bearings seats over 30" but less than 45"..... 3/32".
Bearing seats over 45"..... 1/8".
There shall be no projecting irregularities exceeding 1/32". Bearing seats shall be level within 1:200 slope.

Where bearings are installed with non-shrink grout, the masonry plate must be set to the proper elevation and leveled by adjusting the anchor bolt leveling nuts as shown on the Design Documents.

The masonry plate shall be installed level to within 1:200 slope. The anchor bolt protrusions above the masonry plate surface shall be cut off. The remaining anchor bolts shall be field welded to the masonry plate and ground flat as directed on the approved drawings. The flowable non-shrink grout must be placed at even density beneath the entire masonry plate surface such that no voids are created. Grout shall reach a minimum compressive strength of 4,500 psi before bearing loads shall be applied.

The mating surface with the superstructure shall be a plane surface to within a slope of 1:200. Following alignment of the bearing components, top plate and auxiliary plate shall be field welded in position as shown on the Design Documents. Welding procedures shall be established by the DB Entity to restrict the maximum temperature of the bonded PTFE surfaces to 300 °F and maximum temperature of the elastomer (Polyether-urethane, Neoprene or Natural Rubber) to 250°F. Temperatures shall be determined by temperature indicating wax pencils or other suitable means.

Particular care should be exercised to mask and protect the PTFE and polished stainless steel surfaces to protect them from blast abrasive and paint application during construction.

The DB Entity shall repair any damage to bearing finishes following installation at no cost to the MBTA.

Bearings shall receive touch-up painting after installation as in accordance with other Contract special provision items addressing the painting of structural steel.

A continuous bead of silicone, ¼” thick, shall be applied along the interface between auxiliary plate and the bearing proper following completion of painting where the bearing proper is retained by a recessed opening in the auxiliary plate.

3.2 FABRICATION, TESTING, AND INSTALLATION OF MULTI-ROTATIONAL DISC BEARINGS AND STEEL REINFORCED ELASTOMERIC BEARINGS FOR VIADUCT STRUCTURES

A. Fabrication:

1. General:

- a. The DB Entity shall provide complete design of Multi Rotational Disc Bearings for the loads, and movements indicated on the contract drawings. Bearing dimensions as indicated on the Contract Documents for Disc Bearings shall be used for the design. Any changes to the dimensions and sizes shown shall not be made unless prior written acceptance is made by the MBTA. The DB Entity shall submit to the MBTA shop drawings and design calculations stamped and signed by a Professional Engineer registered in the Commonwealth of Massachusetts.
- b. Bearings shall be accurately machined to the dimensions and tolerances shown on the Design Documents and shall be free from flaws.
- c. All fabrication for steel plates shall comply with Section 11.4 of Division II of AASHTO Standard Specification. All welding shall conform to, and all welders shall be qualified in accordance with, the requirements of the ANSI/AASHTO/AWS D 1.5 Bridge Welding Code.
- d. Disc Bearings shall be attached to the masonry plate a method that permits transfer of all the specified loads and that can allow for future replacement of the bearing.
- e. Unless otherwise indicated, the dimensional tolerances and surface finishes of the bearings shall satisfy the requirements of Table 18.5.1.5-1 of the AASHTO Standard, for Disc Bearings, Steel Reinforced Elastomeric Bearings, Flat PTFE Sliding Bearings, Guides and Load Plates.

2. Fabrication of PTFE elements shall be made of a single piece. All flat sheet PTFE attached to a metal backing plate shall be attached by recessing into the backing plate for one half of the PTFE thickness and bonding. PTFE attached to other materials, such as elastomers, shall be attached by methods approved by the engineer. The PTFE shall be factory-bonded, using an adhesive in accordance with these specifications and the instructions of the adhesive’s manufacturer. Prior to bonding, the surface shall be etched by an approved manufacturer

using the sodium naphthalene or sodium ammonia process. When the backing plate is metal, the bonding shall be conducted under a uniform pressure greater than 100 psi. The peel strength of the bond shall be not less than 20 pounds per inch, tested in accordance with ASTM D 429 Method B. The finished surface of the PTFE shall be smooth, free from bubbles and shall conform to the tolerances shown in AASHTO Table 18.5.1.5-1. Filled PTFE sheets shall be polished after bonding. Lubricant shall be applied to the entire PTFE surface if required by the bearing manufacture.

3. Stainless Steel Mating Surfaces shall be fabricated as a single piece. Each sheet shall be attached to its backing material by seal welding around the entire perimeter so as to prevent entry of moisture between the stainless steel and the backing material. Welds shall conform to the American Welding Society requirements for stainless steel. After welding, the stainless steel sheet shall be flat, free from wrinkles and in continuous contact with its backing plate.
4. Steel Reinforced Elastomeric Bearings shall be manufactured as a single unit to dimensions as indicated on the contract drawings. Flash tolerance, finish, and appearance shall meet the requirements of the latest edition of the Rubber Handbook as published by the Rubber Manufacturers Association, Inc., RMA F3 and T.063 for molded bearings and RMA F2 for extruded bearings. Bearings shall be cast as a unit in a mold and shall be bonded and vulcanized under heat and pressure. The mold finish shall conform to standard shop practice. The internal steel laminates shall be sandblasted and cleaned of all surface coatings, rust, mill scale and dirt before bonding, and shall be free of sharp edges and burrs. External Sole Plates shall be galvanized and vulcanized bonded to the bearing assembly due the manufacturing process.

B. Fabrication Requirements for Disc Bearings:

1. The steel housing of the disc bearing shall be made by machining from a single piece of plate or by fabrication by welding. The shear restriction mechanism shall be connected to the bearing plate by mechanical fastening, welding or other means approved by the MBTA.
2. The polyether urethane rotational element shall be molded as a single piece. The finish of the mold shall be free from burrs and shall conform to good shop practice.
3. Guide bars shall be attached to the body of the bearing by a method which minimizes distortion and allows the flatness tolerances on all parts of the bearing to be met after attachment. The sliding surfaces of the guide system shall be flat and parallel. Bolts or threaded fasteners used to attach the guide bars to their supporting plates shall have an embedded thread length adequate to develop their required strength. PTFE and Stainless steel sliding surfaces shall be attached by two or more of the following methods simultaneously: bonding, recessing and mechanical attachment with countersunk fasteners. If the material is bonded, it shall first be etched by the method recommended by the manufacturer of the material or the bonding agent. Recessing shall be one half of the material thickness. Fasteners shall be countersunk to a depth which ensures that they will not touch the mating material after allowing for wear.
4. Load plates shall be made from a single steel plate or they may be built up from several steel laminates, each oriented in the plane perpendicular to the direction of the load. Built up load plates shall be joined by complete seal welding to prevent ingress of moisture. Such welds shall also provide sufficient shear strength to resist the applied loads. The load plates shall have no sharp comers or edges. Holes may be formed by drilling or punching. All burrs shall be removed by grinding.

- C. Corrosion Protection, all exposed steel surfaces for both Disc Bearings and Steel Reinforced Elastomeric Bearings, except stainless steel, shall be galvanized in accordance with ASTM A123.
- D. Testing and Acceptance for Viaduct Structure Multi Rotational Disc Bearings and Steel Reinforced Elastomeric Bearings, shall be conducted in accordance with AASHTO Standard section 18.7.2 Tests and AASHTO M251, for the following criteria by the Manufacturer and all reports shall be submitted the MBTA for approval. Any bearing test that indicates non-compliance with the requirements will subjected to rejection of the bearing Lot. The Manufacturer may elect to test each bearing in a Lot that is rejected at their own expense. Any bearing found to be acceptable may be used in the final construction at the DB Entity's discretion. Each bearing with a tapered sole plate that is selected for testing shall be delivered to the test site accompanied by an unattached plate identical to the tapered sole plate. The single beveled plate shall be so constructed that, when placed in contact with the tapered sole plate, the two shall form a single body, rectangular in shape and uniform in thickness.
1. Material Certification Tests
 2. Dimensional Check
 3. Material Friction Test (sliding surfaces only)
 4. Bearing Friction Test (sliding surfaces only)
 5. Clearance Test
 6. Short-term Compression Proof Load Test
 7. Long-term Compression Proof Load Test
 8. Long-term Deterioration Test
 9. Bearing Horizontal Force Capacity (fixed and guided bearings only)
- E. Installation for Viaduct Structure Multi Rotational Disc Bearings and Steel Reinforced Elastomeric Bearings: Bearings shall be installed by qualified personnel at the locations shown on the Design Documents. Bearings shall be set to the dimensions and offsets as indicated on Contract Documents and shall be adjusted as necessary to take into account the temperature and future movements of the bridge due to temperature changes.
1. Each bearing shall be located within 1/8" of its correct position in the horizontal plane and oriented to within an angular tolerance of 0.02 radians. All bearings shall be set horizontal to within an angular tolerance of 0.005 radians, and must have full and even contact with load plates, where they exist. The superstructure supported by the bearing shall be set on it so that, under full dead load, its slope lies within an angular tolerance of 0.005 radians of the design value. Any departure from this tolerance shall be corrected by means of a tapered plate or by other means approved by the MBTA.

END OF SECTION

SECTION 05126

STRUCTURAL STEEL FOR RETAINING WALLS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This section specifies the following items.
 - 1. Structural Steel Elements will be used in the Soldier Pile and Lagging Retaining Walls for soldier piles and support angles.
 - 2. Structural Steel Elements will be used in the Noise Barrier Assemblies for steel anchorages.
- B. Items To Be Furnished Only: Furnish the following items for installation by the designated Sections:
 - 1. Section 03300 – CAST-IN-PLACE CONCRETE: Anchor bolts, drilled shaft reinforcement, inserts, embedded wall plates, loose leveling plates and similar items.
- C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 16451 – CORROSION CONTROL AND STRAY CURRENT MITIGATION

1.2 DEFINITIONS

- A. Structural Steel: Elements of structural-steel frame, as classified by AISC's "Code of Standard Practice for Steel Buildings and Bridges", that support design loads.
- B. Soldier Pile: Vertical pile member used in construction of Soldier Pile and Lagging Retaining Walls.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: Show fabrication of structural-steel components.
 - 1. Include details of cuts, connections, splices, camber, holes, and other pertinent data.
 - 2. Include embedment drawings.
 - 3. Indicate welds by standard AWS symbols, distinguishing between shop and field welds, and show size, length and type of each weld.
 - 4. For structural-steel connections indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
- C. Welding Certificates: Certificate from AWS indicating certification in type of welding required for each welder and welding operator.
- D. Welding Records and Data:

1. Before welding, submit the procedure which will be used for qualifying welders and welding procedures. For procedures other than those pre-qualified in accordance with AWS D1.1, submit a copy of procedure qualification test records.
 2. Submit certified copy of qualification test records for each welder, welding operator, and tacker who will be employed in the work.
 3. If field welding is permitted, submit descriptive data for field welding equipment.
 4. Submit all NDE records (radiographs, ultrasonic, magnetic particle) and visual inspection reports upon completion or when otherwise requested by the Engineer.
- E. Qualification Data: For installer, fabricator, professional engineer, testing agency, welding inspectors, NDE inspectors and galvanizer. Submit prior to starting work.
- F. Mill Test Reports: Signed by manufacturers certifying that the following products comply with requirements:
1. Structural steel including chemical and physical properties.
 2. Bolts, nuts, and washers including mechanical properties and chemical analysis.
 3. Shear stud connectors.
 4. Shop primers.

1.4 QUALITY ASSURANCE

- A. Fabricator Qualifications: A qualified fabricator who participates in the AISC Quality Certification Program and is certified for: Steel Building Structures (STD); or Simple Steel Bridge Structures (SBD); or Major Steel Bridges (CBR) as applicable.
- B. Galvanizer Qualifications: Engage the services of a qualified galvanizer who has demonstrated a minimum of five years' experience in the successful application of galvanized coatings specified in this Section in the facility where the work is to be performed and who will apply the coatings within the same facility.
- C. Installer Qualifications: A qualified installer with previous experience in installing structural steel.
- D. Welding: Qualify procedures and personnel according to AWS D1.1, "Structural Welding Code--Steel"
- E. Comply with applicable provisions of the following specifications and documents:
1. AISC's "Code of Standard Practice for Steel Buildings and Bridges"
 2. AISC's "Specification for Allowable Stress Design of Single-Angle Members" and "Specification for Load and Resistance Factor Design of Single-Angle Members"
 3. AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002 with latest Interims
- F. Tests and Inspection
1. The Contractor will test and inspect bolted and welded connections and prepare test reports. Specialty tests shall be performed at no expense to the MBTA by an independent testing laboratory approved by the Engineer. Costs of specialty tests shall be borne by the Contractor. Test reports shall be submitted to the Engineer for approval.
 2. The Engineer reserves the right to inspect high-strength bolted connections and weld connections. Provide access to places where structural steel work is being fabricated or erected

so that required inspection and testing can be accomplished at no change in Contract Price. At times, inspection may require moving or handling of steel to permit proper inspection. Notify Materials Testing Laboratory not less than 48 hours prior to start of fabrication.

3. The Engineer may inspect structural steel at the plant before shipment; however, the Engineer reserves the right, at any time before final acceptance, to reject material not complying with specified requirements.
4. Correct deficiencies in structural steel work that inspections and laboratory test reports have indicated to be not in compliance with requirements at the Contractor's expense. Perform additional tests, at no expense to the MBTA, as may be necessary to reconfirm any non-compliance of the original work, and as may be necessary to show compliance of corrected work.
5. Specialty Tests: Nondestructive examination of welds in accordance with provisions of AWS D1.1 and ASTM Standards noted shall be made in accordance with the following schedule:
 - a. Radiographic Examination of Welds, per ASTM E94 and E142:
 1. Field, complete joint penetration groove welds:
 - a. 1 out of 5 (20 percent) with thickness equal to or less than 3/4 inch.
 - b. 100 percent with thickness greater than 3/4 inch.
 2. Shop, complete joint penetration groove welds:
 - a. 1 out of 10 (10 percent) with thickness equal to or less than 3/4 inch.
 - b. 1 out of 2 (50 percent) with thickness greater than 3/4 inch and equal to or less than 1-1/2 inches.
 - c. 100 percent for thickness greater than 1-1/2 inches.
 - b. Ultrasonic Examination, per ASTM E164: Complete joint penetration groove butt welds not accessible for radiographic examination shall be subjected to ultrasonic testing. The extent shall be the same as noted for radiographic examination. Ultrasonic examination shall be made 48 to 72 hours after welding at locations on weldments or welded joints subject to high restraint as indicated in order to check for lameller tearing. The exact location of the areas to be inspected shall be determined with the Engineer at the time of fabrication. This examination shall be made according to the following schedule unless conditions of tearing require a greater number of tests, as directed:
 1. 1 out of 10 (10 percent) for thickness equal to or less than 3/4 inch.
 2. 1 out of 5 (20 percent) for thickness greater than 3/4 inch and equal to or less than 1-1/4 inches.
 3. 1 out of 2 (50 percent) for thickness greater than 1-1/4 inches.
 - c. Magnetic Particle Examination, per ASTM E709, field and shop:
 1. 1 out of 5 (20 percent) of complete joint penetration groove welds of tee and corner joints.
 2. 1 out of 10 (10 percent) of partial joint penetration groove and fillet welds.

- d. Penetrant Examination, per ASTM E165: Shall be used for detecting discontinuities that are open to the surface use as appropriate.
 - 6. Visual Examination: All welds whether otherwise examined or not shall be visually examined and faulty joints shall be marked for correction.
 - 7. When any testing, examination or inspection reveals faulty welds, all joints of the same type shall be checked at no expense to the MBTA until the integrity of the weld is assured before resuming examination.
 - 8. After faulty welds have been corrected or repaired, they shall each be re-examined at no expense to the MBTA in the manner specified for the original joint.
 - 9. It is intended that inspections shall be performed to permit an orderly flow of completed material from the shop. Work with the Engineer to establish a schedule that will permit this.
 - 10. Test result information shall be forwarded to the Engineer immediately after test results are available stating the acceptance or rejection of fabricated pieces in order that the repairs and re-inspection may be made as soon as possible.
- G. Pre-Installation Conference: Contractor shall schedule a meeting to be attended by Contractor, Engineer, fabricator and galvanizer. Agenda shall include the following: Project schedule, source for each fabrication, coordination between fabricator and galvanizer and adjacent work, finish of surfaces, application of coatings, submittals, and approvals.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Store materials to permit easy access for inspection and identification. Keep steel members off ground and spaced by using pallets, dunnage, or other supports and spacers. Protect steel members and packaged materials from erosion and deterioration.
 - 1. Store fasteners in a protected place. Clean and re-lubricate bolts and nuts that become dry or rusty before use.
 - 2. Do not store materials on structure in a manner that might cause distortion, damage, or overload to members or supporting structures. Repair or replace damaged materials or structures as directed.

1.6 COORDINATION

- A. Furnish anchorage items to be embedded in or attached to other construction without delaying the Work. Provide setting diagrams, sheet metal templates, instructions and directions for installation.

PART 2 - PRODUCTS

2.1 STRUCTURAL-STEEL MATERIALS

- A. Rolled Sections: ASTM A572 Grade 50, AASHTO M270 Grade 50 or higher, galvanized.
- B. Built-Up Sections, Plates, Cap Plates, Plates Serving Non-Structural Purpose, and All Other Sections Including Angles and Channels: ASTM A36, AASHTO M270 Grade 36, galvanized.
- C. Sheet Piles: ASTM A572 Grade 50, AASHTO M222 Grade 50 or higher, ungalvanized.

- D. Grating for Stairs: ASTM A569 or ASTM A36, galvanized.
- E. Welding Electrodes: Comply with AWS requirements.

2.2 BOLTS, CONNECTORS, AND ANCHORS

- A. High-Strength Bolts, Nuts, and Washers: ASTM A325, Type 1, heavy hex steel structural bolts; ASTM A563 heavy hex carbon-steel nuts; and ASTM F436 hardened carbon-steel washers.
 - 1. Finish: Hot-dip zinc coating, ASTM A153, Class C.
- B. Anchor Bolts: ASTM F1554, Grade 55, hot-dip zinc coating, ASTM A153, Class C.
- C. Headed Welded Studs: ASTM A108, Grade 60, low carbon steel, galvanized
- D. Threaded Welded Studs: ASTM A307, Grade 60, carbon steel, galvanized

2.3 MISCELLANEOUS MATERIALS

- A. Galvanizing Repair Paint: Coatings meeting requirements of ASTM A780.
- B. Nonmetallic, Shrinkage-Resistant Grout: ASTM C1107, factory-packaged, non-shrink, nonmetallic aggregate grout, noncorrosive, non-staining, mixed with water to consistency suitable for application and a 30-minute working time.

2.4 FABRICATION

- A. Structural Steel: Fabricate and assemble in shop to greatest extent possible. Fabricate according to AISC's "Code of Standard Practice for Steel Buildings and Bridges" and AISC's "Specification for Structural Steel Buildings--Allowable Stress Design and Plastic Design".
 - 1. Camber structural-steel members where indicated.
 - 2. Identify high-strength structural steel according to ASTM A6/A6M and maintain markings until structural steel has been erected.
 - 3. Mark and match-mark materials for field assembly.
 - 4. Complete structural-steel assemblies, including welding of units, before starting shop-priming operations.
- B. Thermal Cutting: Perform thermal cutting by machine to greatest extent possible. Plane thermally cut edges to be welded to comply with requirements in AWS D1.1.
- C. Bolt Holes: Cut, drill, or punch standard bolt holes perpendicular to metal surfaces.
- D. Finishing: Accurately mill ends of stair columns and other members transmitting bearing loads prior to welding.
- E. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1 and manufacturer's written instructions.
- F. Holes: Provide holes required for securing other work to structural steel and for passage of other work through steel framing members.

1. Cut, drill, or punch holes perpendicular to steel surfaces. Do not thermally cut bolt holes or enlarge holes by burning.
2. Base-Plate Holes: Cut, drill, mechanically thermal cut, or punch holes perpendicular to steel surfaces.
3. Weld threaded nuts to framing and other specialty items indicated to receive other work.

2.5 SHOP CONNECTIONS

- A. High-Strength Bolts: Shop install high-strength bolts according to RCSC's "Specification for Structural Joints Using ASTM A325 or A490 Bolts" for type of bolt and type of joint specified.
- B. Weld Connections: Comply with AWS D1.1 for welding procedure specifications, tolerances, appearance, and quality of welds and for methods used in correcting welding work. Complete welds in accordance with the Contract Drawings.
 1. Remove backing bars or runoff tabs, back gouge, and grind steel smooth.
 2. Assemble and weld built-up sections by methods that will maintain true alignment of axes without exceeding tolerances of AISC's "Code of Standard Practice for Steel Buildings and Bridges" for mill material.
 3. Insufficient welds shall be rejected and corrected until required profiles are met.
 4. Verify that weld sizes, fabrication sequence, and equipment used for architecturally exposed structural steel will limit distortions to allowable tolerances. Prevent weld show-through on exposed steel surfaces.
 - a. Grind butt welds flush.
 - b. Grind or fill exposed fillet welds to smooth profile. Dress exposed welds.
 5. No skip welds will be permitted for steel connections to be coated.

2.6 STEEL PRIMERS AND FINISHES

- A. Hot-Dip Galvanizing for Steel: For steel exposed to the elements, weather or corrosive environments and other steel indicated to be galvanized, provide coating for iron and steel fabrications applied by the hot-dip process. Provide hot-dip galvanizing, certified OTC/VOC compliant less than 2.8 lbs/gal. and conforming to EPA and Commonwealth of Massachusetts requirements. Comply with ASTM A123 for fabricated products and ASTM A153 for hardware. Provide thickness of galvanizing specified in referenced standards. The galvanizing bath shall contain high grade zinc and other earthly materials. Fill vent holes and grind smooth after galvanizing. Blast cleaning of the surface is unacceptable for surface preparation. Coatings must meet or exceed the following performance criteria
 1. Abrasion: ASTM D4060, CS17 Wheel, 1,000 gram load.
 2. Adhesion: ASTM D3359, Method B, 5 mm crosshatch.
 3. Humidity Resistance: ASTM D4585.
 4. Salt Spray (Fog): ASTM B117.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify elevations of concrete-bearing surfaces and locations of anchor rods, bearing plates, and other embedments, with steel erector present, for compliance with requirements. Elevations shall be verified by a surveyor licensed in the Commonwealth of Massachusetts.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Provide temporary shores, guys, braces, and other supports during erection to keep structural steel secure, plumb, and in alignment against temporary construction loads and loads equal in intensity to design loads. Remove temporary supports when permanent structural steel, connections, and bracing are in place, unless noted otherwise.

3.3 ERECTION

- A. Set structural steel accurately in locations and to elevations indicated and according to AISC's "Code of Standard Practice for Steel Buildings and Bridges".
- B. Maintain erection tolerances of structural steel within AISC's "Code of Standard Practice for Steel Buildings and Bridges".
- C. Align and adjust various members forming part of complete frame or structure before permanently fastening. Before assembly, clean bearing surfaces and other surfaces that will be in permanent contact with members. Perform necessary adjustments to compensate for discrepancies in elevations and alignment.
 - 1. Level and plumb individual members of structure.
 - 2. Make allowances for difference between temperature at time of erection and mean temperature when structure is completed and in service.
- D. Splice members only where indicated.
- E. Remove erection bolts on welded structural steel; fill holes with plug welds; and grind smooth at exposed surfaces.
- F. Do not use thermal cutting during erection unless approved by Engineer. Finish thermally cut sections within smoothness limits in AWS D1.1.
- G. Do not enlarge unfair holes in members by burning or using drift pins. Ream holes that must be enlarged to admit bolts.
- H. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1 and manufacturer's written instructions.

3.4 FIELD CONNECTIONS

- A. High-Strength Bolts: Install high-strength bolts according to RCSC's "Specification for Structural Joints Using ASTM A325 or A490 Bolts" for type of bolt and type of joint indicated on the Drawings.

- B. Weld Connections: Comply with AWS D1.1 for welding procedure specifications, tolerances, appearance, and quality of welds and for methods used in correcting welding work.
1. Comply with AISC's "Code of Standard Practice for Steel Buildings and Bridges" for bearing, adequacy of temporary connections, alignment, and removal of paint on surfaces adjacent to field welds.
 2. Remove backing bars or runoff tabs, back gouge, and grind steel smooth.
 3. Assemble and weld built-up sections by methods that will maintain true alignment of axes without exceeding tolerances of AISC's "Code of Standard Practice for Steel Buildings and Bridges" for mill material.
 4. Verify that weld sizes, fabrication sequence, and equipment used for structural steel will limit distortions to allowable tolerances. Prevent weld show-through on exposed steel surfaces.
 - a. Grind butt welds flush.
 - b. Re-profile all steel surfaces (using needle guns or other profiling methods) that have been welded and ground smooth to assure proper adhesion of primers and topcoats.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified independent testing and inspecting agency to inspect field welds and high-strength bolted connections.
- B. Bolted Connections: Bolted connections will be inspected according to RCSC's "Specification for Structural Joints Using ASTM A325 or A490 Bolts". When using bolted connections prime with "slip critical class B" primer as specified in this Section. All surfaces of bolted or bearing connections may be primed. When welding, hold back primer a minimum of 2 inches each side of weld.
- C. Welded Connections: Field welds will be visually inspected according to AWS D1.1. In addition to visual inspection, specialty tests will be performed in accordance with AWS D1.1 and at the frequency stated in Article 1.5.F.5
- D. In addition to visual inspection, test and inspect field-welded shear connectors according to requirements in AWS D1.1 for stud welding and as follows:
1. Perform bend tests if visual inspections reveal either a less-than- continuous 360-degree flash or welding repairs to any shear connector.
 2. Conduct tests on additional shear connectors if weld fracture occurs on shear connectors already tested, according to requirements in AWS D1.1.
- E. Correct deficiencies in Work that test reports and inspections indicate do not comply with the Contract Documents.

3.6 REPAIRS AND PROTECTION

- A. Repair damaged galvanized coatings on galvanized items with galvanized repair paint according to ASTM A780 and manufacturer's written instructions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05210

STEEL JOISTS

PART 1 - GENERAL

1.1 SUMMARY

- A. This section includes the contractor designed hot rolled or cold-formed steel joist framing elements. Work includes:
 - 1. Steel joist.
 - 2. Anchorage, bracing and bridging.
- B. Related Sections
 - 1. Section 05310 – Steel Deck

1.2 REFERENCES

- A. Reference standards:
 - 1. ASTM:
 - a. ASTM A653/A653M-09 “Sheet Steel, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Glavanealed) by the Hot Dip Process.”
 - b. ASTM A780-09 “Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.”
 - c. ASTM A6/A6M-09, Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
 - d. ASTM A36/A36M-08, Standard Specification for Carbon Structural Steel
 - e. ASTM A242/242M-04 (2009), Standard Specification for High-Strength Low-Alloy Structural Steel
 - f. ASTM A307-07b, Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
 - g. ASTM A325/325M-09, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi [830 MPa] Minimum Tensile Strength
 - h. ASTM A370-09ae1, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
 - i. ASTM A500/A500M-07, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
 - j. ASTM A529/A529M-05, Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality
 - k. ASTM A572/A572M-07, Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
 - l. ASTM A588/A588M-05, Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric

Corrosion Resistance

- m. ASTM A606/A606M-09, Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
 - n. ASTM A992/A992M-06a, Standard Specification for Structural Steel Shapes
 - o. ASTM A1008/A1008M-09, Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable
 - p. ASTM A1011/A1011M-09a, Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
2. American Welding Society (AWS)
- a. AWS D1.1 “Structural Welding Code - Steel.”
 - b. AWS D1.3 “Structural Welding Code - Sheet Steel.”
 - c. AWS A5.1/A5.1M-2004, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
 - d. AWS A5.5/A5.5M:2006, Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
 - e. AWS A5.17/A5.17M-97:R2007, Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
 - f. AWS A5.18/A5.18M:2005, Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
 - g. AWS A5.20/A5.20M:2005, Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
 - h. AWS A5.23/A5.23M:2007, Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
 - i. AWS A5.28/A5.28M:2005, Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
 - j. AWS A5.29/A5.29M:2005, Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding
3. American Institute of Steel Construction, Inc. (AISC)ANSI/AISC 360-10 *Specification for Structural Steel Buildings*.
4. American Iron and Steel Institute (AISI)
- a. North American Specification for the Design of Cold-Formed Steel Structural Members; American Iron and Steel Institute; 2007 edition including the 2010 Supplement.
 - b. North American Standard for Cold-Formed Steel Framing - General Provisions; 2007.
5. Steel Joist Institute (SJI)
- a. SJI-COSP-2010, Code of Standard Practice for Steel Joists and Joist Girders
 - b. SJI-CJCOSP-2010, Code of Standard Practice for Composite Steel Joists

- c. SJI-K-2010, Standard Specification for Open Web Steel Joists, K-Series
 - d. SJI-LH/DLH-2010, Standard Specification for Longspan Steel Joists, LH-Series and Deep Longspan Steel Joists, DLH-Series
 - e. SJI-JG-2010, Standard Specification for Joist Girders
 - f. SJI-CJ-2010, Standard Specification for Composite Steel Joists, CJ-Series
6. Occupational Safety and Health Administration (OSHA)
OSHA, U.S. Department of Labor, Code of Federal Regulations 29CFR Part 1926
Safety Standards for Steel Erection, Section 1926.757 Open Web Steel Joists.

1.3 PERFORMANCE REQUIREMENTS

- A. Joist Girders shall be designed in accordance with these specifications as simply-supported primary load-carrying members. All loads shall be applied through steel joists, and placed along the Joist Girder top chord. Where any applicable design feature is not specifically covered herein, the design shall be in accordance with the following specifications:
- 1. Where the steel used consists of hot-rolled shapes, bars or plates, use the American Institute of Steel Construction, *Specification for Structural Steel Buildings*.
 - 2. For members which are cold-formed from sheet or strip steel, use the American Iron and Steel Institute, *North American Specification for the Design of Cold-Formed Steel Structural Members*.

Design Basis:

Joist Girder designs shall be in accordance with the provisions in this Standard Specification using Allowable Strength Design (ASD) as specified by the specifying professional for the project.

Structural Performance:

Design, fabricate, and erect steel joist to withstand specified design loads within limits and under conditions required. Provide joist layout as indicated on the contract documents.

- a. Design Loads: As specified on Contract Documents.
- b. Deflections: Live load deflection meeting the following (unless otherwise specified):
 - 1. Joists: Vertical deflection less than or equal to Length/360.
- c. Design framing systems to provide for movement of framing members without damage or overstressing, sheathing failure, connection failure, undue strain on fasteners and anchors, or other detrimental effects when subject to a maximum ambient temperature change (range) of 120 deg F (67 deg C).

1.4 SUBMITTALS

- A. Submit manufacturer's product data and installation instructions for each type of steel joist framing and accessory required.
- B. Submit detailed joist layouts indicating placement of joists, temporary and permanent bracing and blocking required, connection details and bearing support details with required field installed fasteners for complete installation.

- C. Engage the services of a Professional Engineer registered in the State of Massachusetts to prepare complete shop drawings and structural design computations for work of this Section. Drawings and shall bear the engineer's professional seal and signature. Note: Manufacturer's shop drawings stamped by the engineer are acceptable instead of those actually prepared by the engineer.

Submit individual joist drawings, sealed and signed by a qualified registered Professional Engineer in the Commonwealth of Massachusetts, verifying that joists are designed to the loads as indicated on the contract drawings and in accordance with building code and design Requirements Include:

1. Description of design criteria.
 2. Engineering analysis depicting member stresses and joist deflection for lifting, handling, construction loads and design loads.
 3. Joist member sizes and thickness and connections at joist joints.
 4. Joist support reactions and the connection design to supporting framing or walls.
 5. Top chord, Bottom chord and Web bracing requirements, both temporary and permanent. The structural design computations shall provide a complete structural analysis of all typical and special conditions of construction, and shall certify conformance to the governing laws and building code.
- D. Prior to joist erection, submit certified letter indicating that the contractor, joist fabricator and joist erector have verified the as installed supporting substrate conditions are acceptable for joist installation and that any discrepancies will not impact the performance of the joists in their final condition.
- E. Submit final plan drawings sealed and signed by a qualified registered Professional Engineer in the Commonwealth of Massachusetts depicting final installed joist assembly.

Include:

1. All joist to joist connections.
 2. All joist to structure connections.
 3. Plan and details for the location of all permanent lateral and diagonal bracing and/or blocking required in the top chord, web, and bottom chord planes.
 4. Affidavit signed and sealed by qualified registered Professional Engineer in the Commonwealth of Massachusetts stating that installed system will meet the load requirements and lateral bracing requirements as indicated on the contract documents.
- F. Prior to start of work submit copy of Fabricators certificate stating that conformance with the Steel Joist Institute (SJI) *Code of Standard Practice for Steel Joists and Joist Girders and Code of Standard Practice for Composite Steel Joists*. At the completion of the cold-formed steel truss fabrication and erection, the Contractor/Fabricator shall submit a certificate of compliance to the Engineer stating that all work was performed in accordance with the approved shop drawings and quality control plans.

1.5 QUALITY ASSURANCE

- A. Fabricator Qualifications: Fabrication shall be performed in a quality controlled manufacturing environment by a steel joist fabricator with experience fabricating steel joists equal in material, design, and scope to the joist required for this Project. Fabricator shall be certified by the Truss Plate Institute's Quality Assurance Program.

1. Installation of joist assembly shall be performed by an installer with experience installing steel joist equal in material, design and scope to the joists required for this Project.
- B. Welding Standards: Comply with applicable provisions of AWS D1.1 “Structural Welding Code--Steel” and AWS D1.3 “Structural Welding Code--Sheet Steel.”
 1. Qualify welding processes and welding operators in accordance with AWS “Standard Qualification Procedure.”

1.6 DELIVERY, STORAGE AND HANDLING

- A. Delivery, storage and handling as a minimum shall be in accordance with the SJI Technical Digest 9, “Handling and Erection of Steel Joists and Joist Girders.”
- B. Deliver materials in manufacturer’s unopened containers or bundles, fully identified by name, brand, type and grade. Exercise care to avoid damage during unloading, storing and erection. Each joist shall be tagged with a metal tag showing as a minimum the following information:
 1. Joist member number
 2. Joist member job number
 3. Joist erection mark consistent with the shop drawing
- C. Store joists on blocking, pallets, platforms or other supports off (free from contact with) the ground and in an upright position sufficiently braced to avoid damage from excessive bending. Timbers and/or blocks shall be placed at panel points and not between panel points.
- D. Protect joists and accessories from corrosion, deformation, damage and deterioration when stored at job site. Keep joists free of dirt and other foreign matter.
- E. Care shall be exercised at all times to avoid damage through careless handling during unloading, storing and erecting. Handling shall be done with the joist in the vertical orientation. Dropping of joist shall not be permitted.
- F. In steel framing, where Joist Girders are utilized at column lines, the Joist Girder shall be field-bolted at the column. Before hoisting cables are released and before an employee is allowed on the Joist Girder the following conditions shall be met:
 1. The seat at each end of the Joist Girder is attached in accordance with Section 1004.6.

When a bolted seat connection is used for erection purposes, as a minimum, the bolts shall be snug tightened. The snug tight condition is defined as the tightness that exists when all plies of a joint are in firm contact. This shall be attained by a few impacts of an impact wrench or the full effort of an employee using an ordinary spud wrench.
 2. Where stabilizer plates are required the Joist Girder bottom chord shall engage the stabilizer plate.
- G. During the construction period, the contractor shall provide means for the adequate distribution of loads so that the carrying capacity of any Joist Girder is not exceeded.
- H. Joist Girders shall not be used as anchorage points for a fall arrest system unless written direction to

do so is obtained from a “qualified person”, in accordance with SJI Technical Digest 9, “Handling and Erection of Steel Joists and Joist Girders.”

- I. Field welding shall not damage the Joist Girder. The total length of weld at any one cross-section on cold formed members whose yield strength has been attained by cold working and whose as-formed strength is used in the design, shall not exceed 50 percent of the overall developed width of the cold-formed section.

See Federal Register, Department of Labor, Occupational Safety and Health Administration (2001), 29 CFR Part 1926 Safety Standards for Steel Erection; Final Rule, §1926.757 Open Web Steel Joists - January 18, 2001, Washington, D.C. for definition of “qualified person”.

1.7 PROJECT CONDITIONS

- A. During construction, adequately distribute all loads applied to joists so as not to exceed the carrying capacity of any one joist.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Vulcraft Company, 5362 Railroad Street, Chemung, NY 14825
- B. Canam Steel Corporation, 4010 Clay Street, Point of Rocks, MD 21777
- C. New Millennium Building Systems, 100 Diuguids Lane, Salem VA 24153
- D. Or approved equal.

2.2 COMPONENTS

- A. Provide manufacturer’s standard steel joist members, bracing, bridging, blocking, reinforcements, fasteners and accessories with each type of steel framing required, as recommended by the manufacturer for the applications indicated and as needed to provide a complete steel joist assembly. Comply with the minimum size requirements for joist top and bottom chords and web members as indicated on the Contract Documents and as noted below.

2.3 MATERIALS

- A. Materials:
 - 1. The steel used in the manufacture of Joist Girders shall conform to one of the following ASTM Specifications In the Section 1.2 References, A. Referenced Standards or shall be of suitable quality ordered or produced to other than the listed specifications, provided that such material in the state used for final assembly and manufacture is weldable and is proved by tests performed by the producer or manufacturer to have the properties specified in Section 1002.2.
 - 2. Bracing, bridging and blocking members: Fabricate components of structural quality steel sheet per ASTM A653 with a minimum yield strength of 33,000 psi, and having a galvanized coating of G60 or better.

- B. Finish: Provide components with protective zinc coating complying with ASTM A653, minimum G60 coating.
- C. Fastenings:
 - 1. Framing components shall be fastened to each other by welding only.
 - 2. Electrodes for welding shall conform to AWS D1.1 when applicable and AWS D1.3 for welding base metals less than 1/8" thick for welding low carbon steel. Manufacturer shall furnish instructions with each container of electrodes giving recommended voltage, amperage, polarity of direct current, for all uses and positions for which electrode is suitable.
 - 3. Fastening to structural steel shall be done with bolts of size and spacing as required or by welding to resist the shear and pullout forces generated by the loads listed on the plans.

2.4 FABRICATION

- A. Factory fabricate cold-formed steel joists plumb, square, true to line, and with connections securely fastened, according to manufacturer's recommendations and the requirements of this Section.
 - 1. Fabricate joist assemblies in jig templates.
 - 2. Cut joist members by sawing or shearing or plasma cutting.
 - 3. Fasten cold-formed steel joist members by bolt or weld as indicated on the approved shop drawings and design calculations.
 - a. Locate mechanical fasteners and install according to steel joist component manufacturer's instructions with bolt penetrating joined members by not less than 3 exposed bolt threads.
- B. Care shall be taken during handling, delivery and erection. Brace, block, or reinforce joist as necessary to minimize member and connection stresses. Refer to SJI Technical Digest No. 9 (2008), *Handling and Erection of Steel Joists and Joist Girders*.
- C. Fabrication Tolerances: Fabricate joists to a maximum allowable tolerance variation from plumb, level, and true to line of 1/8 inch in 10 feet (1:960) and as follows:
 - 1. Spacing: Space individual joists no more than plus or minus 1/8 inch (3mm) from plan location. Cumulative error shall not exceed minimum fastening requirements of sheathing or other finishing materials.
 - 2. Squareness: Fabricate each cold-formed steel joist to a maximum out-of-square tolerance of 1/8 inch (3mm).

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine structure, substrates and installation conditions. Do not proceed with steel joist installation until unsatisfactory conditions have been corrected. Contractor and fabricator of joists shall certify that the substrate and installed conditions are acceptable for joist erection and that any discrepancies will not impact the installed joists to perform as intended in their final condition.

- B. Installation constitutes acceptance of existing conditions and responsibility for satisfactory performance.

3.2 INSTALLATION, GENERAL

A. General:

1. Erection of joists, including proper handling, safety precautions, installation bracing and other safeguards or procedures is the responsibility of the Contractor and Contractor's installer. Refer to SJI Technical Digest No. 9 (2008), *Handling and Erection of Steel Joists and Joist Girders*
 2. Exercise care and provide installation bracing required to prevent toppling of joists during erection. Provide for lateral bracing.
- B. Erect joists with plane of joist webs vertical and parallel to each other, accurately located at design spacing indicated. Space individual joists no more than plus or minus 1/8 inch (3 mm) from plan location. Cumulative error shall not exceed minimum fastening requirements of sheathing or other finishing materials.
 - C. Provide proper lifting equipment, including spreader bar, suited to sizes and types of joists required, applied at lift points recommended by joist fabricator. Exercise care to avoid damage to joist members during erection and to keep horizontal bending of the joists to a minimum.
 - D. Provide framing anchors as indicated or accepted on the engineering design drawing or erection drawings. Anchor joists securely at bearing points.
 - E. Install joists plumb, square, true to line, and with connections securely fastened, to a tolerance variation from plumb, level, and true to line of 1/8 inch in 10 feet (1:960) and according to manufacturer's recommendations.
 1. DO NOT cut joist members without prior approval of joist engineer.
 2. Fasten cold-formed steel joists by bolting or welding as indicated on approved erection drawings.
 - a. Comply with AWS requirements and procedures for welding, appearance and quality of welds, and methods used in correcting welding work.
 - b. Locate mechanical fasteners and install according to joist manufacturer's instructions with bolt penetrating joined members by not less than 3 exposed bolt threads.
 3. Install joists in one-piece lengths, unless splice connections are indicated.
 4. Provide installation bracing and leave in place until joists are permanently stabilized.

3.3 JOIST INSTALLATION

- A. Install joists per installation documents provided for in Section 1.4 (B).
- B. Space joists per sealed joist drawings.
- C. Do not alter, cut, or remove joist members or connections of joist members.
- D. Erect joists with plane of joist webs plumb and parallel to each other, align, and accurately

position at spacing indicated.

- E. Erect joists without damaging joist members or connections.
- F. Anchor joists securely at all points of support, per installation documents provided for in Section 1.4 (B).
- G. Install all continuous bridging and permanent joist bracing per installation documents provided for in Section 1.4 (B).
- H. Perform all joist-to-joist connections per installation documents provided for in Section 1.4 (B).

3.4 REPAIRS AND PROTECTION

- A. Galvanizing Repairs: Prepare and repair damaged galvanized coatings on fabricated and installed cold-formed steel framing with galvanizing repair paint according to ASTM A780 and the manufacturer's instructions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05310

STEEL DECK

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Roof deck
 - 2. Composite floor deck
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03300 – CAST-IN-PLACE CONCRETE for normal-weight and lightweight structural concrete fill over steel deck
 - 3. Section 05120 – STRUCTURAL STEEL FOR STATIONS AND BUILDINGS for shop- and field-welded shear connectors
 - 4. Section 05500 – MISCELLANEOUS METALS for framing deck openings with miscellaneous steel shapes
 - 5. Section 09900 – PAINTING for finish painting of exposed structural steel

1.2 SUBMITTALS

- A. Product Data: For each type of deck, accessory, and product indicated.
- B. Shop Drawings: Show layout and types of deck panels, anchorage details, reinforcing channels, pans, cut deck openings, special jointing, accessories, and attachments to other construction.
- C. Product Certificates: For each type of steel deck, signed by product manufacturer.
- D. Welder, tack welder and welding procedure qualifications.
- E. Qualifications of galvanizer and testing and inspection agencies.
- F. Field quality-control and fire resistance test and inspection reports.

1.3 QUALITY ASSURANCE

- A. Testing Agency Qualifications: Qualified according to ASTM E 329 for testing indicated.
- B. Welding: Qualify procedures and personnel according to AWS D1.3, "Structural Welding Code - Sheet Steel".

- C. Fire-Test-Response Characteristics: Where indicated, provide steel deck units identical to those tested for fire resistance per ASTM E 119 by a testing and inspecting agency acceptable to authorities having jurisdiction.
 - 1. Fire-Resistance Ratings: Indicated by design designations of applicable testing and inspecting agency.
 - 2. Steel deck units shall be identified with appropriate markings of applicable testing and inspecting agency.
- D. AISI Specifications: Comply with calculated structural characteristics of steel deck according to AISI's "North American Specification for the Design of Cold-Formed Steel Structural Members".
- E. Galvanizer Qualifications: Engage the services of a qualified galvanizer who has demonstrated a minimum of five years experience in the successful application of galvanized coatings specified in this Section in the facility where the galvanizing work is to be performed.
- F. FM Global Standards: Comply with Factory Mutual Global Standards (including FM deck span limitation). Steel deck shall be installed per its FM Approval listing and Data Sheet 1-29.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Protect steel deck from corrosion, deformation, and other damage during delivery, storage, and handling.
- B. Stack steel deck on platforms or pallets and slope to provide drainage. Protect with a waterproof covering and ventilate to avoid condensation.

1.5 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements shall be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Supply manufactured deck units in accordance with the applicable requirements of the Steel Deck Institute as indicated.

2.2 ROOF DECK

- A. Steel Roof Deck: Fabricate panels, without top-flange stiffening grooves, to comply with Steel Deck Institute (SDI) "SDI Specifications and Commentary for Steel Roof Deck," in SDI Publication No. 30, and with the following:
 - 1. Galvanized Steel Sheet: ASTM A 653/A 653M, Structural Steel (SS), Grade 40 with a minimum yield strength of 40 ksi. Galvanizing shall conform to coating class G90.

2. Deck Profile and Profile Depth: As required by design.
3. Design Uncoated-Steel Thickness: As required by design.
4. Span Condition: required by design.
5. Side Laps: Overlapped or interlocking seam at Contractor's option.
6. Finish: All steel roof deck shall be painted over galvanizing (refer to Section 09900 – PAINTING for finish painting of exposed structural steel).

2.3 COMPOSITE FLOOR DECK

- A. Composite Steel Floor Deck: Fabricate panels, with integrally embossed or raised pattern ribs and interlocking side laps, to comply with "SDI Specifications and Commentary for Composite Steel Floor Deck," in SDI Publication No. 30, with the minimum section properties indicated, and with the following:
1. Galvanized steel sheet: ASTM A 653/A 653M, Structural Steel (SS), Grade 40 minimum, Galvanizing shall conform to coating class G90.
 2. Profile Depth: As indicated.
 3. Design Uncoated-Steel Thickness: As required by design.
 4. Span Condition: As required by design.
 5. Finish: All composite steel deck shall be painted over galvanizing (refer to Section 09900 – PAINTING for finish painting of exposed structural steel).

2.4 ACCESSORIES

- A. General: Provide manufacturer's standard accessory materials for deck that comply with requirements indicated.
- B. Mechanical Fasteners: Corrosion-resistant, low-velocity, power-actuated or pneumatically driven carbon-steel fasteners; or self-drilling, self-threading screws.
- C. Side-Lap Fasteners: Corrosion-resistant, hexagonal washer head; self-drilling, carbon-steel screws, No. 10 minimum diameter.
- D. Flexible Closure Strips: Vulcanized, closed-cell, synthetic rubber.
- E. Miscellaneous Sheet Metal Deck Accessories: Steel sheet, minimum yield strength of 40,000 psi, not less than 0.0359-inch design uncoated thickness, of same material and finish as deck; of profile indicated or required for application.
- F. Pour Stops and Girder Fillers: Steel sheet, minimum yield strength of 40,000 psi, of same material and finish as deck, and of thickness and profile indicated.
- G. Column Closures, End Closures, Z-Closures, and Cover Plates: Steel sheet, of same material, finish, and thickness as deck, unless otherwise indicated.
- H. Weld Washers: Uncoated steel sheet, shaped to fit deck rib, 0.0747 inch thick, with factory-punched hole of 3/8-inch minimum diameter.
- I. Galvanizing Repair Paint: ASTM A 780.

- J. Headed Stud Shear Connectors: Through deck stud welded shear connectors comply with ASTM A108, Grade 1015 or 1020, cold finished carbon steel with dimensions complying with AISC Specifications.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine supporting frame and field conditions for compliance with requirements for installation tolerances and other conditions affecting performance.

3.2 INSTALLATION, GENERAL

- A. Install deck panels and accessories according to applicable specifications and commentary in SDI Publication No. 30, manufacturer's written instructions, and requirements in this Section.
- B. Install temporary shoring before placing deck panels, if required to meet deflection limitations.
- C. Locate deck bundles to prevent overloading of supporting members.
- D. Place deck panels on supporting frame and adjust to final position with ends accurately aligned and bearing on supporting frame before being permanently fastened. Do not stretch or contract side-lap interlocks.
- E. Place deck panels flat and square and fasten to supporting frame without warp or deflection.
- F. Cut and neatly fit deck panels and accessories around openings and other work projecting through or adjacent to deck.
- G. Provide additional reinforcement and closure pieces at openings as required for strength, continuity of deck, and support of other work.
- H. Comply with AWS requirements and procedures for manual shielded metal arc welding, appearance and quality of welds, and methods used for correcting welding work.
- I. Mechanical fasteners may be used in lieu of welding to fasten deck. Locate mechanical fasteners and install according to deck manufacturer's written instructions.

3.3 ROOF-DECK INSTALLATION

- A. Fasten roof-deck panels to steel supporting members by arc spot (puddle) welds of the surface diameter indicated or arc seam welds with an equal perimeter that is not less than 1-1/2 inches long, and as follows:
 - 1. Weld Diameter: 3/4 inch, nominal.
 - 2. Weld Spacing: Weld edge and interior ribs of deck units with a minimum of two welds per deck unit at each support. Space welds 12 inches apart in the field of roof and 6 inches apart in roof corners and perimeter.
- B. Side-Lap and Perimeter Edge Fastening: Fasten side laps and perimeter edges of panels between supports, at intervals not exceeding the lesser of 1/2 of the span or 18 inches and as follows:

1. Fasten with a minimum of 1-1/2-inch-long welds.
- C. End Bearing: Install deck ends over supporting frame with a minimum end bearing of 1-1/2 inches, with end joints as follows:
- D. Roof Sump Pans and Sump Plates: Install over openings provided in roof deck and weld flanges to top of deck. Space welds not more than 12 inches apart with at least one weld at each corner.
1. Install reinforcing channels or zees in ribs to span between supports and weld.
- E. Miscellaneous Roof-Deck Accessories: Install ridge and valley plates, finish strips, end closures, and reinforcing channels according to deck manufacturer's written instructions. Weld to substrate to provide a complete deck installation.
1. Weld cover plates at changes in direction of roof-deck panels, unless otherwise indicated.
- F. Flexible Closure Strips: Install flexible closure strips over partitions, walls, and where indicated. Install with adhesive according to manufacturer's written instructions to ensure complete closure.

3.4 FLOOR-DECK INSTALLATION

- A. Fasten floor-deck panels to steel supporting members by arc spot (puddle) welds of the surface diameter indicated and as follows:
1. Weld Diameter: 3/4 inch, nominal.
 2. Weld Spacing: Weld edge ribs of panels at each support. Space additional welds an average of 12 inches apart, but not more than 18 inches apart.
- B. Side-Lap and Perimeter Edge Fastening: Fasten side laps and perimeter edges of panels between supports, at intervals not exceeding the lesser of half of the span or 36 inches, and as follows:
1. Fasten with a minimum of 1-1/2-inch-long welds.
- C. End Bearing: Install deck ends over supporting frame with a minimum end bearing of 1-1/2 inches, with end joints as follows:
- D. Pour Stops and Girder Fillers: Weld steel sheet pour stops and girder fillers to supporting structure according to SDI recommendations, unless otherwise indicated.
- E. Floor-Deck Closures: Weld steel sheet column closures, cell closures, and Z-closures to deck, according to SDI recommendations, to provide tight-fitting closures at open ends of ribs and sides of deck.

3.5 SHEAR CONNECTORS

- A. Weld shear connectors to supporting through decking units in accordance with manufacturer's instructions. Do not weld shear connectors through two layers of decking units. Weld only on clean, dry deck foundations.
- B. Space and align shear connectors as shown on drawings.

3.6 REINFORCEMENT AT OPENINGS

- A. Provide additional metal reinforcement and closure pieces as required for strength, continuity of decking and support of other work shown on the Drawings.
- B. Reinforce decking around openings 6 inches to 12 inches in size by means of a flat galvanized steel sheet placed over the openings on the top of decking and fusion welded to the surface of the deck. Provide not less than 18 gauge steel sheet of same quality as the deck units, at least 12 inches wider and longer than the opening, unless otherwise indicated. Space welds at each corner and not more than 12 inches o.c. along each side.

3.7 FIELD QUALITY CONTROL

- A. Testing Agency: The Contractor shall engage a qualified independent testing and inspecting agency to perform field tests and inspections and prepare inspection and test reports.
- B. Field welds will be subject to visual inspection.
- C. Testing agency will report inspection results promptly and in writing to Contractor and Engineer.
- D. Remove and replace work that does not comply with specified requirements.
- E. Additional inspecting, at Contractor's expense, will be performed to determine compliance of corrected work with specified requirements.

3.8 REPAIRS AND PROTECTION

- A. Galvanizing Repairs: Prepare and repair damaged galvanized coatings on both surfaces of deck with galvanized repair paint according to ASTM A 780 and manufacturer's written instructions.
- B. Repair Painting: Wire brush and clean rust spots, welds, and abraded areas on both surfaces of prime-painted deck immediately after installation, and apply repair paint.
- C. Provide final protection and maintain conditions to ensure that steel deck is without damage or deterioration at time of Substantial Completion.

3.9 PLUG WELD QUALIFICATION PROCEDURE

- A. The erector shall establish the welding procedure for the plug weld of the steel decking for the particular gauge used, which is to be witnessed by the Contractors's Testing Agency.
- B. The welder should start by clamping a piece of the deck on the top flange of a scrap beam or plate of at least 1/2 in. in thickness with the edge of the sheet steel protruding over the edge of the beam by 3 in.
- C. Welding cables of length and size similar to that which will be used on the actual construction should be used for this test.
- D. The welder should make what he believes is a good 3/4 in. puddle weld through 20 gauge sheet steel to the beam with the crater filled and reasonable reinforcement above the sheet metal. The following are suggested settings for this equipment:
 - 1. Electrode - E-60.

2. Three welds per electrode.
 3. 19 second duration per weld.
 4. Burn-off rate of 4.7 seconds per inch.
- E. When the weld has cooled, strike the edge of the sheet steel with a sledge hammer so as to rotate the sheet around the puddle weld until the sheet or the weld breaks.
- F. Measure the diameter of the weld nugget remaining on the structural steel. If the weld is not satisfactory, adjust the amperage and repeat by making test welds and breaking them until the proper 3/4 in. nugget is obtained. Once the proper welds are consistently obtained (a minimum of 3 welds), have the welder make another test weld by first welding on a scrap plate to consume at least 6 in. of a new electrode and then immediately, while the electrode is still hot, make another puddle weld, test this weld and compare the results with the welds made previously and considered satisfactory.
- G. Using the same electrode, power supply unit, setting, and cable lengths established above, determine an average burn-off rate of 3 electrodes. Then make another puddle weld as a final check on the procedure.
- H. Each welder on the steel deck shall be qualified using the above procedure, prior to welding any steel roof or floor deck to the structure.

3.10 SHEAR CONNECTOR WELDING REQUIREMENTS

- A. All shear studs as indicated on the Drawings shall be based on the allowable shear capacities for shear studs in lightweight or normal weight stone concrete solid slabs as listed in the AISC.
- B. Shear connectors shall be applied in accordance with the manufacturer's printed instructions. Use only personnel and equipment authorized by the manufacturer.
- C. Inspection
1. Set-up: Two test welds shall be performed at the start of each shift or when plate thickness and/or stud type changes. Test welds, after cooling, should be bent by hammer 45 degrees from the vertical position without failure. Failure of either stud or weld will require appropriate adjustments in equipment and/or amperage and two additional test welds shall be initiated. The process of adjustment and testing shall continue until two consecutive stud welds pass the 45 degree test. Non-failure of either stud indicates that the weld set-up is satisfactory and production welding may be started.
 2. Production: After welding, the ceramic ferrule should be removed from each stud and the weld fillet visually inspected. A fillet of less than 360 degrees is cause for further inspection. Such studs, but, at a minimum, not less than four studs per frame, shall be tested for weld adequacy. After allowing the initial studs and plate to cool, test by bending to an angle of 15 degrees with the vertical by striking with a hammer. If failure occurs in the weld zone of any stud, the procedure shall be corrected and four more studs shall be welded to the member and tested. If any of the second four studs fail, additional welding shall be continued on separate material until four consecutive studs are tested and found to be satisfactory. Four consecutive studs shall then be welded to the member, tested, and found to be satisfactory before any more production studs are welded to the member. If failure occurs in the stud shank, an investigation shall be made to ascertain and correct the cause upon the review and approval of the project director, before further welds are made. All rejected studs shall be removed and replaced by studs which meet these requirements.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05411

LIGHT GAUGE METAL FRAMING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies exterior stud wall framing for metal cladding and interior finish and exterior and interior soffit framing, including cross-bridging, bracing, and anchoring to the building structure.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 06400 – CARPENTRY
 - 3. Section 07210 – BUILDING INSULATION
 - 4. Section 09260 – GYPSUM BOARD ASSEMBLIES

1.2 REFERENCES

- A. Comply with applicable requirements of the following standards. Where these standards conflict with other specified requirements, the most restrictive requirement shall govern.
 - 1. American Institute of Steel Construction (AISC)
 - a. Code: Code of Standard Practice for Steel Buildings and Bridges Specification for the Design, Fabrication and Erection of Structural Steel for Buildings
 - 2. American Iron and Steel Institute (AISI):
 - a. Specifications: Specifications for the Design of Light Gage Cold-Formed Steel Structural Members
 - 3. American Society for Testing and Materials (ASTM):
 - a. A 446: Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality
 - b. A 525: General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process
 - c. A 570: Hot-Rolled Carbon Steel Sheet and Strip, Structural Quality
 - d. A 780: Repair of Damaged Hot-Dip Galvanized Coatings
 - 4. Steel Structures Painting Council (SSPC):
 - a. Manual: Painting Manual - Volumes 1 and 2

1.3 SUBMITTALS

- A. Shop Drawings and Design Computations:
 - 1. Provide under the supervision of a Professional Engineer registered in the State of Massachusetts. Submit completed shop drawings and structural design computations, prepared under the supervision of a professional engineer licensed in the State of Massachusetts for work of this Section. Drawings and computations shall bear the engineer's professional seal and signature.
 - 2. The shop drawings shall show all pertinent details of construction, installation, and anchorage of the light gauge steel framing work. Show sizes, gages, types and spacings.
 - 3. The structural design computations shall provide a complete structural analysis of all typical and special conditions of construction, and shall certify conformance to the governing laws and building code.
- B. Samples: Submit representative samples of all light gauge steel framing components to Engineer for approval.
- C. Product Data: Submit manufacturer's product data for all components to be used in the construction and anchoring of the light gauge steel framing. Include specifications, installation instructions, and data substantiating that the materials comply with specified requirements.
- D. Do not order materials or begin fabrication or installation until Engineer approves submittals.

1.4 QUALITY ASSURANCE

- A. All work shall comply with the governing laws and building code and applicable provisions of the following standards:
 - 1. AISC Specification.
 - 2. AISC Code.
 - 3. AWS D1.3.
 - 4. AISI Specifications.
 - 5. SSPC Manual.
- B. Materials and workmanship shall be subject to inspection and testing in mill, shop, and/or field by the Engineer or a designated independent testing laboratory, approved by Authority and paid by the Contractor.

1.5 QUALIFICATIONS OF WELDERS

- A. Welders shall be qualified for the work by tests as prescribed in AWS D1.3 and shall submit certification of such qualifications to the Engineer before beginning work.

1.6 DESIGN

- A. The information shown on the Drawings is intended to establish the sizes of framing members, their points of attachment, the materials to which they are to be attached, and materials which are to be attached to them. Within these limitations it is the responsibility of the Contractor to design the framing to withstand the applied loading required by State of Massachusetts State Building Code

except where more strict requirements are specified herein. The maximum allowable deflection of the steel stud backup system under full lateral load shall be $L/720$. Structural properties of members shall be computed in accordance with AISI Specifications. No composite action is to be considered between the studs and any collateral wall material. Provide delegated design meeting the requirements of subsection 1.3.A.1.

1.7 INSPECTION, TESTING, AND QUALITY CONTROL

- A. Inspection and testing of welded connections will be performed by an independent testing laboratory, engaged and paid for by the Contractor. Welded connections shall be subjected to inspection and testing in shop and field by the Engineer and/or testing laboratory. Such inspection and testing shall not relieve Contractor of his responsibility to provide his own inspection, testing, and quality control as necessary to furnish workmanship in accordance with requirements of Contract Documents.
- B. Notify the Engineer and testing laboratory prior to start of any fabrication, erection, or other phase of work requiring welded connections so as to afford them a reasonable opportunity to inspect work.
- C. Facilitate inspection and testing by the testing laboratory. The Contractor shall, upon request and at his own expense, furnish the testing laboratory with:
 - 1. Complete sets of approved Shop Drawings and corrective work procedures at shop(s) and in field.
 - 2. Representative sample pieces of materials requested for testing.
- D. The testing laboratory will inspect welded connections for burned welds, adequate size and length of welds, and general appearance and integrity of welds as required by the Engineer.
- E. Do not remove any marks or tags applied by the testing laboratory identifying rejected work.
- F. Welded connections which have been rejected by the Engineer and/or testing laboratory in shop or field shall be corrected without delay and at no expense to the Authority.
- G. Acceptance of work in the shop shall not prevent final rejection of the work at the job site, even after erection, if the work is found to be defective in any way.

1.8 STORAGE AND HANDLING

- A. Protect metal framing units from weather and damage. Deliver to the fabrication site in manufacturer's unopened containers or bundles, fully identified with name, brand, type, and grade. Store off the ground in a dry ventilated space or protect with suitable waterproof coverings.

1.9 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, the engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between the engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 FRAMING COMPONENTS

- A. Studs shall be minimum 16 gauge or heavier punched C-studs of sizes required, except provide 12 gage studs at load bearing wall framing at locations indicated. Studs shall be manufactured from steel sheet meeting the requirements of ASTM A 1003, Structural Grade, Type H with a minimum yield strength of 50,000 psi. Studs shall be hot dip galvanized in accordance with the following:
1. Grade: ST50H (ST340H).
 2. Coating: G90 (Z275).
- B. Tracks shall be 18 gauge or heavier unpunched tracks manufactured of commercial quality steel sheet meeting the requirements of ASTM A 1003 with a minimum yield strength of 50,000 psi. Provide special shaped tracks with one 4 in. high leg where required. Tracks shall be hot dip galvanized in accordance with the following:
1. Grade: ST50H (ST340H).
 2. Coating: G90 (Z275).
- C. Bridging shall be manufacturer's recommended type as required to meet the design criteria set forth in Paragraph 1.6A of this Section.
- D. Attachment angles, closure angles, and other miscellaneous components shall be manufactured of commercial quality steel sheet meeting the requirements of ASTM A 446 with a minimum yield strength of 50,000 psi and shall be formed to profiles as required. All components shall be hot dip galvanized in accordance with ASTM A 525, G 60 Coating Designation.
- E. Single Deflection Track: Manufacturer's single, deep-leg, U-shaped steel track; unpunched, with un-stiffened flanges, of web depth to contain studs while allowing free vertical movement, with flanges designed to support horizontal and lateral loads, and as follows:
1. Minimum Uncoated-Steel Thickness: 0.0538 inch (1.37 mm).
 2. Flange Width: A minimum of 2 inches (50 mm), unless otherwise noted.
- F. Double Deflection Tracks: Manufacturer's double, deep-leg, U-shaped steel tracks, consisting of nested inner and outer tracks, un-punched, with un-stiffened flanges.
1. Outer Track: Of web depth to allow free vertical movement of inner track, with flanges designed to support horizontal and lateral loads, and as follows:
 - a. Minimum Uncoated-Steel Thickness: 0.0538 inch (1.37 mm).
 - b. Flange Width: A minimum of 3 inches (75 mm), unless otherwise noted.
 2. Inner Track: Of web depth indicated, and as follows:
 - a. Minimum Uncoated-Steel Thickness: 0.0538 inch (1.37 mm).
 - b. Flange Width: Minimum flange width of 4 inches (100 mm).
- G. Vertical Deflection Clips: Manufacturer's standard bypass or head clips, capable of accommodating upward and downward vertical displacement of primary structure.

2.2 FASTENERS

- A. Framing components shall be fastened to each other by welding only.
 - 1. Electrodes for welding shall conform to AWS requirements for welding low carbon steel. Manufacturer shall furnish instructions with each container of electrodes giving recommended voltage, amperage, polarity of direct current, for all uses and positions for which electrode is suitable.
- B. Fastening to structural steel shall be done with powder activated fasteners, self-drilling screws, or bolts of size and spacing as required to resist the shear and pullout forces generated by the loads listed in Paragraph 1.6A of this Section.
- C. Fastening of sheet metal sheathing to metal studs shall be by self-drilling screws, through holes pre-drilled in sheet metal.

2.3 ZINC RICH PAINT

- A. Zinc rich paint for touch up repair of galvanized coatings damaged during handling and erection and field welding shall conform to ASTM A 780 for zinc-rich primer.

PART 3 - EXECUTION

3.1 FABRICATION

- A. Light gauge steel framing shall be field assembled or shop assembled as part of an assembly including modular wall assemblies.
- B. Metal framing shall be fabricated in accordance with manufacturer's printed or written instructions, unless otherwise indicated.
- C. Framing components shall be straight and true prior to fabrication. Flattening or straightening of components shall be done by a process not injurious to materials.
- D. Framing components shall be cut squarely (or on an angle as with bracing) to fit squarely against abutting members.
- E. No splices will be allowed in studs. Stud tracks shall be continuous, with splices butt welded.
- F. Provide all angles, clips, and other miscellaneous pieces necessary to attach light gauge framing panels to building structure or to attach other materials to light gauge framing panels.
- G. Cut all openings in light gauge framing required for ducts, grilles, pipes, etc.
- H. Components shall be set square and in line and shall be held firmly in position until properly fastened.
- I. Panel components may be joined by shop welding at the discretion of the contractor.
 - 1. Welders shall be grade certified for the weight and type of materials and the type of equipment being used.
 - 2. Welding shall be done in accordance with AWS D1.3.
 - 3. All shop welded components shall be hot-dip galvanized after welding.

- J. Finished assemblies shall be free from twists, bends, or open joints with all members straight, square, and true to line.

3.2 ERECTION

- A. Light gauge steel framing shall be erected by approved methods using equipment of adequate capacity to safely perform the work.
- B. Any damage to other building materials caused by erection of light gauge steel framing shall be repaired or replaced as directed by the Engineer at no additional cost to the Authority.
- C. Work shall be erected plumb, level, and to dimensions and elevations indicated.
- D. Do not install any member or panel which is bent or racked. Such items shall be replaced.
- E. Provide nested studs and tracks at openings, as indicated on Drawings.
- F. Provide supplementary framing, blocking, and bracing as required where walls are indicated to support fixtures, equipment, and accessories.
- G. Isolate non-load-bearing steel framing from building structure to prevent transfer of vertical loads while providing lateral support.
 - 1. Install double deep-leg deflection tracks and anchor outer track to building structure.

3.3 FIELD TOUCH UP

- A. Touch up all field welds and abrasions of galvanized materials with zinc rich paint in accordance with ASTM A 780, Annex A2.
- B. Touch up work shall be complete prior to attachment of the work of any other sections to the light gauge steel framing.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05420

TEMPORARY STEEL UTILITY BRIDGES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. All labor, materials, and equipment necessary for the modification and removal of the Temporary Steel Utility Bridges.
 2. This item shall conform to the relevant provisions of MassDOT Standard Specifications (with Supplemental Specifications) Section 995 and the specific requirements stipulated for component parts of the items. Where no specific requirement is directed for a component part of an item, the Standard Specification shall apply, except for payment. For payment for components refer to Part 4 of this section. The work includes all materials and labor for the completed structures.
 3. The work under this item shall consist of the modifications of the Temporary Utility Bridge Structure for the Bridge No. S-17-013 (Broadway Bridge) and Bridge No. S-17-007 (Medford Street Bridge) as well as the removal of the Temporary Utility Bridge Structure for Bridge No. S-17-008 (School Street Bridge) in accordance with the Contract Documents, specifications, and in accordance with guidelines of the manufacturer's requirements..
 4. The work shall include detailed coordination with the operating railroads as required under Section 01571 – MAINTENANCE AND PROTECTION OF RAILROAD OPERATIONS.
- B. Related Work:
1. Section 02221 – DEMOLITION.
 2. Section 02650 – EXISTING SITE UTILITIES.
 3. Section 02800 – EXTERIOR CONDUIT SYSTEMS.
- C. For all Temporary Steel Utility Bridge requirements regarding General Information, Products, and Execution not referred to in this Specification, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 960.

1.2 DEFINITIONS

- A. See MassDOT Standard Specifications (with Supplemental Specifications) Section 995.

1.3 PERFORMANCE REQUIREMENTS

- A. See MassDOT Standard Specifications (with Supplemental Specifications) Section 960.

1.4 SUBMITTALS

- A. The Contractor shall submit shop drawings and calculations for the modification and removal of temporary steel utility support bridges. The procedures and all submissions shall be prepared by a Professional Engineer registered in the Commonwealth of Massachusetts. This engineer must be familiar with these specifications, those of the American Association of State Highway and Transportation Officials (AASHTO), the Work, and be experienced in this technical field. All submitted plans and calculations shall be stamped with the seal of a Registered Professional Engineer in the Commonwealth of Massachusetts. Note: Any acceptance or approvals of the above submissions by the Engineer shall not relieve the Contractor from responsibility for all design, construction, and demolition procedures and operations.
- B. The Contractor shall submit proposed erection and demolition procedures and methods to be used including crane capacity and location, equipment, tools, devices, etc. to the Engineer for utility bridge modifications and demolition. These submittals shall indicate a sequence of work such that at no time does an unsafe condition exist, and shall detail a specific coordination of activities with the operating railroads as part of the sequence of activities. The requirements for equipment and all procedures utilized shall be in conformance with the intent of Subsection 960.61D, Steel Erection of the Standard Specifications for Highways and Bridges. Erection procedures and any necessary calculations and drawings shall be stamped by a Professional Engineer registered in the Commonwealth of Massachusetts certifying that all structural members are suitably braced and supported throughout the erection process. Work under this item may not commence until the Engineer has given written approval.
- C. Removal Plan: Forty five days before any removal activity takes place, the Contractor shall submit to the Engineer a removal plan with a sequence of operations for review and approval. The sequence of operations shall be established such that at no time during the removal process does an unsafe condition exist. Submittals shall indicate in the sequence of operations the specific coordination activities that will be carried out with the operation railroads.

1.5 QUALITY ASSURANCE

- A. For Quality Assurance, refer to the MassDOT Standard Specifications (with Supplemental Specifications) including, but not limited to, Sections 901, 953, 960, and 995.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. See MassDOT Standard Specifications (with Supplemental Specifications) Section 960.

1.7 COORDINATION

- A. See MassDOT Standard Specifications (with Supplemental Specifications) Section 960.

1.8 UTILITIES

- A. Utility lines will be temporarily supported on temporary steel utility support bridges adjacent to the existing bridge structures. These lines will be permanently relocated to the proposed bridge structures. The removal of temporary steel utility support bridges once the utilities are in their permanent position shall be included in this Item.

PART 2 – PRODUCTS

2.1 MATERIALS

- A. Concrete
 - 1. The work to be done hereunder shall include construction of temporary reinforced concrete foundations for the utility bridges. The work shall conform to the relevant provisions of MassDOT Standard Specifications (with Supplemental Specifications) Section 901.
- B. Steel Reinforcement
 - 1. Steel reinforcement shall conform to the provisions of MassDOT Standard Specifications (with Supplemental Specifications) Section 901.
- C. Structural Steel
 - 1. Structural steel shall conform to the provisions of MassDOT Standard Specifications (with Supplemental Specifications) Section 960.

PART 3 – EXECUTION

3.1 ERECTION

- A. Assembly and Erection shall be performed in accordance with the approved Contractor assembly and erection submittals and the requirements of the Standard Specifications. The Contractor shall insure the stability of the structure during erection/modification. The Contractor shall not allow debris, tools, or incidental equipment of any kind to swing over areas where vehicular, train, or pedestrian traffic exists.
- B. Elements Left In Place
 - 1. No elements of the temporary bridges will be left in place, except when specific permission is given by the Engineer, or as described in contract documents. Any excavated areas shall be backfilled and any disturbed areas shall be restored to their original conditions. For any elements left in place, the Contractor shall provide as-built survey location information in a format approved by the Engineer.
- C. Disposal of Materials
 - 1. Materials will be removed from the project work sites for reuse by the Contractor or for legal disposal.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 05500

MISCELLANEOUS METALS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. All Work in this Section; refer to Schedule in Article 2.1 and as indicated on the Drawings.
 2. Furnish lintels, sleeves, anchors, inserts plates and similar miscellaneous metal items to concrete trade for installation.
- B. Related Work:
1. Section 03300 – CAST-IN-PLACE CONCRETE, for installing anchor bolts, threaded sleeves, and other items cast into concrete.
 2. Section 05120 – STRUCTURAL STEEL FOR STATIONS AND BUILDINGS
 3. Section 05122 – STRUCTURAL STEEL FOR RAIL STRUCTURES
 4. Section 05123 – STRUCTURAL STEEL FOR ROADWAY BRIDGES
 5. Section 05124 – BRIDGE RAILS
 6. Section 05126 – STRUCTURAL STEEL FOR RETAINING WALLS
 7. Section 05041 – HOT-DIP GALVANIZING.
 8. Section 05510 – PROCESS METAL WORK
 9. Section 05511 – METAL STAIRS
 10. Section 05700 – DECORATIVE METAL; for custom grilles, perforated sheet metals and other decorative formed metal.
 11. Section 05710 – METAL COLUMN COVERS
 12. Section 05720 – METAL RAILINGS AND GATES
 13. Section 05721 – STAINLESS STEEL RAILINGS AND GATES
 14. Section 07610 – SHEET METAL ROOFING
 15. Section 06610 – FIBERGLASS GRATINGS
 16. Section 09900 – PAINTING
 17. Section 10401 – METAL SIGN FRAMES

1.2 PERFORMANCE REQUIREMENTS

- A. Structural Performance of Ladders: Provide ladders capable of withstanding the effects of loads and stresses within limits and under conditions specified in ANSI A14.3.
- B. Structural Performance: of Gratings: Gratings shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated.

1. Floors: Uniform load of 250 lbf/sq. ft. (11.97 kN/sq. m) or concentrated load of 3000 lbf (13.40 kN), whichever produces the greater stress.
 2. Walkways and Elevated Platforms: Uniform load of 60 lbf/sq. ft. (2.87 kN/sq. m).
- C. Limit deflection to L/240 or 1/4 inch (6.4 mm), whichever is less. Thermal Movements: Provide exterior metal fabrications that allow for thermal movements resulting from the following maximum change (range) in ambient and surface temperatures by preventing buckling, opening of joints, overstressing of components, failure of connections, and other detrimental effects. Base engineering calculation on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.
1. Temperature Change (Range): 120 deg F ambient; 180 deg F material surfaces.
- D. The engineering for all miscellaneous metals shall be delegated design engineered and stamped by registered engineer in the state of Massachusetts to accommodate all related snow loads, wind loads and point loads as per Massachusetts State Building codes and FM Global requirement. Design layouts for miscellaneous metals are as shown on drawings.

1.3 SUBMITTALS

- A. Samples: One sample of each type of fabricated item, showing all types of component materials, surfaces, edges, joints, welds, and mechanical connections in selected finish and color.
- B. Shop Drawings: Show fabrication and installation details for metal fabrications.
1. Include plans, elevations, sections, and details of metal fabrications and their connections. Show anchorage and accessory items.
 2. Provide templates for anchors and bolts specified for installation under other Sections.
 3. For installed products indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer licensed in the Commonwealth of Massachusetts responsible for their preparation.
 4. Where fabrications are to receive sprayed-on fire resistive material, include statement that primer is compatible with fire resistive material proposed for use.
- C. Certificates: Welder and weld procedure qualifications.
- D. Qualifications for Inspection and Testing Agency and Contractor's professional engineer indicating registration in the Commonwealth of Massachusetts.
- E. Weld inspection reports.

1.4 QUALITY ASSURANCE

- A. Welding: Qualify procedures and personnel according to the following:
1. AWS D1.1, "Structural Welding Code--Steel".
 2. AWS D1.2, "Structural Welding Code--Aluminum".
 3. AWS D1.3, "Structural Welding Code--Sheet Steel".
 4. AWS D1.6, "Structural Welding Code--Stainless Steel".

- B. Metal Surfaces, General: Provide materials with smooth, flat surfaces, unless otherwise indicated. For metal fabrications exposed to view in the completed Work, provide materials without seam marks, roller marks, rolled trade names, or blemishes.
- C. HotDip Galvanizing: See Section 05041 – HOT DIP GALVANIZING.
- D. Pre-Installation Conference: Contractor shall schedule a meeting to be attended by Contractor, Engineer, fabricator, and galvanizer prior to starting Work. Agenda shall include the following: Project schedule, source for each fabrication, coordination between fabricator and galvanizer and adjacent Work, finish of surfaces, application of coatings, submittals, and approvals.
- E. Inspection: Except as otherwise specified, only visual inspection of welds, materials, workmanship, finished products, and installation is required. Inspector shall be independent third party with 10 years experience with work of similar size and scope. Welds to be inspected before covering of finishes. Shop welds shall be inspected for both methods and materials before galvanizing and painting. If welds are visible to public, architect shall also approve at that time.

1.5 PROJECT CONDITIONS

- A. Field Measurements: Verify actual locations of walls and other construction contiguous with metal fabrications by field measurements before fabrication and indicate measurements on Shop Drawings. Provide allowance for trimming and fitting at site.

1.6 COORDINATION

- A. Coordinate installation of anchorages for metal fabrications. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to Project site in time for installation.
- B. Coordinate installation of steel weld plates and angles for casting into concrete that are specified in this Section but required for work of another Section. Deliver such items to Project site in time for installation.

1.7 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 SCHEDULE

- A. Miscellaneous Metals include, but are not limited to, the following:

	Item	Material	Finish
1	Lintels	Steel	Galv/shop primer/shop paint
2	Interior ladders	Steel	Galv/shop prime/shop paint
3	Exterior ladders	Steel / Aluminum	Galv/shop prime/shop paint OR Anodized
4	Elevator pit ladders	Steel	Galv/shop prime/shop paint
5	Elevator door sill support angles	Steel	Galv/shop prime/shop paint
6	Elevator hoistway beams	Steel	Galv/shop prime/shop paint
7	Metal floor plate	Steel, non-slip surface	Galv/shop prime/shop paint
8	Shelf angles	Steel	Galv/shop prime/shop paint
9	Loose bearing and leveling plates	Steel	Galv/shop prime/shop paint
10	Weld plates and angles	Steel	Galv/shop prime/shop paint
11	Gratings and frames	Steel	Galv/shop prime/shop paint
12	Supports for canopies	Steel	Galv/shop prime/shop paint
13	Supports for coiling doors	Steel	Galv/shop prime/shop paint
14	Supports for countertops	Steel	Galv/shop prime/shop paint
15	Pipe Guards	Steel	Primer/Paint
16	Nosings	Steel	None
17	Wheel guards and column guards	Cast iron & Alum	None
18	Base Plates and anchor bolts	Steel	Galv/shop prime/shop paint
19		Steel	Galv/shop prime/shop paint
20	Gutters and rain leaders	Steel	Galv/shop prime/shop paint
21	Downspouts	Steel	Galv/shop prime/shop paint
22	Scuppers	Stainless Steel	No. 4
23	Sleeves	Stainless Steel	No. 4
24	Cornices and trim pieces	Stainless Steel	No. 4
25	Corner guards	Stainless Steel	No. 4
26	Ductbank enclosure system	Steel	Galv/shop prime/shop paint
27	Metal bar grilles	Steel	Galv/shop prime/shop paint
28	Metal bar gratings	Steel	Galv/shop prime/shop paint
29	Metal bar gratings W-09		
30	All other misc. metal items shown on the drawings as needed to complete the work	Steel	Galv/shop prime/shop paint

(All Galvanized metal shall be shop primed and shop Painted. Refer to 05041-Hot Dip Galvanizing)

2.2 FERROUS METALS

- A. Steel Plates, Shapes, and Bars: ASTM A 36/A 36M.
- B. Stainless-Steel Sheet, Strip, Plate, and Flat Bars: ASTM A 666, Type 316L
- C. Stainless-Steel Bars and Shapes: ASTM A 276, Type 316L
- D. Steel Bars for Bar Gratings: ASTM A 36/A 36M or steel strip, ASTM A 1011/A 1011M or ASTM A 1018/A 1018M.
- E. Wire Rod for Bar Grating Crossbars: ASTM A 510 (ASTM A 510M).
- F. Rolled-Steel Floor Plate: ASTM A 786/A 786M, rolled from plate complying with ASTM A 36/A 36M or ASTM A 283/A 283M, Grade C or D.

- G. Steel Tubing: ASTM A 500, cold-formed steel tubing.
- H. Steel Pipe: ASTM A 53/A 53M, standard weight (Schedule 40), unless another weight is indicated or required by structural loads.
- I. Slotted Channel Framing: Cold-formed metal channels with continuous slot complying with Metal Framing Manufacturers Association MFMA-3.
- J. Cast Iron: ASTM A 48/A 48M, Class 30, unless another class is indicated or required by structural loads.

2.3 NONFERROUS METALS

- A. Aluminum Plate and Sheet: ASTM B 209, Alloy 6061-T6.
- B. Aluminum Extrusions: ASTM B 221, Alloy 6063-T6.
- C. Aluminum-Alloy Rolled Tread Plate: ASTM B 632/B 632M, Alloy 6061-T6.
- D. Aluminum Castings: ASTM B 26/B 26M, Alloy 443.0-F.

2.4 FASTENERS

- A. General: Unless otherwise indicated, provide Type 316 stainless-steel fasteners for exterior use and zinc-plated fasteners with coating complying with ASTM B 633, Class Fe/Zn 5, within exterior walls. Provide stainless-steel fasteners for fastening aluminum. Select fasteners for type, grade, and class required.
- B. Anchor Bolts: ASTM F 1554, Grade 36. Provide hot-dip, zinc-coated anchor bolts where item being fastened is indicated to be galvanized.
- C. Cast-in-Place Anchors in Concrete: Anchors shall be capable of sustaining, without failure, a load equal to four times the load imposed. Tests shall be as determined by testing according to ASTM E 488, conducted by a qualified independent testing agency. Threaded or wedge type; galvanized ferrous castings, either ASTM A 47/A 47M malleable iron or ASTM A 27/A 27M cast steel. Provide bolts, washers, and shims as needed, hot-dip galvanized per ASTM A 153/A 153M.
- D. Expansion Anchors: Anchor bolt and sleeve assembly with capability to sustain, without failure, a load equal to six times the load imposed when installed in unit masonry and four times the load imposed when installed in concrete, as determined by testing according to ASTM E 488. Tests shall be conducted by a qualified independent testing agency.
 - 1. Material for Anchors in Interior Locations: Carbon-steel components zinc-plated to comply with ASTM B 633, Class Fe/Zn 5.
 - 2. Material for Anchors in Exterior Locations: Stainless-steel bolts complying with ASTM F 593 and nuts complying with ASTM F 594.

2.5 MISCELLANEOUS MATERIALS

- A. Welding Rods and Bare Electrodes: Select according to AWS specifications for metal alloy welded.
- B. Galvanizing Repair Paint: High-zinc-dust-content paint for regalvanizing welds in steel, complying

with The Society for Protective Coatings SSPC-Paint 20 or ASTM A780.

- C. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.
- D. Nonshrink, Nonmetallic Grout: Factory-packaged, nonstaining, noncorrosive, nongaseous grout complying with ASTM C 1107. Provide grout specifically recommended by manufacturer for interior and exterior applications.

2.6 FABRICATION, GENERAL

- A. Shop Assembly: Preassemble items in the shop to greatest extent possible. Disassemble units only as necessary for shipping and handling limitations. Use connections that maintain structural value of joined pieces. Clearly mark units for reassembly and coordinated installation.
- B. Cut, drill, and punch metals cleanly and accurately. Remove burrs and ease edges to a radius of approximately 1/32 inch, unless otherwise indicated. Remove sharp or rough areas on exposed surfaces.
- C. Form bent-metal corners to smallest radius possible without causing grain separation or otherwise impairing work.
- D. Form exposed work true to line and level with accurate angles and surfaces and straight edges.
- E. Weld corners and seams continuously to comply with the following:
 - 1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 - 2. Obtain fusion without undercut or overlap.
 - 3. Remove welding flux immediately.
 - 4. At exposed connections, finish exposed welds and surfaces smooth and blended so no roughness shows after finishing and contour of welded surface matches that of adjacent surface.
 - 5. Welds in water conveying vessels shall be performed by a welder qualified for producing waterproof welds and a minimum of five (5) years of experience in work requiring waterproof welds.
- F. Form exposed connections with hairline joints, flush and smooth, using concealed fasteners where possible. Where exposed fasteners are required, use Phillips flat-head (countersunk) screws or bolts, unless otherwise indicated. Locate joints where least conspicuous.
- G. Fabricate seams and other connections that will be exposed to weather in a manner to exclude water. Provide weep holes where water may accumulate.
- H. Cut, reinforce, drill, and tap metal fabrications as indicated to receive finish hardware, screws, and similar items.
- I. Provide for anchorage of type indicated; coordinate with supporting structure. Space anchoring devices to secure metal fabrications rigidly in place and to support indicated loads.
- J. Fabricate entire assembly before hot-dip galvanizing unless restricted by size of galvanizing tank to

sub-components.

2.7 MISCELLANEOUS FRAMING AND SUPPORTS

- A. General: Provide steel framing and supports not specified in other Sections as needed to complete the Work.
- B. Fabricate units from steel shapes, plates, and bars of welded construction, unless otherwise indicated. Fabricate to sizes, shapes, and profiles indicated and as necessary to receive adjacent construction retained by framing and supports. Cut, drill, and tap units to receive hardware, hangers, and similar items.
 - 1. Fabricate units from slotted channel framing where indicated.
 - 2. Furnish inserts if units are installed after concrete is placed.

2.8 LOOSE STEEL LINTELS

- A. Fabricate loose steel lintels from steel angles and shapes of size indicated for openings and recesses in masonry walls and partitions at locations indicated. Weld adjoining members together to form a single unit where indicated.
- B. Size loose lintels to provide bearing length at each side of openings equal to 1/12 of clear span but not less than 8 inches, unless otherwise indicated.

2.9 SHELF ANGLES

- A. Fabricate shelf angles from steel angles of sizes indicated and for attachment to structure. Provide horizontally slotted holes to receive 3/4-inch bolts, spaced not more than 6 inches from ends and 24 inches o.c., unless otherwise indicated.
 - 1. Provide mitered and welded units at corners.
 - 2. Provide open joints in shelf angles at expansion and control joints. Make open joint approximately 2 inches larger than expansion or control joint.
- B. For cavity walls, provide vertical channel brackets to support angles from backup masonry and concrete.
- C. Furnish wedge-type concrete inserts, complete with fasteners, to attach shelf angles to cast-in-place concrete.

2.10 LOOSE BEARING AND LEVELING PLATES

- A. Provide loose bearing and leveling plates for steel items bearing on masonry or concrete construction. Drill plates to receive anchor bolts and for grouting.

2.11 STEEL WELD PLATES AND ANGLES

- A. Provide steel weld plates and angles not specified in other Sections, for items supported from concrete construction as needed to complete the Work. Provide each unit with not less than two integrally welded steel strap anchors for embedding in concrete.

2.12 MISCELLANEOUS STEEL TRIM

- A. Unless otherwise indicated, fabricate units from steel shapes, plates, and bars of profiles shown with continuously welded joints and smooth exposed edges. Miter corners and use concealed field splices where possible.
- B. Provide cutouts, fittings, and anchorages as needed to coordinate assembly and installation with other work. Provide with integrally welded steel strap anchors for embedding in concrete or masonry construction.

2.13 PIPE GUARDS

- A. Fabricate pipe guards from 3/8-inch-thick by 12-inch wide steel plate, bent to fit flat against the wall or column at both ends and to fit around pipe with 2-inch clearance between pipe and pipe guard. Drill each end for two 3/4-inch anchor bolts.

2.14 METAL FLOOR PLATE

- A. Fabricate from rolled-steel patterned non-skid floor plate or rolled-aluminum-alloy non-skid tread of minimum 1/4 inch steel unless thicker units are required for anticipated loadings. Pattern to be selected by architect.
- B. Include steel angle stiffeners, and fixed and removable sections as indicated.
- C. Provide flush steel bar drop handles for lifting removable sections, one at each end of each section.

2.15 METAL BAR GRATINGS

- A. Welded Steel Grating:
 - 1. Bearing Bar Spacing: 11/16 inch (17 mm) o.c.
 - 2. Bearing Bar Depth: As required to comply with structural performance requirements.
 - 3. Bearing Bar Thickness: As required to comply with structural performance requirements.
 - 4. Crossbar Spacing: 2 inches (51 mm) o.c.
 - 5. Grating Mark: As indicated.
 - 6. Traffic Surface: Serrated.
 - 7. Steel Finish: Hot-dip galvanized with a coating weight of not less than 1.8 oz./sq. ft. (550 g/sq. m) of coated surface.
- B. Removable Grating Sections: Fabricate with banding bars attached by welding to entire perimeter of each section. Include anchors and fasteners of type indicated or, if not indicated, as recommended by manufacturer for attaching to supports.
- C. Fabricate cutouts in grating sections for penetrations indicated. Arrange cutouts to permit grating removal without disturbing items penetrating gratings.
 - 1. Edge-band openings in grating that interrupt four or more bearing bars with bars of same size and material as bearing bars.
- D. Do not notch bearing bars at supports to maintain elevation.

2.16 CABINETS FOR PANELS AND CONTROLS

- A. Cabinets for fire graphic annunciator panel, remote textual annunciator, telephone and additional controls for each station: Basis-of-design is Hoffman Pentair Equipment Protection or equal with the following characteristics:
 - 1. Material: 12 gauge Type 304 stainless steel with seams continuously welded and ground smooth.
 - 2. Hardware: Heavy-duty 3-point latching mechanism operated by Type 316L stainless steel padlocking handle on all doors. Ends of latch rods with rollers to facilitate door closing.
 - 3. Industry Standards: UL 508A Listed 508; Type 3R, 4, 4X, 12 as applicable.

2.17 WATER CONVEYING FABRICATIONS

- A. Scuppers, gutters, and other water conveying elements are intended to be complete, fully welded, water-tight vessels for conveying water from the collection point to the outlet connection. As such, these elements shall be fully welded at all seams, including any transition "tail pipe" outlet which connects to the plumbing system.
- B. After fabrication, each assembly shall be tested to determine that water is retained for 24 hours without detection of any leaks by temporarily sealing the outlet and filling the vessel with water. If any leaks are discovered during the test period, the vessel's seam or other defect shall be repair and the testing repeated until such time the unit passes the flood test.
- C. Comply with the National Association of Architectural metal Manufacturer's (NAAMM) "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
- D. Finish metal fabrications after assembly.

2.18 STEEL AND IRON FINISHES

- A. Preparation for Shop Priming: For steel elements concealed from public view and protected from the elements, prepare uncoated ferrous-metal surfaces to comply with minimum requirements indicated below for SSPC surface preparation specifications and environmental exposure conditions of installed metal fabrications:
 - 1. Exteriors (SSPC Zone 1B) and Items Indicated to Receive Zinc-Rich Urethane Primer: SSPC- SP 6/NACE No. 3, "Commercial Blast Cleaning " or SSPC-SP-16, "Brush-Off Blast Cleaning of Non-Ferrous Metals."
 - 2. Interiors (SSPC Zone 1A): SSPC-SP 7, "Brush Off Blast Cleaning".
 - 3. Apply shop primer to uncoated surfaces of metal fabrications, except those with galvanized finishes and those to be field welded, embedded in concrete or masonry, unless otherwise indicated. Extend priming of partially embedded members to a depth of 2 inches.
 - 4. Comply with SSPC-PA 1, "Paint Application Specification No. 1: Shop, Field, and Maintenance Painting of Steel", for shop painting.
 - 5. Comply with SSPC-PA 2, "Measurement of Dry Coating Thickness with magnetic Gages".

- B. Hot-Dip Galvanizing: For steel exposed to the elements but not in public view, weather or corrosive environments and other steel indicated to be galvanized, provide coating for iron and steel fabrications applied by the hot-dip process. Refer to Section 05041 "Hot-Dip Galvanizing."
- C. Hot-Dip Galvanizing and Factory-Applied Urethane Primer and Finish for Steel: Provide factory-applied architectural coating over primed hot-dip galvanized steel matching approved samples. For all steel elements exposed to public view, see Section 05041 "Hot Dip Galvanizing."

2.19 STAINLESS-STEEL FINISHES

- A. Remove tool and die marks and stretch lines or blend into finish.
- B. Grind and polish surfaces to produce uniform, directionally textured #4 polished finish, free of cross scratches. Run grain with long dimension of each piece. When polishing is completed, passivate and rinse surfaces. Remove embedded foreign matter and leave surfaces chemically clean. Remove all heat tint at welds and heat affected zones.
- C. Grind and polish surfaces to produce uniform, omni-directionally angel hair finish, free of cross scratches. Run grain with long dimension of each piece. When polishing is completed, passivate and rinse surfaces. Remove embedded foreign matter and leave surfaces chemically clean. Remove all heat tint at welds and heat affected zones.

2.20 ALUMINUM FINISHES

- A. Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.
- B. As-Fabricated Finish: AA-M10 (Mechanical Finish: as fabricated, unspecified).
- C. Class I, Clear Anodic Finish: AA-M12C22A41 (Mechanical Finish: nonspecular as fabricated; Chemical Finish: etched, medium matte; Anodic Coating: Architectural Class I, clear coating 0.018 mm or thicker) complying with AAMA 611.
- D. High-Performance Organic Finish: Three coat fluoropolymer finish complying with AAMA 2605 and containing not less than 70 percent PVDF resin by weight in both color coat and clear topcoat. Prepare, pretreat, and apply coating to exposed metal surfaces to comply with coating and resin manufacturers' written instructions.
 - 1. Color and Gloss: As selected by Architect from manufacturer's full range.

PART 3 - EXECUTION

3.1 INSTALLATION, GENERAL

- A. Cutting, Fitting, and Placement: Perform cutting, drilling, and fitting required for installing metal fabrications. Set metal fabrications accurately in location, alignment, and elevation; with edges and surfaces level, plumb, true, and free of rack; and measured from established lines and levels.
- B. Fit exposed connections accurately together to form hairline joints. Weld connections that are not to be left as exposed joints but cannot be shop welded because of shipping size limitations. Do not weld, cut, or abrade surfaces of exterior units that have been hot-dip galvanized after fabrication and are for bolted or screwed field connections.

- C. Field Welding: Comply with the following requirements:
 - 1. Field welding shall be performed only on elements not exposed to public view.
 - 2. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 - 3. Obtain fusion without undercut or overlap.
 - 4. Remove welding flux immediately.
 - 5. At exposed connections, finish exposed welds and surfaces smooth and blended so no roughness shows after finishing and contour of welded surface matches that of adjacent surface.
 - 6. At final build-out, no visible welds are permitted unless otherwise approved by architect prior to welding.
- D. Fastening to In-Place Construction: Provide anchorage devices and fasteners where metal fabrications are required to be fastened to in-place construction. Provide threaded fasteners for use with concrete and masonry inserts, toggle bolts, through bolts, lag bolts, wood screws, and other connectors.
- E. Provide temporary bracing or anchors in formwork for items that are to be built into concrete, masonry, or similar construction.
- F. Corrosion Protection: Coat concealed surfaces of metals that will come into contact with grout, concrete, masonry, wood, or dissimilar metals with a heavy coat of bituminous paint. Separate dissimilar materials with galvanic barriers to prevent galvanic corrosion.

3.2 INSTALLING MISCELLANEOUS FRAMING AND SUPPORTS

- A. General: Install framing and supports to comply with requirements of items being supported, including manufacturer's written instructions and requirements indicated on Shop Drawings.
- B. Support steel girders on solid grouted masonry, concrete, or steel pipe columns. Secure girders with anchor bolts embedded in grouted masonry or concrete or with bolts through top plates of pipe columns. Where grout space under bearing plates is indicated for girders supported on concrete or masonry, install as specified in this Section.
- C. Install pipe columns on concrete footings with grouted baseplates. Position and grout column baseplates as specified in this Section. Grout baseplates of columns supporting steel girders after girders are installed and leveled

3.3 INSTALLING BEARING AND LEVELING PLATES

- A. Clean concrete and masonry bearing surfaces of bond-reducing materials, and roughen to improve bond to surfaces. Clean bottom surface of plates.
- B. Set bearing and leveling plates on wedges, shims, or leveling nuts. After bearing members have been positioned and plumbed, tighten anchor bolts. Do not remove wedges or shims but, if protruding, cut off flush with edge of bearing plate before packing with grout.
 - 1. Use nonshrink grout, either metallic or nonmetallic, in concealed locations where not exposed to moisture; use nonshrink, nonmetallic grout in exposed locations, unless otherwise indicated.

2. Pack grout solidly between bearing surfaces and plates to ensure that no voids remain.

3.4 INSTALLING PIPE BOLLARDS

- A. Anchor bollards in place with concrete footings. Center and align bollards in holes 3 inches above bottom of excavation. Place concrete and vibrate or tamp for consolidation. Support and brace bollards in position until concrete has cured.
- B. Fill bollards solidly with concrete, mounding top surface to shed water.

3.5 INSTALLING PIPE GUARDS

- A. Provide pipe guards at exposed vertical pipes in parking garage where not protected by curbs or other barriers. Install by bolting to wall or column with expansion anchors. Provide four 3/4-inch bolts at each pipe guard. Mount pipe guards with top edge 26 inches above driving surface.

3.6 INSTALLING STAIR NOSINGS

- A. Center extruded aluminum nosing housing in concrete stair, as shown on the architectural drawings, but no more than 4" from the edge of stair. The nosing housing shall be cast into the concrete stair, whether it is precast or cast-in-place. Install a disposable wood insert for the construction phase.
- B. At the end of construction, install the extruded aluminum nosing insert with epoxy abrasive filler, colored yellow, with stainless steel flush bolts. Install in accordance with manufacturer's instructions.

3.7 ADJUSTING AND CLEANING

- A. Touchup Painting: Immediately after erection, clean field welds, bolted connections, and abraded areas. Paint uncoated and abraded areas with the same material as used for shop painting to comply with SSPC-PA 1 for touching up shop-painted surfaces.
 1. Apply by brush or spray to provide a minimum 2.0-mil dry film thickness.
- B. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair galvanizing to comply with ASTM A 780.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05510

PROCESS METAL WORK

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The Work of this section includes all labor, materials, tools and equipment required to furnish, fabricate, deliver and erect miscellaneous metal items as shown on the Contract Drawings, specified herein, and evidently required to complete the Work at the stormwater pumping stations.
- B. Construction of the Red Bridge and Washington Street pump stations (RPS and WSP, respectively) was initiated under IGMP-03, a previous GLX construction contract. That work was advanced to near completion of the basic structure. The pumps, variable frequency motor controllers, communication programmable logic controllers, pump station controls and metal work were not (or may not have been) completed, however certain items of that equipment were procured by the Owner and will be provided to the Design-Builder. The Design-Builder shall complete the construction of these two pump stations in full compliance with the specifications. The Design-Builder shall complete all work within this Section and all related work, to provide complete operable pump station facilities.
- C. The specifications relative to the WPS and RPS pump stations, including all operating parameters, control logic and other parameters, shall not be modified in any way.
- D. The Design-Builder may elect to adapt these specifications, if appropriate, to any pump station it may propose at Gilman Square.
- E. Certain work under this Section was, or may have been, completed by the previous GLX contractor. The Design-Builder shall be responsible for making its own assessments and evaluations as to the exact scope and limits of the completed and the uncompleted work. The Design-Builder shall complete any and all work associated with this Section and all Related Sections, including any and all uncompleted and/or partially completed work. The Design-Builder shall coordinate all related work, to provide complete and operable stormwater pumping facilities.
- F. The use of the word "Contractor" has been retained in this Section; however, it shall be interpreted to mean the Design-Builder for any and all work remaining to be completed. Likewise, the word "Engineer" has been retained; however, it shall be interpreted to mean the Owner for any and all work remaining to be completed.
- G. Items to be embedded in concrete or masonry shall be furnished under this section but installed under DIVISION 3- CONCRETE WORK or DIVISION 4 - MASONRY, as applicable.

1.2 SUBMITTALS

- A. Shop drawings shall be submitted for all items to be furnished in accordance Section 01300 - SUBMITTALS.
- B. Submittals required under this section include, but are not limited to, the following:
 - 1. Fabricator's quality control procedures.

2. Copies of welding certificates for welding procedures and personnel.
3. Drawings shall show finish, sizes of metal, method of assembly, hardware, and anchorage or connection with other Work.
4. Sample of proposed rail(s) indicating weld, splicing, and finish.
5. Sample of proposed stair nosing(s).

PART 2 - PRODUCTS

2.1 GENERAL PROVISIONS

- A. Standard products meeting the requirements of the Specifications may be accepted as the equivalent of those specified, if approved by the Engineer.
- B. Gauges for iron sheets and steel are U.S. Standard; for non-ferrous products is Brown & Sharpe; and for wire is United States Steel Wire.
- C. Steel W-shapes shall conform to ASTM A992 (50 ksi yield strength). Other steel shapes, and plates and bars shall conform to ASTM A36.
- D. Steel pipe columns shall conform to ASTM A53, Grade B.
- E. Structural tubing columns shall conform to ASTM A500, Grade B.
- F. Cast iron shall conform to ASTM A48.
- G. Aluminum items shall be fabricated from bars, plates, pipes, rolled and extruded shapes conforming to the following alloy designation unless otherwise indicated or specified.
 1. Standard structural shapes shall be rolled 6061-T6 conforming to ASTM B308.
 2. Rolled rod and bar shall be 6061-T6 conforming to ASTM B211.
 3. Sheets, Plates, Checkered Plates, etc., shall be 6061-T6 conforming to ASTM B209.
 4. Bolts shall be 2024-T4; Nuts shall be 6061-T6; and Washers shall be Alclad 2024-T4.
- H. Stainless Steel Items shall be Type 316 unless otherwise specified herein and/or as shown on the drawings.

2.2 SPECIFIC PRODUCTS

- A. Aluminum Railing
 1. Aluminum railing shall be formed of 1-1/2-inch round aluminum pipe in all welded construction. Posts shall be Schedule 80, alloy 6061-T6, and rails shall be Schedule 40, alloy 6063-T6. All welds shall be continuous at all intersections and ground smooth on all exposed areas. Radius corners shall be used and mitered corners are not acceptable. Where intersections occur, pieces shall be shaped and cut to fit, no distortion of the circular shape will be allowed. Railing shall be furnished in the largest practical sections with the locations and details of field connections indicated on the shop drawings. After fabrication, all railing shall be

cleaned, light circumferentially brushed, caustic etched and clear anodized in accordance with Aluminum Association M31C22A31 (0.4 mil minimum thickness).

2. Post spacing shall be a maximum of four (4) feet on centers measured along the rail. Posts shall be single, unspliced pipe length. Lower rails shall be single, unspliced length between posts. Top rails shall be continuous wherever possible and a single unspliced length shall be attached to a minimum of three (3) posts. Provide 4-inch high toe plate mechanically connected to posts, where shown on the Contract Drawings.
3. Unless otherwise noted, top rail on platforms and other level runs shall be forty-two (42) inches from upper surface of rail to floor, tank wall or other horizontal surface and intermediate rail shall be located approximately half way between top rail and floor. On stairs, railing shall be similar except that vertical height shall be thirty-six (36) inches from upper surface of top rail to surface of tread in line with face of riser at forward edge of tread.
4. Design and anchorage of all railing shall be such that the completed structure shall be capable of withstanding the loads prescribed by the Building Code of the Project state. Wall mounted railing shall be supported with cast brackets and fastened with stainless steel expansion or toggle bolts.
5. Removable railings shall be furnished at the locations shown on the Contract Drawings. Removable railings shall be mounted such that when the railing is removed, it is separated from the mounting bracket.

B. Guard Chain

1. Guard chain shall be provided at the locations shown on the Contract Drawings. Chain shall be stainless steel chain as made by Lawrence Metal Products, Inc., American Chain & Cable Co., Turner & Seymour Manufacturing Company or approved equal.
2. Chain shall be of 3/16-inch diameter stainless steel wire with welded links and thirteen (13) links per foot. Each chain shall be permanently fastened to one end, and provided with a swivel snap hook to attach to the other end. Lengths of guard chain shall be sufficient to span the openings with a minimal amount of slack.

C. Bar Rack

1. Shall be fabricated from 6061-T6 aluminum alloy stock in accordance with the details shown on the Contract Drawings. The Bar Rack shall be fabricated with 1/2" x 2" bars spaced 2" on center for a 1-1/2" clear opening. All materials shall be furnished under this section. However, those parts to be fastened to concrete shall be installed under Section 03300 - CAST-IN-PLACE CONCRETE. The rack shall be fabricated and installed under this section from field measurements after cast-in sections are in place.

D. Aluminum Gratings and Frames

1. One (1) type of aluminum grating and frames is required for the depths indicated on the Contract Drawings. Grating shall be I-bar swage locked with 1/4-inch bearing bars at 1-3/16-inches on center and cross bars at 4-inches on center. Grating shall conform to National Association of Architectural Metal Manufacturers (NAAMM) standards and be fabricated to NAAMM tolerances. Grating and frames shall be as manufactured by IKG Industries, Klemp Corporation, Ohio Gratings, Inc., or approved equal.

2. Supporting members shall be aluminum of the size and shape indicated. Grating shall be made of alloy 6063-T6 bearing bars and alloy 6063-T5 cross bars with mill finish. Straps, bolts, ties, and all necessary accessories shall be aluminum. Grating shall be fastened in accordance with the manufacturer's standard clips using micarta between the aluminum and dissimilar materials.
 3. Gratings, supports, and all other necessary accessories shall be installed under this section except that all anchor bolts and frames to be strapped into concrete shall be installed under Section 03300 - CAST-IN-PLACE CONCRETE. Portions of aluminum to be bedded in concrete shall be given a coating of heavy bodied bituminous paint. Grating sections shall be limited to a size that can be removed by one (1) man. At the ends of all sections and at openings, grating shall be banded with a 1/4-inch thick band of width equal to the full depth of grating, welded on. When span of grating changes direction, such as at channel intersections, provide suitable supporting members, as required.
- E. Expansion Bolts. Where concrete anchors or expansion bolts are noted on the Contract Drawings or as evidently required to secure members, Hilti Kwik-Bolt, Parabolt or RedHead Wedge Anchors shall be furnished and used. Stainless steel bolts shall be used when anchoring aluminum and in all submerged locations.
- F. Aluminum Ladder(s). Aluminum ladders shall be formed of alloy 6061-T6 with 2-1/2 inch by 3/8-inch flat bar side rails and alloy 6063-T5 aluminum 1-inch square corrugated, or other approved, skid proof rungs. Rails shall be bracketed to wall areas at no greater than 4 foot centers so that the center of the rungs are 7-inches from the face of wall areas. Provide aluminum ladders where shown on the Contract Drawing. Ladder and Safety Cages shall conform to all requirements of ANSI A14.3 and OSHA regulations.
- G. Hatch Covers.
1. Hatch covers shall be of the styles, types, and sizes shown on the Contract Drawings. All hatch covers shall be of the same manufacturer. Manufacturer shall guarantee proper operation and against defects in material or workmanship for a period of five (5) years. All hatch covers shall be of aluminum as manufactured by the Bilco Company, Halliday Products, Inc., or approved equal. Hatches show with in roadway shall be H20 rated.
 2. Type J and JD hatch covers shall be single leaf and double leaf, respectively, watertight, self-draining type. Door leaf shall be of 1/4-inch thick aluminum diamond pattern plates reinforced with aluminum stiffeners as required and capable of withstanding a live load of 300 pounds per square foot. Channel frame shall be 1/4-inch thick aluminum with anchor flange around the perimeter. Each door leaf shall be equipped with a minimum of two (2) hinges, with stainless steel pins, compression spring operators enclosed in telescopic tubes to afford easy operation, and an automatic hold-open arm with release handle. Snap locks with removable handle and safety chains shall be provided. A 1-1/2-inch drainage coupling shall be located in the front right corner of the channel frame. Hardware shall be stainless steel with factory mill finish and bituminous coating applied to exterior of frame.
 3. Type J and JD hatches that are not shown connected to a drainage system shall be provided with extensions to the drainage coupling to allow drainage to the area below.
 4. Hatch covers shall be installed in accordance with the recommendations of the manufacturer and as approved by the Engineer.
 5. All hatch covers shall be equipped with a factory installed fall protection grating system designed to meet OSHA 29 CFR 1910.23 and be equipped with a type 316 stainless steel hold-

open device to lock the grating panel(s) in the open position at a 90° position. The aluminum grating panel(s) shall be safety-yellow powder coat paint finish.

- H. Miscellaneous Structural Steel Items. All miscellaneous structural steel items, galvanized angles, relieving angles, plates, channels, headed concrete anchors, and all required fastenings shown on the Contract Drawings shall be fabricated as detailed and furnished under this section. They shall be installed under the applicable section of the Specifications. Miscellaneous items shall be galvanized as indicated and as specified herein.
- I. Steel frames for miscellaneous openings shall be fabricated from structural shapes and plates of the sizes indicated. Frames shall be accurately squared, mitered, butted, or coped as necessary and shall be fully welded, welded flush and ground smooth. Stops, where required, shall be plug-welded and ground smooth. Joints exposed to weather shall be seal welded.
- J. Anchor bolts shall be of the sizes indicated, threaded, headed and made of ASTM F1554 Grade 36 steel, galvanized except where stainless steel is noted. Plates shall be furnished as indicated. Stainless steel bolts shall be used in attaching aluminum, and in all submerged locations, and shall include stainless steel nuts and washers. In general, anchor bolts to be supplied under this section will only be for the other items supplied under this section that requires them.
- K. Steel Gratings and Frames shall be of the types and sizes as shown on the Contract Drawings. Gratings shall be welded steel grating with 4 inch deep by 1/4-inch bearing bars 13/16-inch on center and cross bars 4-inches on center. Gratings and frames shall be galvanized after fabrication.
- L. Manhole Rungs. Manhole rungs shall be Part No. F-14-2-D as manufactured by Washington Aluminum, or similar as made by Neenah Foundry, Flockhart Foundry or approved equal. Steps shall be of alloy 6061-T6 and portions to be embedded in concrete shall have a coat of zinc chromate paint.
- M. Aluminum Stairs. Aluminum stairs shall be fabricated and installed according to the details shown on the Contract Drawings and/or as approved by the Engineer. Aluminum shall be alloy 6061-T6. Stainless steel bolts, nuts, and washers shall be provided as required. Grating stairway treads shall be aluminum cross bar type with extruded aluminum corrugated nosing as made by the grating manufacturer. Treads shall have 3-inch by 3/16-inch carrier plates welded to the ends of the tread, punched for bolting to stringers. Bar size shall be as recommended by the manufacturer for the length of the tread as approved by the Engineer.
- N. Weirs and Baffles. Weirs and baffles shall be aluminum construction (including plates, angles, straps, bracing, channels) and shall be fabricated and installed in accordance with the details shown on the Contract Drawings and/or approved by the Engineer. Stainless steel bolts, nuts, washers shall be provided as required. Aluminum weirs and baffles shall be aluminum alloy 6061-T6. Welding shall be in accordance with the requirements as specified herein. The weir in the Red Bridge Storm water Pump Station shall have a minimum of one (1) foot of adjustment and shall be anchor bolted a maximum of two and half (2-1/2') feet apart for a minimum of 8; 1/2 inch stainless steel bolts.
- O. Lifting Eye Bolts
 1. Bolts shall be in accordance with the details shown on the Contract Drawings.
 2. Bolts shall be stainless steel.
- P. Ships Ladder and Landing

1. Stringers shall be fabricated from Alloy 6061-T6 mill finish.
 2. Grating for landing shall be I-bar swage locked with 3/16-inch bearing bars at 1-3/16-inches on center and cross bars at 4-inches on center. Grating shall conform to NAAMM standards and be fabricated to NAAMM tolerances. Grating shall be as manufactured by IKG Industries, Klemp Corporation, or Reliance Steel Products Co. or approved equal.
 3. Grating treads shall be aluminum with 6-inch tread and corrugated nosing.
 4. Railing shall be in conformance with the requirements specified herein.
 5. Entire assembly shall be capable of supporting a live load of 100 pounds per square foot.
- Q. Metal Lintels shall be of galvanized steel and of the size and shape shown on the Contract Drawings and shall have a minimum bearing on the masonry of 8-inches. Lintels shall be installed under Section 04800 - MASONRY.

PART 3 - EXECUTION

3.1 WORKMANSHIP

- A. Materials and workmanship shall be subject to the approval of the Engineer. Built-up Work shall be assembled in sections in the shop so far as practicable, accurately finished and the separate sections match marked for field erection.
- B. Where necessary, pertinent measurements shall be made before fabrication of the items so that work herein included shall properly fit the construction.

3.2 INSTALLATION

- A. Work shall be installed at the proper time and as rapidly as the condition of the supporting work will allow. Sections shall be installed in the most substantial manner, reinforced with steel shapes where necessary, using bolts, screws, or other necessary fastenings. All bolts projecting beyond the nuts, in exposed work shall be cut off close to the nuts and peened.
- B. All cutting, fitting, drilling and tapping required to install the Work and to make proper connections with adjoining supporting work, and all anchors, sockets, pipe sleeves, and fastening devices required for the proper and secure installation of the Work shall be included.

3.3 WELDING OF STEEL

- A. Welding shall be in accordance with the Structural Welding Code D1.1, current edition, as formulated by the American Welding Society. Welds shall be continuous along entire line of contact, except where plug or tack welding is noted. Exposed welds shall be ground smooth.

3.4 WELDING OF ALUMINUM

- A. Aluminum shall be fusion welded by the inert gas-shielded arc method. Where appearance is not a factor and anodizing is not required, alloy 4043 rods may be used. For appearance match, rods shall be of an alloy similar to the alloy being welded.

3.5 SHOP COATINGS

- A. Interior Service. All ferrous metal items which will be in interior service shall be cleaned in accordance with SSPC specification SP-6 for commercial blast cleaning and shall be prime painted compatible with the finish paints as specified in Section 09900 - PAINTING, for interior service. Stainless steel shall not be painted.
- B. Immersion Service. All ferrous metal items which will be in submerged service shall be cleaned in accordance with SSPC specification SP-10 for near white blast cleaning and shall be prime painted compatible with the finish paints as specified in Section 09900 - PAINTING, for immersion service.
- C. Dissimilar Material
 - 1. Where aluminum surfaces come in contact with metals other than stainless steel or other metals not compatible with aluminum, aluminum surfaces shall be kept from direct contact with such parts by painting the dissimilar metal with a coating of zinc chromate paint or use a good grade caulking or non-absorptive tape between dissimilar metals.
 - 2. Similarly, when aluminum comes in contact with concrete, masonry or by-products of these materials, the aluminum shall be given a coat of bituminous paint. Steel to be welded or encased in concrete shall not be painted.
- D. Galvanizing. All items specified as galvanized shall be coated by the hot-dip process in accordance with ASTM A123, ASTM A153, ASTM A386, and ASTM A525 as applicable in molten zinc, producing a continuous coating of uniform thickness of weight required by the referenced specifications.
 - 1. Coating shall be of best commercial quality, free from injurious defects, flux and uncoated spots, and of such quality as will endure without penetration of the coating not less than four (4) immersions in copper sulfate, conforming to ASTM A239.
 - 2. A stamp showing the name of the galvanizer, the weight of the coating and ASTM specification compliance shall identify galvanized items.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05511

METAL STAIRS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Preassembled steel stairs with concrete filled treads.
 2. Industrial-type stairs with steel grating treads.
 3. Steel tube railings attached to metal stairs.
 4. Steel tube handrails attached to walls adjacent to metal stairs.
- B. Related Work:
1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 2. Section 03300 - CAST-IN-PLACE CONCRETE for concrete fill for stair treads and platforms.
 3. Section 04800 - MASONRY for concrete masonry unit assemblies for anchoring landings and railings.
 4. Section 05041 – HOT-DIP GALVANIZING for galvanizing steel and iron products.
 5. Section 05500 – MISCELLANEOUS METALS for metal treads and nosings not installed in metal stairs.
 6. Section 09900 - PAINTING for field applied coatings.

1.2 PERFORMANCE REQUIREMENTS

- A. Structural Performance of Stairs: Provide metal stairs capable of withstanding the effects of gravity loads and the following loads and stresses within limits and under conditions indicated:
1. Uniform Load and Concentrated Loads: As required by IBC 780 CMR Mass State Building Code.
 2. Stair Framing: Capable of withstanding stresses resulting from railing loads in addition to loads specified above.
 3. Limit deflection of treads, platforms, and framing members to L/360 or 1/4 inch, whichever is less.
- B. Structural Performance of Railings: Provide railings capable of withstanding the effects of gravity loads and Code required loads and stresses within limits.

1.3 SUBMITTALS

- A. Product Data: For metal stairs and the following:
1. Site-filled metal-pan stair treads.
 2. Paint products.

- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Provide templates for anchors and bolts specified for installation under other Sections.
 - 2. For installed products indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer licensed in the Commonwealth of Massachusetts responsible for their preparation.
 - 3. Indicate required field welding.
- C. Welding certificates. Qualifications for welding procedures and welders.
- D. Weld inspection reports.
- E. Qualification Data: For professional engineer licensed in the Commonwealth of Massachusetts.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Fabricator of products.
- B. NAAMM Stair Standard: Comply with "Recommended Voluntary Minimum Standards for Fixed Metal Stairs" in NAAMM AMP 510, "Metal Stairs Manual", for class of stair designated, unless more stringent requirements are indicated.
 - 1. Preassembled Stairs: Commercial class.
- C. Welding: Qualify procedures and personnel according to the following:
 - 1. AWS D1.1, "Structural Welding Code--Steel".
 - 2. AWS D1.3, "Structural Welding Code--Sheet Steel".
- D. As a minimum, welds shall be visually inspected.

1.5 COORDINATION

- A. Coordinate installation of anchorages for metal stairs. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to Project site in time for installation.
- B. Coordinate locations of hanger rods and struts with other work so that they will not encroach on required stair width and will be within the fire-resistance-rated stair enclosure.

PART 2 - PRODUCTS

2.1 METALS, GENERAL

- A. Metal Surfaces, General: Provide materials with smooth, flat surfaces, unless otherwise indicated. For components exposed to view in the completed Work, provide materials without seam marks, roller marks, rolled trade names, or blemishes.

2.2 FERROUS METALS

- A. Steel Plates, Shapes, and Bars: ASTM A 36/A 36M.
- B. Steel Tubing: ASTM A 500 (cold formed) or ASTM A 513, Type 5 (mandrel drawn)
- C. Rolled-Steel Floor Plate: ASTM A 786/A 786M, rolled from plate complying with ASTM A 36/A 36M or ASTM A 283/A 283M, Grade C or D.
- D. Uncoated, Hot-Rolled Steel Sheet: ASTM A 1011/A 1011M commercial steel, Type B, or structural steel, Grade 30, unless another grade is required by design loads.

2.3 FASTENERS

- A. General: Provide hot-dipped galvanized fasteners for exterior use, and where built into exterior walls with coating complying with galvanizing requirements as specified in Section 05041 "Hot-Dipped Galvanizing." Select fasteners for type, grade, and class required.

2.4 MISCELLANEOUS MATERIALS

- A. Welding Rods and Bare Electrodes: Select according to AWS specifications for metal alloy welded.
- B. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.
- C. Concrete Materials and Properties: Comply with requirements in Section 03300 - CAST-IN-PLACE CONCRETE for normal-weight, air-entrained, ready-mix concrete with a minimum 28-day compressive strength of 4000 psi, unless otherwise indicated.

2.5 FABRICATION, GENERAL

- A. Provide complete stair assemblies, including metal framing, hangers, struts, railings, clips, brackets, bearing plates, and other components necessary to support and anchor stairs and platforms on supporting structure.
 - 1. Join components by welding, unless otherwise indicated.
 - 2. Use connections that maintain structural value of joined pieces.
- B. Preassembled Stairs: Assemble stairs in shop to greatest extent possible. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation.
 - 1. All field assembly shall be by fasteners; all welding is to be done in the shop.
- C. Cut, drill, and punch metals cleanly and accurately. Remove burrs and ease edges to a radius of approximately 1/32 inch, unless otherwise indicated. Remove sharp or rough areas on exposed surfaces.
- D. Form bent-metal corners to smallest radius possible without causing grain separation or otherwise impairing work.
- E. Form exposed work true to line and level with accurate angles and surfaces and straight edges.
- F. Weld connections to comply with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 2. Obtain fusion without undercut or overlap.
 3. Remove welding flux immediately.
 4. Weld exposed corners and seams continuously, unless otherwise indicated.
 5. At exposed connections, finish exposed welds and surfaces smooth and blended so no roughness shows after finishing and contour of welded surface matches that of adjacent surface.
- G. Form exposed connections with hairline joints, flush and smooth, using concealed fasteners where possible. Where exposed fasteners are required, use Phillips flat-head (countersunk) screws or bolts unless otherwise indicated. Locate joints where least conspicuous. Where exposed fasteners are visible in final configuration, screws will be tamperproof type.
- H. Fabricate joints that will be exposed to weather in a manner to exclude water. Provide weep holes where water may accumulate.
- I. To the greatest extent possible, Hot-Dip Galvanize after welding components and minimize post- galvanizing welding.

2.6 STEEL-FRAMED STAIRS

- A. Stair Framing:
1. Fabricate stringers of steel plates or channels. Provide closures for exposed ends of stringers.
 2. Construct platforms of steel plate or channel headers and miscellaneous framing members as needed to comply with performance requirements.
 3. Weld stringers to headers; weld framing members to stringers and headers.
 4. Where masonry walls support metal stairs, provide temporary supporting struts designed for erecting steel stair components before installing masonry.
- B. Metal-Pan Stairs: Form risers, subtread pans, and subplatforms to configurations shown from steel sheet of thickness needed to comply with performance requirements but not less than 0.0677 inch.
1. Steel Sheet: Uncoated hot-rolled steel sheet, unless otherwise indicated.
 2. Directly weld metal pans to stringers; locate welds on top of subtreads where they will be concealed by concrete fill. Do not weld risers to stringers.
 3. Shape metal pans to include nosing integral with riser.
 4. Provide subplatforms of configuration indicated or, if not indicated, the same as subtreads. Weld subplatforms to platform framing.
- C. Metal Bar-Grating Stairs: Form grate treads to comply with required loads as provided in Section 05500 "Miscellaneous Metals."

2.7 STEEL TUBE RAILINGS

- A. General: Fabricate railings to comply with requirements indicated for design, dimensions,

details, finish, and member sizes, including wall thickness of tube, post spacings, and anchorage, but not less than that needed to withstand indicated loads.

- B. Welded Connections: Fabricate railings with welded connections. Cope components at connections to provide close fit, or use fittings designed for this purpose. Weld all around at connections, including at fittings.
 - 1. All welded connections will be done in shop, before hot-dip galvanizing.
- C. Form changes in direction of railings as detailed on the Drawings.
- D. Form simple and compound curves by bending members in jigs to produce uniform curvature for each repetitive configuration required; maintain cross section of member throughout entire bend without buckling, twisting, cracking, or otherwise deforming exposed surfaces of components.
- E. Close exposed ends of railing members with welded semi-special ends, ground smooth.
- F. Provide wall returns at ends of wall-mounted handrails, unless otherwise indicated. Close ends of returns unless clearance between end of rail and wall is 1/4 inch or less.
- G. Brackets, Flanges, Fittings, and Anchors: Provide wall brackets, end closures, flanges, miscellaneous fittings, and anchors for interconnecting components and for attaching to other work. Furnish inserts and other anchorage devices for connecting to concrete or masonry work.
 - 1. Connect posts to stair framing with bolted fasteners, unless otherwise indicated.
 - 2. For galvanized railings, provide galvanized fittings, brackets, fasteners, sleeves, and other ferrous-metal components.
 - 3. For galvanized railings, provide galvanized painted ferrous-metal fittings, brackets, fasteners, and sleeves, except galvanize anchors embedded in exterior masonry and concrete construction.
- H. Fillers: Provide fillers made from steel plate, or other suitably crush-resistant material, where needed to transfer wall bracket loads through wall finishes to structural supports. Size fillers to suit wall finish thicknesses and to produce adequate bearing area to prevent bracket rotation and overstressing of substrate.

2.8 STAIR RAILINGS

- A. Comply with applicable requirements in Section 05720 "Metal Railings and Gates."

2.9 FINISHES

- A. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
- B. All metal stairs shall be hot-dip galvanized.
- C. Galvanizing: Hot-dip galvanize items as indicated to comply with applicable standard listed in Section 05041 "Hot-Dip Galvanizing."
- D. Galvanizing and Painting: Hot-dipped galvanized and painted items as indicated shall comply with applicable standards listed in Section 05041 "Hot-Dip Galvanizing."

PART 3 - EXECUTION

3.1 INSTALLATION, GENERAL

- A. Fastening to In-Place Construction: Provide anchorage devices and fasteners where necessary for securing metal stairs to in-place construction. Include threaded fasteners for concrete and masonry inserts, through-bolts, lag bolts, and other connectors.
- B. Cutting, Fitting, and Placement: Perform cutting, drilling, and fitting required for installing metal stairs. Set units accurately in location, alignment, and elevation, measured from established lines and levels and free of rack.
- C. Install metal stairs by bolting stair framing to steel structure or to weld plates cast into concrete, unless otherwise indicated.
- D. Provide temporary bracing or anchors in formwork for items that are to be built into concrete, masonry, or similar construction.
- E. Fit exposed connections accurately together to form hairline joints. Do not weld, cut, or abrade surfaces of exterior units that have been hot-dip galvanized after fabrication and are for bolted or screwed field connections.
- F. Place and finish concrete fill for treads and platforms to comply with Section 033000 - CAST-IN- PLACE CONCRETE.
 - 1. Install abrasive nosings with inlaid yellow epoxy strips mechanically fastened to concrete tread.Center nosings on tread width.

3.2 INSTALLING STEEL TUBE RAILINGS

- A. Adjust railing systems before anchoring to ensure matching alignment at abutting joints. Space posts at spacing indicated or, if not indicated, as required by design loads. Plumb posts in each direction. Secure posts and rail ends to building construction as follows:
 - 1. Anchor posts to steel stringers by bolted connections.
 - 2. Anchor handrail ends to concrete and masonry with steel inserts, embedded or otherwise fastened in wall, and inserted inside handrail end, and secured with bolt flush with handrail.
- B. Attach handrails to wall with wall brackets or to floor below. Provide bracket with 1-1/2-inch clearance from inside face of handrail and finished wall surface. Locate brackets as indicated or, if not indicated, at spacing required to support structural loads. Secure wall brackets to building construction as follows:
 - 1. Use type of bracket with flange tapped for concealed anchorage to threaded hanger bolt.
 - 2. For concrete and solid masonry anchorage, use drilled-in expansion shields and hanger or lag bolts.
 - 3. For hollow masonry anchorage, use toggle bolts.

3.3 ADJUSTING AND CLEANING

- A. Touchup Painting: Immediately after erection, clean field welds, bolted connections, and abraded areas of shop paint, and paint exposed areas with the same material as used for shop painting to comply with SSPC-PA 1 for touching up shop-painted surfaces.
 - 1. Apply by brush or spray to provide a minimum 2.0-mil dry film thickness.
- B. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair galvanizing to comply with ASTM A 780. For painted galvanized, prime and paint according to Section 09900 "Painting."

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05720

METAL RAILINGS AND GATES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies steel railings and steel fences and gates.
- B. Related Work:
 - 1. Section 05041 – HOT DIP GALVANIZING for requirements for hot-dip painting for steel.
 - 2. Section 05511 – METAL STAIRS for railings associated with metal stairs.
 - 3. Section 05721 - STAINLESS STEEL RAILINGS AND GATES for railings fabricated from stainless steel.

1.2 DEFINITIONS

- A. Railings: Guards, handrails, and similar devices used for protection of occupants at open-sided floor areas, pedestrian guidance and support, visual separation, or wall protection.

1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design railings, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated. Signed and sealed structural calculations and drawings shall be prepared under the supervision of a qualified professional engineer licensed in the Commonwealth of Massachusetts.
- B. General: In engineering railings to withstand structural loads indicated, determine allowable design working stresses of railing materials based on the following:
 - 1. Steel: 72 percent of minimum yield strength.
- C. Structural Performance: Railings shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated:
 - 1. Handrails and Top Rails of Guards:
 - a. Uniform load of 50 lbf/ ft. (0.73 kN/m) applied in any direction.
 - b. Concentrated load of 200 lbf (0.89 kN) applied in any direction.
 - c. Uniform and concentrated loads need not be assumed to act concurrently.
 - 2. Infill of Guards:
 - a. Concentrated load of 50 lbf (0.22 kN) applied horizontally on an area of 1 sq. ft. (0.093 sq. m).
 - b. Infill load and other loads need not be assumed to act concurrently.

- D. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes acting on exterior metal fabrications by preventing buckling, opening of joints, overstressing of components, failure of connections, and other detrimental effects.
 - 1. Temperature Change: 120 deg F (67 deg C), ambient; 180 deg F (100 deg C), material surfaces.
- E. Control of Corrosion: Prevent galvanic action and other forms of corrosion by insulating metals and other materials from direct contact with incompatible materials.

1.4 SUBMITTALS

- A. Product Data: For the following:
 - 1. Manufacturer's product lines of mechanically connected railings.
 - 2. Railing brackets.
 - 3. Grout, anchoring cement, and paint products.
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
- C. Samples for Verification: For each type of exposed assembly required. If shop welding is required, provide sample of joint and geometry with weld processed to be invisible with adjacent steel; including finishes and geometry.
 - 1. Sections of each distinctly different linear railing member, including handrails, top rails, bottom rails, mid-rails, posts, and balusters.
 - 2. Fittings and brackets.
- D. Qualification Data: For qualified professional engineer and testing agency.
- E. Welding certificates.
- F. Paint Compatibility Certificates: From manufacturers of topcoats applied over shop primers certifying that shop primers are compatible with topcoats.
- G. Product Test Reports: Based on evaluation of comprehensive tests performed by a qualified testing agency, according to ASTM E 894 and ASTM E 935.
- H. Engineering Submittal: For installed products indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1.5 QUALITY ASSURANCE

- A. Source Limitations: Obtain each type of railing from single source from single manufacturer.
- B. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- C. Welding Qualifications: Qualify procedures and personnel according to the following:
 - 1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."

2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."

- D. Inspection: Inspector shall be independent third party with 10 years experience with work of similar size and scope. Welds to be inspected before covering of finishes. Shop welds shall be inspected for both methods and materials before galvanizing and painting. If welds are visible to public, architect shall also approve at that time.

1.6 PROJECT CONDITIONS

- A. Field Measurements: Verify actual locations of walls and other construction contiguous with metal fabrications by field measurements before fabrication.

1.7 COORDINATION AND SCHEDULING

- A. Coordinate installation of anchorages for railings. Furnish setting drawings, templates, and directions for installing anchorages, including bolt holes in stringers or mounting brackets and bottom of rails, sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to Project site in time for installation.
- B. Schedule installation so wall attachments are made only to completed walls and floors. Do not support railings temporarily by any means that do not satisfy structural performance requirements.

PART 2 - PRODUCTS

2.1 METALS, GENERAL

- A. Metal Surfaces, General: Provide materials with smooth surfaces, without seam marks, roller marks, rolled trade names, stains, discolorations, or blemishes.
- B. Brackets, Flanges, and Anchors: Cast or formed metal of same type of material and finish as supported rails unless otherwise indicated.

2.2 STEEL AND IRON

- A. Tubing: ASTM A 500 (cold formed).
- B. Pipe: ASTM A 53/A 53M, Type F or Type S, Grade A, Standard Weight (Schedule 40), unless another grade and weight are required by structural loads.
- C. Plates, Shapes, and Bars: ASTM A 36/A 36M.
- D. Cast Iron: Either gray iron, ASTM A 48/A 48M, or malleable iron, ASTM A 47/A 47M, unless otherwise indicated.

2.3 FASTENERS

- A. General: Provide the following:
1. Hot-Dip Galvanized Painted Railings: Hot-dip zinc-coated painted steel fasteners complying with ASTM A 153/A 153M or ASTM F 2329 for zinc coating. Refer to spec 05041 – Hot-Dip Galvanizing.

2. Railings: Type 316 stainless-steel fasteners and brackets.
- B. Fasteners for Anchoring Railings to Other Construction: Select fasteners of type, grade, and class required to produce connections suitable for anchoring railings to other types of construction indicated and capable of withstanding design loads. Handrail brackets shall be type 316 stainless steel.
- C. Fasteners for Interconnecting Railing Components:
 1. Provide concealed fasteners for interconnecting railing components and for attaching them to other work, unless otherwise indicated.
- D. Post-Installed Anchors: Torque-controlled expansion anchors or chemical anchors capable of sustaining, without failure, a load equal to six times the load imposed when installed in unit masonry and four times the load imposed when installed in concrete, as determined by testing according to ASTM E 488, conducted by a qualified independent testing agency.
 1. Material for Interior Locations: Carbon-steel components zinc-plated to comply with ASTM B 633 or ASTM F 1941, Class Fe/Zn 5, unless otherwise indicated.
 2. Material for Exterior Locations: Alloy Group 2 (A4) stainless-steel bolts, ASTM F 593, and nuts, ASTM F 594.

2.4 MISCELLANEOUS MATERIALS

- A. Welding Rods and Bare Electrodes: Select according to AWS specifications for metal alloy welded.
- B. Galvanizing Repair Paint: Refer to specification 05401 – Hot- Dip Galvanizing.
- C. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.
- D. Nonshrink, Nonmetallic Grout: Factory-packaged, nonstaining, noncorrosive, nongaseous grout complying with ASTM C 1107. Provide grout specifically recommended by manufacturer for interior and exterior applications.
- E. Anchoring Cement: Factory-packaged, nonshrink, nonstaining, hydraulic-controlled expansion cement formulation for mixing with water at Project site to create pourable anchoring, patching, and grouting compound.
 1. Water-Resistant Product: At exterior locations provide formulation that is resistant to erosion from water exposure without needing protection by a sealer or waterproof coating and that is recommended by manufacturer for exterior use.

2.5 FABRICATION

- A. General: Fabricate railings and guards to comply with requirements indicated for design, dimensions, member sizes and spacing, details, finish, and anchorage, but not less than that required to support structural loads. Fabricate units in the maximum size suitable for hot-dip galvanizing. Do not weld any galvanized elements.
- B. Assemble railings and guard units in the shop to verify dimensions and fit. Disassemble units only as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation. All connections of galvanized elements shall be mechanical.

- C. Cut, drill, and punch metals cleanly and accurately. Remove burrs and ease edges to a radius of approximately 1/32 inch (1 mm) unless otherwise indicated. Remove sharp or rough areas on exposed surfaces.
- D. Form work true to line and level with accurate angles and surfaces.
- E. Fabricate connections that will be exposed to weather in a manner to exclude water. Provide weep holes where water may accumulate.
- F. Cut, reinforce, drill, and tap as indicated to receive finish hardware, screws, and similar items.
- G. Connections: Fabricate railings with welded connections unless otherwise indicated.
- H. Welded Connections: Cope components at connections to provide close fit, or use fittings designed for this purpose. Weld all around at connections, including at fittings.
 - 1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 - 2. Obtain fusion without undercut or overlap.
 - 3. Remove flux immediately.
 - 4. At exposed connections, finish exposed surfaces smooth and blended so no roughness shows after finishing and welded surface matches contours of adjoining surfaces.
- I. Form changes in direction as follows:
 - 1. By bending.
- J. Bend members in jigs to produce uniform curvature for each configuration required; maintain cross section of member throughout entire bend without buckling, twisting, cracking, or otherwise deforming exposed surfaces of components.
- K. Close exposed ends of railing members with stainless steel end fittings, welded and ground smooth and finished to match rest of the railings.
- L. Brackets, Flanges, Fittings, and Anchors: Provide wall brackets, flanges, miscellaneous fittings, and anchors to interconnect railing members to other work unless otherwise indicated.
- M. Provide inserts and other anchorage devices for connecting railings to concrete or masonry work. Fabricate anchorage devices capable of withstanding loads imposed by railings. Coordinate anchorage devices with supporting structure.
- N. For railing posts set in concrete, provide steel sleeves not less than 6 inches (150 mm) long with inside dimensions not less than 1/2 inch (13 mm) greater than outside dimensions of post, with metal plate forming bottom closure.
- O. Form gates of same size and shape as guards, with infill to match guards, or as indicated on the drawings. Fabricate gates and adjacent frames to accommodate specified hardware, including hinges, closers, locks, latches, panic hardware, and all associated conduit.

2.6 FINISHES, GENERAL

- A. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for

recommendations for applying and designating finishes.

- B. Protect mechanical finishes on exposed surfaces from damage by applying a strippable, temporary protective covering before shipping.

2.7 STEEL AND IRON FINISHES

- A. Galvanized Guards, Posts, Newels:

1. Hot-dip galvanize and paint all steel and iron guards, including hardware, after fabrication.
2. Comply with Section 05041 "Hot-Dip Galvanizing."
3. Fill vent and drain holes that will be exposed in the finished Work, unless indicated to remain as weep holes, by plugging with zinc solder and filing off smooth.

- B. For galvanized railings, provide hot-dip galvanized fittings, brackets, fasteners, sleeves, and other ferrous components.

PART 3 - EXECUTION

3.1 INSTALLATION, GENERAL

- A. Fit exposed connections together to form tight, hairline joints.
- B. Perform cutting, drilling, and fitting required for installing railings. Set railings accurately in location, alignment, and elevation; measured from established lines and levels and free of rack.
 1. Do not weld, cut, or abrade surfaces of railing components that have been coated or finished after fabrication and that are intended for field connection by mechanical or other means without further cutting or fitting.
 2. Set posts plumb within a tolerance of 1/16 inch in 3 feet (2 mm in 1 m).
 3. Align rails so variations from level for horizontal members and variations from parallel with rake of steps and ramps for sloping members do not exceed 1/4 inch in 12 feet (5 mm in 3 m).
- C. Adjust railings before anchoring to ensure matching alignment at abutting joints.
- D. Fastening to In-Place Construction: Use anchorage devices and fasteners where necessary for securing railings and for properly transferring loads to in-place construction.

3.2 RAILING CONNECTIONS

- A. Welded Connections: Use fully welded joints for permanently connecting railing components. Comply with requirements for welded connections in "Fabrication" Article 2.6.
- B. Expansion Joints: Install expansion joints at locations indicated but not farther apart than required to accommodate thermal movement. Provide slip-joint internal sleeve extending 2 inches (50 mm) beyond joint on either side, fasten internal sleeve securely to one side, and locate joint within 6 inches (150 mm) of post.

3.3 ANCHORING POSTS

- A. Use metal sleeves preset and anchored into concrete for installing posts. After posts have been inserted into sleeves, fill annular space between post and sleeve with nonshrink, nonmetallic grout or anchoring cement, mixed and placed to comply with anchoring material manufacturer's written instructions.
- B. Cover anchorage joint with flange of same metal as post, mechanically fastened to post after placing anchoring material.
- C. Anchor posts to metal surfaces with flanges, angle type, or floor type as required by conditions and detailed on drawings, bolted to posts and to metal supporting members.

3.4 ADJUSTING AND CLEANING

- A. Clean aluminum by washing thoroughly with clean water and soap and rinsing with clean water.
- B. Touchup Painting: Immediately after erection, clean field welds, bolted connections, and abraded areas of shop paint, and paint exposed areas with the same material as used for shop painting to comply with SSPC-PA 1 for touching up shop-painted surfaces.
 - 1. Apply by brush or spray to provide a minimum 2.0-mil (0.05-mm) dry film thickness.
- C. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair galvanizing to comply with ASTM A 780.

3.5 PROTECTION

- A. Protect finishes of railings from damage during construction period with temporary protective coverings approved by railing manufacturer. Remove protective coverings at time of Substantial Completion.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 05810

EXPANSION JOINT COVER ASSEMBLIES

PART 1 GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies expansion joint assemblies in stations and platforms.
- B. Related Work:
 - 1. Section 03300, CAST-IN-PLACE CONCRETE.
 - 2. Section 07911, EXPANSION JOINT ASSEMBLIES.
 - 3. Section 07920, JOINT SEALANTS; Sealants and backer-rods.

1.2 SUBMITTALS

- A. Product data in form of manufacturer's product specifications, installation instructions, and general recommendations for each type of expansion joint cover assembly indicated.
- B. Material test reports from qualified independent testing laboratory indicating and interpreting test results relative to compliance of fire-rated expansion joint assemblies with requirements indicated.
- C. Shop drawings showing full extent of expansion joint cover assemblies; include large-scale details indicating profiles of each type of expansion joint cover assembly, splice joints between sections, joinery with other types, special end conditions, anchorages, fasteners, and relationship to adjoining work and finishes. Include description of materials and finishes.
- D. Samples for each type of metal finish indicated on metal of same thickness and alloy to be used in work. Where normal color and texture variations are to be expected, include 2 or more units in each set of samples showing limits of such variations.
- E. Mill Certificates: Signed by manufacturers of stainless-steel certifying that products furnished comply with requirements.

1.3 QUALITY ASSURANCE

- A. Manufacturer's Instructions: In addition to requirements of these specifications, comply with manufacturer's instructions recommendations for all phases of work, including preparation of substrate, applying materials, and protection of installed units.
- B. Single-Source Responsibility: Obtain expansion joint cover assemblies from one source from a single manufacturer.
- C. Fire Performance Characteristics: Where indicated, provide expansion joint cover assemblies identical to those of assemblies whose fire resistance has been determined per ANSI/UL 263, NFPA 251, U.B.C. 43-1, or ASTM E 119 and E 814 including hose stream test at full-rated period by a nationally recognized testing and inspecting organization or by another means, as acceptable to authorities having jurisdiction.

1. Fire Rating: Not less than the rating of adjacent construction.

PART 2 PRODUCTS

2.1 EXPANSION JOINT COVER ASSEMBLIES

- A. Manufacturer: Subject to compliance with requirements, provide the following products:
 1. At interior floors, provide an expansion joint cover with a concrete-filled floating pan by Construction Specialties, Inc.; Pan Seismic Floor Covers or an approved equal.
 2. At exterior floors, provide an interlocking dual slide plate assembly expansion joints by MM Systems or an approved equal.
 3. At exterior plazas, provide Slip NOT stainless steel Grade 2 cover plate, fastened along fixed side, with ¼" Teflon pad below the opposite side.
 4. Wall and Ceiling: Provide expansion joints by Construction Specialties, Inc. or MM Systems or an approved equal; profiles as indicated on the Drawings.
 5. Preformed Expansion Joint Sealants: Provide EMSeal or equal; typical joint width 2 inches.

2.2 MATERIALS

- A. Metals:
 1. Aluminum: ASTM B 221, alloy 6063-T5 for extrusions; ASTM B 209, alloy 6061-T6, sheet and plate. Protect aluminum surfaces in contact with cementitious materials with zinc chromate primer or chromate conversion coating.
 2. Stainless Steel: ASTM A 666, Type 316, unless otherwise indicated, for plates, sheet, and strips.
- B. Nonmetal Products:
 1. Extruded Preformed Seals: Single or multilayered rubber extrusions as classified under ASTM D 2000, designed with or without continuous, longitudinal, internal baffles and formed to fit compatible frames, in color indicated, or, if not indicated, as selected by Engineer from manufacturer's standard colors.
 2. Elastomeric Sealant: Manufacturer's standard elastomeric sealant complying with ASTM C 920, Use T, factory-formed and -bonded to metal frames or anchor members; in color indicated, or, if not indicated, as selected by Engineer from manufacturer's standard colors.
 - a. Joints Up to 2 in. Wide: Withstand plus or minus 35 percent movement of the joint width without failure.
 - b. Joints 2 in. to 4 in. Wide: Withstand plus or minus 50 percent movement of the joint width without failure.
 3. Seismic Seals: Typically two single layered rubber extrusions, one interior and one exterior, as classified under ASTM D 2000, retained in a set of compatible frames, in color indicated, or, if not indicated, as selected by Engineer from manufacturer's standard colors.

4. Fire Barriers: Designed for indicated or required dynamic structural movement without material degradation or fatigue. Tested in maximum joint width condition with a field splice as a component of an expansion joint cover in accordance with ANSI/UL 263, NFPA 251, U.B.C. 43-1, or ASTM E 119 and E 814 including hose stream test at full-rated period by a nationally recognized testing and inspecting organization or by another means, as acceptable to authorities having jurisdiction.
 5. Concrete polished to match adjacent polished concrete floors in color of matrix species of aggregate, exposure of aggregate, coefficient of friction and gloss.
 6. Polyurethane joint filler, color to be selected by Architect.
- C. Preformed Foam Sealants: Provide manufacturer's standard preformed, precompressed, impregnated, open-cell foam sealant manufactured from high-density urethane foam impregnated with a nondrying, water-repellent agent; factory produced in precompressed sizes and in roll or stick form to fit joint widths indicated and to develop a watertight and airtight seal when compressed to the degree specified by manufacturer; and complying with the following:
1. Properties: Permanently elastic, mildew resistant, nonmigratory, nonstaining, and compatible with joint substrates and other joint sealants.
 2. Impregnating Agent: Manufacturer's standard.
 3. Density: Manufacturer's standard.
 4. Backing: Pressure-sensitive adhesive, factory applied to one side with protective wrapping.
- D. Accessories: Manufacturer's standard anchors, fasteners, set screws, spacers, flexible vapor seals and filler materials, drain tubes, adhesive, and other accessories compatible with material in contact, as indicated or required for complete installations.

2.3 FABRICATION

- A. General: Provide expansion joint cover assemblies of design, basic profile, materials, and operation indicated. Select units comparable to those indicated or required to accommodate joint size, variations in adjacent surfaces, and structural movement. Furnish units in longest practicable lengths to minimize number of end joints. Provide hairline mitered corners where joint changes directions or abuts other materials. Include closure materials and transition pieces, tee-joints, corners, curbs, cross-connections, and other accessories as required to provide continuous joint cover assemblies.
- B. Metal Joint Cover Assemblies: Provide continuous extruded metal frames of profile indicated with seating surface and raised floor rim to accommodate flooring and concealed bolt and steel anchors for embedment in concrete. Provide assemblies formed to receive cover plates of design indicated and to receive filler materials (if any) between raised rim of frame and edge of plate. Furnish depth and configuration to suit type of construction and to produce a continuous flush wearing surface with adjoining finish floor surface.
1. Floor-to-Floor Joints with Exposed Cover: Provide one frame on each side of joint, designed to support floor plate and filler.
 2. Flat Cover Plates: Provide cover plates of profile and wearing surface indicated. Extend flat plates to lap each side of joint. If required, furnish abrasive-resistant flexible filler for space between edge of cover plate and raised rim of frame.

- a. Fixed Cover Plates: Attach one side of the cover plate to a frame or finished wearing surface with other side resting on other frame or finished wearing surface in such a manner to allow free movement.
 - b. Floating Cover Plates: Secure the cover plate in or on top of frames in such a manner as to have free movement on both sides.
 3. Floor Cover Plate Wearing Surfaces: Provide cover plates with slip-resistant wearing surface.
 4. Provide manufacturer's continuous standard flexible vinyl moisture seals under covers at locations indicated.
 5. Floor-to-Wall Joints: Provide one frame on floor side of joint only. Provide wall side frame where required by manufacturer's design.
 6. Angle Cover Plates: Attach angle cover plates for floor-to-wall joints to wall with countersunk, flat-head exposed fasteners secured to drilled-in-place anchor shields, unless otherwise indicated, at spacing recommended by joint cover manufacturer.
 7. Wall, Ceiling, Roof, and Soffit Joint Cover Assemblies:
 - a. Fixed Metal Cover Plates: Provide on one side of the joint a concealed, continuously anchored frame fastened to wall, ceiling, or soffit only on one side of joint. Extend cover to lap each side of joint and to permit free movement on one side. Attach cover to frame with cover in close contact with adjacent finish surfaces.
 - b. Floating Metal Cover Plates: Secure the cover plate in or on top of frames in such a manner as to have free movement on both sides.
 - c. Flexible Filler: Secure the approved flexible filler between frames in such a manner that it will compress and expand.
 8. Spliced expansion joints: fabricate joints so that opposite interlocking plates shall overlap a minimum of 12 inches to preclude ant two opposite plates from butting.
- C. Joint Cover Assembly with Preformed Seal: Provide joint cover assemblies consisting of continuously anchored aluminum extrusions and continuous extruded preformed seals of profile indicated or required to suit types of installation conditions shown. Furnish extrusions designed for embedment in concrete and mechanical retention of lugs of field-installed extruded preformed seals. Vulcanize or heat-seal splices (if any) to ensure hermetic joint condition.
1. Include extruded aluminum cover plate with fluted surface; fasten plate to one side of joint and extend plate to lap each side of joint, with free movement and with cover in close contact with adjacent contact surfaces.
- D. Joint Cover Assembly with Elastomeric Sealant: Provide continuous cover joint assemblies consisting of elastomeric sealant factory-bonded to extruded aluminum frames of profile indicated or required to suit types of installation conditions shown. Provide frames for floor joints with means for embedment or anchorage to concrete without use of exposed fasteners and that will result in exposed surfaces of sealant and aluminum frames finishing flush with adjacent finished floor surface without exposing anchors.

2.4 METAL FINISHES

- A. General: Comply with NAAMM "Metal Finishes Manual" for finish designations and application recommendations, except as otherwise indicated. Apply finishes in factory after products are fabricated. Protect finishes on exposed surfaces with protective covering before shipment.
- B. Aluminum Finishes: Clear Anodized, AA-C22A41; medium matte etched finish with 0.7-mil minimum thick anodic coating.
- C. Stainless-Steel Finish Type 1:
 - 1. Remove tool and die marks and stretch lines or blend into finish.
 - 2. Grind and polish surfaces to produce uniform, directionally textured, polished finish indicated, free of cross scratches. Run grain with long dimension of each piece.
 - 3. Bright, Directional Polish: No. 4 finish.
 - 4. When polishing is completed, passivate and rinse surfaces. Remove embedded foreign matter and leave surfaces chemically clean.
- D. Stainless Steel Finish Type 2: SlipNOT, grit-free, stainless steel Grip Plate / Grip Grate Grade #2 – Medium, as manufactured by the W.S. Molnar Company (1-800-SlipNOT) manufactured to details indicated on the drawings. Stainless steel Grip Plate/ Grip Grate shall incorporate an anti-slip stainless steel surface covering 100% of substrate consisting of a random hatch matrix with a surface hardness between 55 – 63 on the Rockwell “C” scale and a surface to substrate bond strength of at least 4,000 psi. The non-slip surface shall have a minimum coefficient of friction of 0.8 and be listed as slip resistant by Underwriters Laboratories or approved equal.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Coordinate and furnish anchorages, setting drawings, templates, and instructions for installation of expansion joint cover assemblies to be embedded in concrete or have recesses formed into edges of concrete slab for later placement and grouting-in of frames.

3.2 INSTALLATION

- A. Fastening to In-Place Construction: Provide anchorage devices and fasteners where necessary for securing expansion joint cover assemblies to in-place construction, including threaded fasteners with drilled-in expansion shields for masonry and concrete where anchoring members are not embedded in concrete. Provide fasteners of metal, type, and size to suit type of construction indicated and provide for secure attachment of expansion joint cover assemblies.
- B. Cast-in-place concrete floors: Provide blocking in floor slabs to accommodate proper relationship between slabs and covers. Cutting, Fitting and Placement: Perform all cutting, drilling, and fitting required for installation of expansion joint covers. Install joint cover assemblies in true alignment and proper relationship to expansion joints and adjoining finished surfaces measured from established lines and levels. Allow adequate free movement for thermal expansion and contraction of metal to avoid buckling. Set floor covers at elevations to be flush with adjacent finished floor materials. Locate wall, ceiling, roof, and soffit covers in continuous contact with adjacent surfaces. Securely attach in place

with all required accessories. Locate anchors at interval recommended by manufacturer, but not less than 3 inches from each end and not more than 24 inches on centers.

- C. Joinery and Continuity: Maintain continuity of expansion joint cover assemblies with end joints held to a minimum and metal members aligned mechanically using splice joints. Cut and fit ends to produce joints that will accommodate thermal expansion and contraction of metal to avoid buckling of frames. Adhere flexible filler materials (if any) to frames with adhesive or pressure-sensitive tape as recommended by manufacturer. If exterior floor joint length exceeds longest manufactured length, stagger joints of side plate assembly.
- D. Installation of Extruded Preformed Seals: Install seals to comply with manufacturer's instructions and with minimum number of end joints. For straight sections provide preformed seals in continuous lengths. Vulcanize or heat-seal all field splice joints in preformed seal material to provide watertight joints using manufacturer's recommended procedures. Apply manufacturer's approved adhesive, epoxy, or lubricant-adhesive to both frame interfaces prior to installing preformed seal. Seal transitions in accordance with manufacturer's instructions.
- E. Installation of Preformed Foam Sealants: Install each length of sealant immediately after removing protective wrapping, taking care not to pull or stretch material, to produce seal continuity at ends, turns, and intersections of joints. For applications at low ambient temperatures where expansion of sealant requires acceleration to produce seal, apply heat to sealant to comply with sealant manufacturer's written instructions.
- F. Installation of Elastomeric Sealant Joint Assemblies: Seal all end joints within continuous runs and joints at transitions in accordance with manufacturer's directions to provide a watertight installation.
- G. Installation of Seismic Seals: Install interior seals in continuous lengths; vulcanize or heat-seal all field splice joints in interior seal material to provide watertight joints using manufacturer's recommended procedures. Install exterior flexible seal in standard lengths. Seal transitions and butt joints in accordance with manufacturer's instructions.
- H. Installation of Fire Barriers: Install fire barriers in accordance with federal, state, and local building codes using manufacturer's recommended procedures. Install transition and end joints to provide continuous fire resistance and in accordance with manufacturer's instructions.

3.3 CLEANING AND PROTECTION

- A. Do not remove strippable protective material until finish work in adjacent areas is complete. When protective material is removed, clean exposed metal surfaces to comply with manufacturer's instructions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 06100

CARPENTRY

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Wood furring, blocking, cants, and nailers.
 - 2. Plywood sheathing and backing panels.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS

1.2 DEFINITIONS

- A. Dimension Lumber: Lumber of 2 inches nominal or greater but less than 5 inches nominal in least dimension.
- B. Lumber grading agencies, and the abbreviations used to reference them include the following:
 - 1. ALSC: American Lumber Standard Committee
 - 2. AWWPA: American Wood-Preservers Association
 - 3. DHI: Door and Hardware Institute
 - 4. NELMA: Northeastern Lumber Manufacturers Association
 - 5. NHLA: National Hardware Lumber Association
 - 6. NLGA: National Lumber Grades Authority

1.3 SUBMITTALS

- A. Submit for each type of process and factory-fabricated product. Indicate component materials and dimensions, and include construction and application details.
 - 1. Include data for wood preservative treatment from chemical treatment manufacturer and certification by treating plant that treated materials comply with requirements. Indicate type of preservative used and net amount of preservative retained.
 - 2. Include data for fire retardant treatment from chemical treatment manufacturer and certification
by treating plant that treated materials comply with requirements. Include physical properties of treated materials based on testing by a qualified independent testing agency.
 - 3. For fire retardant treatments specified to be High-Temperature (HT) type, include physical properties of treated lumber both before and after exposure to elevated temperatures, based on testing by a qualified independent testing agency according to ASTM D 5664.
 - 4. For products receiving a waterborne treatment, include statement that moisture content of treated materials was reduced to levels specified before shipment to project site.

5. Include copies of warranties from chemical treatment manufacturers for each type of treatment.
- B. For the following products, provide compliance documentation with applicable building and state codes:
1. Preservative treated wood.
 2. Fire- retardant-treated wood.
 3. Power driven fasteners.
 4. Powder-actuated fasteners.
 5. Expansion anchors.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Stack lumber flat with spacers between each bundle to provide air circulation. Provide for air circulation around stacks and under coverings.
- B. Deliver interior wood materials that are to be exposed to view only after building is enclosed and weatherproof, wet work other than painting is dry, and HVAC system is operating and maintaining temperature and humidity at occupancy levels.

1.5 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 WOOD PRODUCTS

- A. Lumber: Provide lumber graded by DOC PS 20 standards and applicable rules of grading agencies. If no grading agency is indicated, provide lumber that complies with the applicable rules of any rules- writing agency certified by the ALSC Board of Review to inspect and grade lumber under the rules indicated.
1. Factory mark each piece of lumber with grade stamp of grading agency.
 2. For exposed lumber indicated to receive a stained or natural finish, mark grade stamp on end or back of each piece.
 3. Where nominal sizes are indicated, provide actual sizes required by DOC PS 20 for moisture content specified. Where actual sizes are indicated, produce minimum dressed sizes for dry lumber.
 4. Provide dressed lumber sanded four sides (S4S) unless otherwise indicated.

2.2 WOOD PANEL PRODUCTS

- A. Plywood: Complying with the requirements of DOC PS 1.

- B. Thickness: As needed to comply with requirements specified, but not less than thickness indicated.
- C. Factory mark panels to indicate compliance with applicable standard.

2.3 WOOD PRESERVATIVE-TREATED MATERIALS

- A. Preservative Treatment by Pressure Process complying in requirements of AWPA C2.
 - 1. Preservative Chemicals: Acceptable to the Authority and containing no arsenic or chromium.
- B. Kiln-dry lumber after treatment to maximum moisture content of 19 percent.
- C. Mark lumber with treatment quality mark of an inspection agency approved by the ALSC Board of Review.
- D. Application: Treat miscellaneous carpentry, including the following:
 - 1. Wood blocking, furring, and similar concealed members in contact with masonry, concrete or metal deck.
 - 2. Wood furring attached directly to the interior of below-grade exterior masonry or concrete walls.

2.4 FIRE- RETARDANT-TREATED MATERIALS.

- A. General: Comply with performance requirements in AWPA C20 (Lumber) and AWPA C27 (Plywood).
 - 1. Use treatment that does not promote corrosion of metal fasteners.
 - 2. Use exterior type for exterior locations and where indicated.
 - 3. Use Interior Type A, unless otherwise indicated.
- B. Identify fire-retardant-treated wood with appropriate classification marking of Underwriters Laboratory.
 - 1. All lumber and plywood to have a flame spread rating of 25 or less when tested in accordance with ASTM E-84, Standard Test Method for Surface Burning Characteristics of Building Materials
- C. Application: Treat concealed miscellaneous carpentry, including but not limited to the following:
 - 1. Concealed blocking at partition framing and window openings.
 - 2. Plywood backing panels.
 - 3. All blocking at roofing.

2.5 MISCELLANEOUS LUMBER

- A. General: Provide miscellaneous lumber indicated and lumber for support or attachment of other construction, including the following:
 - 1. Blocking
 - 2. Nailers

3. Cants
 4. Furring
- B. For items of dimension lumber size, provide Construction or No.2 grade lumber with 15 percent maximum moisture content and any of the following species:
 1. Hem-fir (north); NLGA
 2. Spruce-Pine-fir;NLGA
 - C. For concealed boards, provide lumber with 15 percent maximum moisture content and any of the following species and grades:
 1. Hem-fir or hem fir (North), Construction or 2 Common grade;NLGA.
 2. Spruce-pine-fir (south) or spruce-pine fir, Construction or 2 common grade; NELMA or NLGA
 - D. For blocking not used for attachment of other construction, utility, stud, or No.3 grade lumber of any species may be used provided that it is cut and selected to eliminate defects that will interfere with the attachment and purpose.
 - E. For blocking and nailers used for attachment of other construction, select and cut lumber to eliminate knots and other defects that will interfere with attachment of other work.
 - F. For furring strips for installing plywood or hardboard paneling, select boards with no knots capable of producing bent-over nails and damage to paneling.
 - G. Application: Provide kiln dried lumber in the following locations:
 1. Wood cants, nailers, curbs, equipment support bases, blocking, stripping, and similar members in connection with roofing, flashing, vapor barriers, and waterproofing.

2.6 PLYWOOD SHEATHING

- A. Plywood Sheathing: APA B-B Marine Grade. Fire rated as required by code.
- B. Species: Douglas-fir or Western Larch.
- C. Thickness: 5/8 inch thickness.

2.7 PLYWOOD BACKING PANELS

- A. Electrical Equipment Backing Panels: DOC PS1, Exposure 1, C-D Plugged, fire-retardant treated, in thickness indicated, or if not indicated, not less than 3/4 inch nominal thickness.

2.8 FASTENERS

- A. General: Provide fasteners of size and type indicated that comply with requirements specified in this Article for material and manufacture.
 1. Where carpentry is exposed to weather, in ground contact, pressure-preservative treated, or in area of high relative humidity, provide fasteners of Type 316 stainless steel.
- B. Nails, Brads, and Staples: Complying with the requirements of ASTM F 1667.

1. All nails and brads shall be coated with hot-dip galvanize.
- C. Power-Driven Fasteners: Complying with NES NER-272.
- D. Wood Screws: Complying with the requirements of ASME B18 .6.1.
1. All wood screws shall be hot-dip galvanized.
- E. Screws for Fastening to Cold-Formed Metal Framing: Complying with the requirements ASTM C954, except with wafer heads and reamer wings, length as recommended by screw manufacturer for material be fastened.
1. All screws for fastening to cold-formed metal framing shall be type 316 stainless steel or hot- dip galvanized.
- F. Lag Bolts: Complying with ASEM B18. 2.1.
1. All lag bolts shall be hot-dip galvanized.
- G. Bolts: Steel bolts complying with ASTM A 307, Grade A; with ASTM A 563 hex nuts and, where indicated flat washers.
1. All steel bolts shall be hot-dip galvanized.
- H. Expansion Anchors: Anchor bolt and sleeve assembly of material indicated below with capability to sustain, without failure, a load equal to 6 times the load imposed when installed in unit masonry assemblies and equal to 4 times the load imposed when installed in concrete as determined by testing per ASTM E 488 conducted by a qualified independent testing and inspecting agency.
1. Material: Stainless steel with bolts and nuts complying with ASTM F593 and ASTM F 594 Alloy group 1 or 2.

PART 3 - EXECUTION

3.1 GENERAL

- A. Set carpentry to required levels and lines with members plumb, true to line, cut, and fitted. Fit carpentry to other construction; scribe and cope as needed for accurate fit. Locate furring, nailers, blocking and similar supports to comply with requirements for attaching other construction.
- B. Provide blocking and framing as indicated and as required to support facing materials, fixtures, specialty items and trim.
- C. Provide fire blocking in furred spaces, stud spaces, and other concealed cavities as indicated and as follows:
 1. Fire block furred spaces of walls, at each floor level, at ceiling, and not more than 96 inches on- center (o.c.) with solid wood blocking or noncombustible materials accurately fitted to close furred spaces.
 2. Fire block concealed spaces behind combustible cornices and exterior trim at not more than 20 feet o.c.

- D. Sort and select lumber so that natural characteristics will not interfere with installation or fastening other materials to lumber. Do not use materials with defects that interfere with function of member or pieces that are too small to use with minimum number of joints or optimum joint arrangement.
- E. Comply with AWWA M4 for applying field treatment to cut surfaces of preservative-treated lumber.
 - 1. 1. Use inorganic boron for items that are continuously protected from liquid water.
- F. Securely attach carpentry work to substrate by anchoring and fastening as indicated, complying with the following:
 - 1. 1. Use inorganic boron for items that are continuously protected from liquid water.
 - 2. Table 2304.9.1, "Fastening Schedule", in the International Building Code.
- G. Use common wire nails, unless otherwise indicated. Select fasteners of size that will not fully penetrate members where opposite side will be exposed to view or will receive finish materials. Make tight connections between members. Install fasteners without splitting wood; do not countersink nail heads, unless otherwise indicated.

3.2 WOOD BLOCKING AND NAILER INSTALLATION

- A. Install where indicated and where required for screeding or attaching other work. Form to shapes indicated and cut as required for true line and level of attached work. Coordinate locations with other work involved.
- B. Attach items to substrates to support applied loading. Recess bolts and nuts flush with surfaces, unless otherwise indicated.

3.3 WOOD FURRING INSTALLATION

- A. Install level and plumb with closure strips at edges and openings. Shim with wood as required for tolerance of finish work.
- B. Furring to Receive Plywood: Install 1-by-3 inch nominal-size furring vertically 24 inches o.c.

3.4 FIRE- RETARDANT-TREATED (FRT) MATERIALS INSTALLATION

- A. Cutting to length, drilling holes, joining cuts and light sanding are permissible. It is not necessary to field treat cut ends to maintain flame spread rating.
 - 1. Ripping, milling and surfacing of FRT lumber is not permitted.
 - 2. FRT Plywood can be cut in either direction without loss of fire protection

3.5 PROTECTION

- A. Protect wood that has been treated with inorganic boron (SBX) from weather. If, despite protection inorganic boron-treated wood becomes wet, apply EPA-registered borate treatment. Apply borate solution by spraying to comply with EPA-registered label.
- B. Protect rough carpentry from weather. If despite protection, rough carpentry becomes wet, apply EPA- registered borate treatment. Apply borate solution by spraying to comply with EPA-registered label.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 06400

ARCHITECTURAL WOODWORK

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Plastic laminate faced cabinets.
 - 2. Architectural cabinets and millwork.
 - 3. Wood benches (IPE).

- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03331 – ARCHITECTURAL CONCRETE FINISH
 - 3. Section 05411 – LIGHT GAUGE METAL FRAMING
 - 4. Section 06100 – CARPENTRY: for wood furring, blocking, shims, and hanging strips required for installing cabinets and concealed within other construction before cabinet installation.
 - 5. Section 06502 – COUNTERTOPS: for solid surface countertops.

1.2 REFERENCES

- A. Comply with applicable requirements of following standards. Where these standards conflict with other specified requirements, the most restrictive requirements shall govern.
 - 1. American National Standards Institute (ANSI):
 - A161.2 Performance Standards for Fabricated High Pressure Decorative Laminate Countertops
 - A208.1 Particleboard, Mat-Formed Wood
 - 2. American Society for Testing and Materials (ASTM):
 - E 84 Surface Burning Characteristics of Building Materials
 - 3. The Architectural Woodwork Institute (AWI):
 - Quality Standards Architectural Woodwork Quality Standards, Guide Specifications and Quality Certification Program

1.3 SUBMITTALS

- A. Product Data: Submit manufacturer’s printed product data, specifications, standard details, installation instructions, use limitations and recommendations for each material used. Provide certifications that materials and systems comply with specified requirements.

- B. Shop Drawings: Provide large scale shop Drawings for fabrication, installation and erection of parts

of work. Provide plans, elevations, and details of anchorages, connections and accessory items. Provide installation templates for work installed by others. Show interfaces and relationships to work of other trades.

- C. Field Measurements: Take necessary field measurements before preparation of shop Drawings and fabrication. Do not delay progress of job. If field measurements are not possible prior to fabrication, allow for field cutting and fitting.
- D. Verification Samples: Submit representative samples of each material that is to be exposed in completed work. Show full color ranges and finish variations expected. Provide samples having minimum size of 144 sq. in.
- E. Wood certification: Provide internationally recognized certification that the Ipe being used has been grown and harvested from a sustainably managed forest.

1.4 QUALITY ASSURANCE

- A. Source: For each material type required for work of this Section, provide primary materials which are product of one manufacturer. Provide secondary or accessory materials which are acceptable to manufacturers of primary materials.
- B. Installer: A firm with a minimum of five years experience in type of work required by this Section and which is acceptable to manufacturers of primary materials.
- C. Quality Standard: Provide work complying with applicable requirements of AWI Quality Standards.
Where not otherwise indicated, fabricator may choose among options permitted by AWI for grade of work specified.
 - 1. Panel Products: Provide minimum 45 pounds per cubic foot medium density fiberboard. Do not use hardboard.
 - 2. Fire Performance: All concealed work in this Section shall be UL labeled fire-retardant treated.
Exposed woodwork shall have a flame spread of less than 200 when tested in compliance with ASTM E 84.

1.5 PROJECT CONDITIONS

- A. Substrates: Proceed with work only when substrate construction and penetration work is complete.
- B. Wet Work: Proceed with work of this Section after wet work has been complete and fully dry or cured. Wet work is defined as plaster, gypsum drywall, paint, concrete, etc.
- C. Conditioning: Advise Contractor of temperature and humidity requirements for woodwork installation. Do not install work of this Section until required temperature and relative humidity in areas of installation has been stabilized and will be maintained.

1.6 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual

agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 PLASTIC-LAMINATE-FACED ARCHITECTURAL CABINETS

- A. Quality Standard: Unless otherwise indicated provide AWI 'Premium Grade' materials and workmanship and comply with the "Architectural Woodwork Standards" for grades of architectural plastic-laminate cabinets indicated for construction, finishes, installation, and other requirements.
- B. Grade: Premium.
- C. Type of Construction: Frameless.
- D. Cabinet, Door, and Drawer Front Interface Style: Flush overlay.
- E. High-Pressure Decorative Laminate: NEMA LD 3, grades as indicated or if not indicated, as required by woodwork quality standard.
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Formica Corporation.
 - b. Lamin-Art, Inc.
 - c. Wilsonart International; Div. of Premark International, Inc.
 - d. Or approved equal.
- F. Laminate Cladding for Exposed Surfaces:
 - 1. Horizontal Surfaces: Grade HGS.
 - 2. Postformed Surfaces: Grade HGP.
 - 3. Vertical Surfaces: Grade HGS.
 - 4. Edges: Grade HGS.
 - 5. Pattern Direction: Vertically for drawer fronts, doors, and fixed panels.
- G. Concealed Backs of Panels with Exposed Plastic-Laminate Surfaces: High-pressure decorative laminate, NEMA LD 3, Grade BKL.
- H. Drawer Construction: Fabricate with exposed fronts fastened to subfront with mounting screws from interior of body.
- I. Colors, Patterns, and Finishes: Provide materials and products that result in colors and textures of exposed laminate surfaces complying with the following requirements:
 - 1. As selected by Architect from laminate manufacturer's full range.

2.2 WOOD CASEWORK FOR TRANSPARENT FINISH

- A. Grade: Premium.
- B. AWI Type of Casework Construction: Flush overlay.
- C. Wood Species and Cut for Exposed Surfaces: Clear rift cut ash veneer with solid wood edges; stained black.
 - 1. Grain Direction: Vertically for drawer fronts, doors, and fixed panels.
 - 2. Matching of Veneer Leaves: Slip match.
 - 3. Vertical Matching of Veneer Leaves: End match.
 - 4. Veneer Matching within Panel Face: Slip, center, book matchh.
- D. Semiexposed Surfaces: Provide surface materials indicated below:
 - 1. Surfaces Other Than Drawer Bodies: Compatible species to that indicated for exposed surfaces, stained to match.
 - 2. Drawer Sides and Backs: Solid-hardwood lumber, stained to match species indicated for exposed surfaces.
 - 3. Drawer Bottoms: Hardwood plywood.

2.3 WOOD MATERIALS

- A. Wood Products: Provide materials that comply with requirements of referenced quality standard for each type of woodwork and quality grade specified unless otherwise indicated.
- B. Benches: Clear IPE, dark brown or reddish brown walnut color as acceptable to Architect, with fine to medium texture, air dried or kiln dried to 12 percent moisture content, with no applied finish. Use stainless steel fasteners.
- C. Composite Wood and Agrifiber Products: Provide materials that comply with requirements of referenced quality standard for each type of woodwork and quality grade specified unless otherwise indicated.
 - 1. Particleboard: ANSI A208.1, Grade M-2, made with 100% recycled and recovered wood fibre containing no urea formaldehyde.
 - a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
 - 1) Uniboard; NU Green Zero.
- D. Appleply: Premium quality veneer core panel constructed of uniform laminations of solid grade 1/16" Birch. Tolerances comply with American National Standards Institute (ANSI/HPVA) grade rules, HP-1-2004. Treat with Fire Stop II to achieve Class A Flame Spread and Smoke Development.
- E. Rough Sawn Wood Products: Provide Western Red Cedar rough sawn surface 4 sides, Grade D and Better Clear. Edges to form butt joints or 1/4" open joint with 7° beveled edge to be machined adjacent boards as shown on drawings. Finish long edges as required and shown in drawings.

F. Architectural millwork shall be clear birch.

2.4 SOLID SURFACING

A. Refer to Section 06502, "Countertops."

2.5 CABINET HARDWARE AND ACCESSORIES

A. General: Provide cabinet hardware and accessory materials associated with architectural cabinets. Stainless steel unless indicated otherwise.

B. Frameless Concealed Hinges (European Type): BHMA A156.9, B01602, 170 degrees of opening, self-closing as manufactured by Hafele or approved equal.

C. Wire Pulls: Back mounted, solid metal, 4 inches (100 mm) long, 5/16 inch (8 mm) in diameter.

D. Blind Pulls: ½" quarter round routed into drawer and door edges as shown on drawings.

E. Catches: Magnetic catches, BHMA A156.9, B03141

F. Adjustable Shelf Standards and Supports: BHMA A156.9, B04071; with shelf rests, B04081.

G. Shelf Rests: BHMA A156.9, B04013; metal.

H. Drawer Slides: BHMA A156.9.

1. Grade 1 and Grade 2: Side mounted full-extension type; zinc-plated steel with polymer rollers.
2. Grade 1HD-100 and Grade 1HD-200: Side mounted; full-overtravel-extension type; zinc-plated-steel ball-bearing slides.
3. For drawers not more than 3 inches (75 mm) high and not more than 24 inches (600 mm) wide, provide Grade 1.
4. For drawers more than 3 inches (75 mm) high but not more than 6 inches (150 mm) high and not more than 24 inches (600 mm) wide, provide Grade 1HD-100.
5. For drawers more than 6 inches (150 mm) high or more than 24 inches (600 mm) wide, provide Grade 1HD-200.

I. Door Locks: BHMA A156.11, E07121.

J. Drawer Locks: BHMA A156.11, E07041.

K. Brackets: Countertop Hybrid-brackets – Model HYB(1.5) 18- 18"x18".

L. Door and Drawer Silencers: BHMA A156.16, L03011.

M. Exposed Hardware Finishes: For exposed hardware, provide finish that complies with BHMA A156.18 for BHMA finish number indicated. Provide one of the following:

1. Satin Chromium Plated: BHMA 626 for brass or bronze base; BHMA 652 for steel base.
2. Satin Stainless Steel: BHMA 630.

- N. For concealed hardware, provide manufacturer's standard finish that complies with product class requirements in BHMA A156.9.

2.6 MISCELLANEOUS MATERIALS

- A. Furring, Blocking, Shims, and Hanging Strips: Fire-retardant-treated, FSC Certified softwood lumber, kiln dried to less than 15 percent moisture content. Rough sawn Cedar shims, as required at concrete form work.
- B. Anchors: Select material, type, size, and finish required for each substrate for secure anchorage. Provide nonferrous-metal or hot-dip galvanized anchors and inserts on inside face of exterior walls and elsewhere as required for corrosion resistance. Provide toothed-steel or lead expansion sleeves for drilled-in-place anchors.
- C. Adhesives, General: Do not use adhesives that contain urea formaldehyde.
- D. VOC Limits for Installation Adhesives and Glues: Use installation adhesives that comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24):
 - 1. Wood Glues: 30 g/L.
 - 2. Contact Adhesive: 250 g/L.
 - 3. Refer to section 01800 – SUSTAINABLE REQUIREMENTS for compliance.

2.7 SHOP FINISHING

- A. General: Comply with AWI/AWMAC/WI's "Architectural Woodwork Standards" for factory finishing.
 - 1. Finish architectural woodwork at fabrication shop as specified in this Section. Defer only final touchup, cleaning, and polishing until after installation.
- B. Preparation for Finishing: Comply with referenced quality standard for sanding, filling countersunk fasteners, sealing concealed surfaces, and similar preparations for finishing architectural woodwork, as applicable to each unit of work.
 - 1. Backpriming: Apply one coat of sealer or primer, compatible with finish coats, to concealed surfaces of woodwork. Apply two coats to back of paneling and to end-grain surfaces. Concealed surfaces of plastic-laminate-clad woodwork do not require backpriming when surfaced with plastic laminate, backing paper, or thermoset decorative panels.
- C. Transparent Finish: Comply with requirements indicated below for grade, finish system, staining, and sheen with sheen measured on 60-degree gloss meter per ASTM D 523:
 - 1. Grade: Same as item to be finished.
 - 2. AWS Finish System 5: Water white conversion varnish.
 - 3. Staining: Match approved sample for color.
 - 4. Wash Coat for Stained Finish: Apply wash-coat sealer to woodwork made from closed-grain wood before staining and finishing.
 - 5. Open Finish for Open-Grain Woods: Do not apply filler to open-grain woods.

6. Sheen: Satin, 30-50 gloss units.
7. Effect: Partially filled pore.

2.8 FABRICATION

- A. Sand wood to remove raised grain on exposed surfaces before fabrication.
- B. Fabricate woodwork to dimensions, profiles, and details indicated. Ease edges to radius indicated for the following:
 1. Corners of Cabinets: 1/16 inch (1.5 mm) unless otherwise indicated.
- C. Complete fabrication, including assembly, finishing, and hardware application, to maximum extent possible before shipment to Project site. Disassemble components only as necessary for shipment and installation. Where necessary for fitting at site, provide ample allowance for scribing, trimming, and fitting.
 1. Trial fit assemblies at fabrication shop that cannot be shipped completely assembled. Install dowels, screws, bolted connectors, and other fastening devices that can be removed after trial fitting. Verify that various parts fit as intended and check measurements of assemblies against field measurements before disassembling for shipment.
- D. Shop-cut openings to maximum extent possible to receive hardware, appliances, electrical work, and similar items. Locate openings accurately and use templates or roughing-in diagrams to produce accurately sized and shaped openings. Sand edges of cutouts to remove splinters and burrs.

PART 3 - EXECUTION

3.1 WORKMANSHIP - GENERAL

- A. Work of this Section shall conform to design and detail indicated. Where practicable, work shall be finished and assembled at architectural millwork shop.
- B. Work shall be finished smooth and free from machine or tool marks that will telescope through finish.

3.2 INSTALLATION

- A. The Installer shall examine substrates, supports, and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning of installation work means Installer's acceptance of substrates and conditions.
- B. Proceed with installation only when required ambient conditions have been properly maintained, as determined by all attending pre-installation conference.
 1. Provide work to sizes, shapes, and profiles indicated on approved shop drawings.
 2. Install work to comply with quality standards and tolerances specified for shop work.
- C. Install architectural woodwork plumb, level, true and straight. Shim as required using concealed shims. Install work, including tops, to a tolerance of $\pm 1/8$ in. in 8 ft.

- D. Scribe and cut architectural woodwork to fit adjoining work. Refinish cut surfaces.
- E. Anchor casework securely in place.
- F. Cabinets: Install without distortion so doors and drawers fit openings properly and are accurately aligned. Adjust hardware to center doors and drawers in openings and to provide unencumbered operation. Complete installation of hardware and accessory items as indicated.

3.3 REPAIRING AND PROTECTION

- A. Repair minor damage to eliminate all evidence of repair. Remove and replace work which cannot be satisfactorily repaired.
- B. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and re-clean as necessary immediately before final acceptance

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 06502
COUNTERTOPS
PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies countertops fabricated from solid surfacing.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 06400 – ARCHITECTURAL WOODWORK
 - 3. Division 15 - MECHANICAL for sinks and plumbing fittings.

1.2 SUBMITTALS

- A. Product Data: For countertop materials.
- B. Shop Drawings: For countertops. Show materials, finishes, edge and backsplash profiles, methods of joining, and cutouts for plumbing fixtures.
- C. Samples for Verification: For the following products:
 - 1. Countertop material, 6 inches (150 mm) square with two edges finishes as directed by 2.2.A.

1.3 PROJECT CONDITIONS

- A. Field Measurements: Verify dimensions of countertops by field measurements after base cabinets are installed but before countertop fabrication is complete.

1.4 COORDINATION

- A. Coordinate locations of utilities that will penetrate countertops or backsplashes.

PART 2 - PRODUCTS

2.1 COUNTERTOP MATERIALS

- A. Plywood: Exterior softwood plywood complying with DOC PS 1, Grade C-C Plugged, touch sanded.
- B. Adhesives: Adhesives shall not contain urea formaldehyde.
- C. Quartz Agglomerate: Solid sheets consisting of quartz aggregates bound together with a matrix of filled plastic resin and complying with the "Physical Characteristics of Materials" Article of ANSI SS1.
 - 1. Available Products: Subject to compliance with requirements, provide product by Ceasarstone or one of the following comparable:

- a. Cambria.
 - b. Ceasarstone.
 - c. Silestone.
 - d. Zodiaq.
 - e. Or approved equal
2. Colors and Patterns: As selected by Architect from manufacturer's full range.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install countertops level to a tolerance of +/- 1/16 inch in 8 feet (3 mm in 2.4 m).
- B. Fasten countertops by screwing through corner blocks of base units into underside of countertop. Pre-drill holes for screws as recommended by manufacturer. Align adjacent surfaces and, using adhesive in color to match countertop, form seams to comply with manufacturer's written instructions. Carefully dress joints smooth, remove surface scratches, and clean entire surface.
 1. Install backsplashes and end splashes to comply with manufacturer's written instructions for adhesives, sealers, fabrication, and finishing.
 2. Seal edges of cutouts in plywood subtops by saturating with varnish.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 06610

FIBERGLASS GRATING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This section specifies fiberglass gratings in traction power substations.

1.2 SUBMITTALS

- A. Product Data: Indicate product description, fabrication information, and compliance with specified performance requirements.
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
- C. Samples for Verification: Submit minimum 6 by 6 inch sample for each type, texture, pattern and color of grating.

1.3 QUALITY ASSURANCE

- A. Source: For each material type required for work of this Section, provide primary materials that are product of one manufacturer. Provide secondary or accessory materials that are acceptable to manufacturers of primary materials.

1.4 PRODUCT DELIVERY AND STORAGE

- A. All gratings and components shall be shop fabricated. Piece match marked to assembly or erection drawings.
- B. Delivery of Materials: All manufactured materials shall be delivered in original, unbroken pallets, packages, containers, or bundles bearing the label of the manufacturer. Adhesives, resins and their catalysts and hardeners shall be crated or boxed separately and noted as such to facilitate their movement to a dry indoor storage facility.
- C. Storage of Products: All materials shall be carefully handled to prevent them from abrasion, cracking, chipping, twisting, other deformations and other types of damage. Store items in an enclosed area and free from contact with soil and water. Store adhesives, resins and their catalysts and hardeners in dry indoor storage facilities until they are required.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Fiberglass Gratings: Strongwell, McNichols, AMD or equal.
 - 1. Configuration: T-bars, 2 inches deep by 1.5 inches on center.
 - 2. Fasteners: Stainless steel power-actuated stud and disk.
 - 3. Loading: 40 psf live load.
 - 4. Color: Gray color.

- B. All finished surfaces of FRP items and fabrications shall be smooth, resin-rich, free of voids and without dry spots, cracks, crazes or unreinforced areas. All glass fibers shall be well covered with resin to protect against their exposure due to wear or weathering.
- C. All FRP products shall be tested flame spread rating of 25 or less when tested in accordance with the ASTM E-84 Tunnel Test.

2.2 MOLDED GRATING

- A. Manufacture: Grating shall be of a one piece molded construction with tops and bottoms of bearing bars and cross bars in the same plane. Grating shall be reinforced with continuous rovings of equal number of layers in each direction. The top layer of reinforcement shall be no more than 6.35 mm below the top surface of the grating so as to provide maximum stiffness and prevent resin chipping of unreinforced surfaces. Percentage of glass (by weight) shall not exceed 40% so as to achieve maximum corrosion resistance, and as required to maintain the structural requirements.
- B. After molding, no dry glass fibers shall be visible on any surface of bearing bars or cross bars. All bars shall be smooth and uniform with no evidence of fiber orientation irregularities, interlaminar voids, porosity, resin rich or resin starved areas.
- C. Non-slip surfacing: Grating shall be manufactured with a concave profile on the top of each bar providing maximum slip resistance.

2.3 GRATING FABRICATION

- A. Measurements: Grating supplied shall meet the minimum dimensional requirements as shown or specified. The Contractor shall provide and/or verify measurements in field for work fabricated to fit field conditions as required by grating manufacturer to complete the work. Determine correct size and locations of required holes or cutouts from field dimensions before grating fabrication.
- B. Layout: Each grating section shall be readily removable, except where indicated on drawings. Manufacturer to provide openings and holes where located on the contract drawings. Grating supports shall be provided at openings in the grating by contractor where necessary to meet load/deflection requirements specified herein. Grating openings which fit around protrusions (pipes, cables, machinery, etc.) shall be discontinuous at approximately the centerline of opening so each section of grating is readily removable. Gratings shall be fabricated free from warps, twists, or other defects which affect appearance and serviceability.
- C. Sealing: All shop fabricated grating cuts shall be coated with a resin comparable to grating resin to provide maximum corrosion resistance. All field fabricated grating cuts shall be coated similarly by the contractor in accordance with the manufacturer's instructions.
- D. Hardware: Hold-down clips shall be provided and spaced at a maximum of four feet apart with a minimum of four per piece of grating, or as recommended by the manufacturer.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions where installation of gratings will occur, with

Installer present, for compliance with manufacturer's requirements. Verify that substrates and conditions are satisfactory for installation and comply with requirements specified.

3.2 INSTALLATION

- A. Contractor shall install gratings in accordance with manufacturer's assembly drawings. Lock grating panels securely in place with hold-down fasteners as specified herein.
- B. Field cut and drill fiberglass reinforced plastic products with carbide or diamond tipped bits and blades. Seal cut or drilled surfaces in accordance with manufacturer's instructions. Follow manufacturer's instructions when cutting or drilling fiberglass products or using resin products; provide adequate ventilation.
- C. Install items specified as indicated and in accordance with manufacturer's instructions

3.3 CLEANING AND PROTECTION

- A. Protect surfaces from damage until date of substantial completion. Repair work or replace damaged work, which cannot be repaired to Architect's satisfaction.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07115

BITUMINOUS DAMPPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies cold-applied, emulsified-asphalt dampproofing applied to the exterior of below-grade surfaces on concrete and masonry foundation and retaining walls.
- B. Related Work:
 - 1. Section 07131 - SHEET WATERPROOFING.
 - 2. Section 07141 - COLD FLUID-APPLIED WATERPROOFING.
 - 3. Section 07170 - BENTONITE WATERPROOFING.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include recommendations for method of application, primer, number of coats, coverage or thickness, and protection course. Indicate material interactions with substrate, accessories or adjacent materials that could impair the performance of either item.
- B. Sample: 12 by 12 inch sample of dampproofing on typical project substrate.
- C. Installer Certificates: Signed by manufacturers certifying that installers comply with requirements.
- D. Qualification Data: For Installer and for Testing and Inspection Agency.
- E. Product Test Reports: From a qualified independent testing agency indicating and interpreting test results of waterproofing for compliance with requirements, based on comprehensive testing of current waterproofing formulations.

1.3 QUALITY ASSURANCE

- A. Source Limitations: Obtain primary dampproofing materials and primers through one source from a single manufacturer. Provide secondary materials recommended by manufacturer of primary materials.
- B. Installer's Qualification: Installer with 5 year experience who is approved, authorized, or licensed by manufacture in installing dampproofing systems similar to scope and complexity of work for this Project.

1.4 PROJECT CONDITIONS

- A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit asphalt dampproofing to be performed according to manufacturers' written instructions.

- B. Ventilation: Provide adequate ventilation during application of dampproofing in enclosed spaces. Maintain ventilation until dampproofing has thoroughly cured.

PART 2 - PRODUCTS

2.1 BITUMINOUS DAMPPROOFING

- A. Cold-Applied, Emulsified-Asphalt Dampproofing, Brush and Spray Coats: ASTM D 1227, Type III, Class 1.

2.2 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. Euclid Chemical Company.
 2. Henry Company.
 3. Karnak Corporation.
 4. Meadows, W. R., Inc.
 5. Sonneborn, Div. of ChemRex, Inc.
 6. Or approved equal.

2.3 MISCELLANEOUS MATERIALS

- A. Emulsified-Asphalt Primer: ASTM D 1227, Type III, Class 1, except diluted with water as recommended by manufacturer.
- B. Asphalt-Coated Glass Fabric: ASTM D 1668, Type I.
- C. Protection Course, Polystyrene Type: Fan-folded, rigid, extruded-polystyrene board insulation; nominal thickness not less than 3/16 inch.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, with Applicator present, for compliance with manufacturer's requirements for surface smoothness and other conditions affecting performance of work. Begin dampproofing application only after substrate construction and penetrating work have been completed and unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Protection of Other Work: Mask or otherwise protect adjoining exposed surfaces from being stained, spotted, or coated with dampproofing. Prevent dampproofing materials from entering and clogging weep holes and drains.
- B. Clean substrates of projections and substances detrimental to work; fill voids, seal joints, and

apply bond breakers if any, as recommended by prime material manufacturer. Concrete shall be allowed to cure for a minimum of 5 days after form removal prior to dampproofing application, or as required by manufacturer.

- C. Patch holes with mortar and allow to properly cure prior to dampproofing application and in accordance with manufacturer's instructions.

3.3 APPLICATION

- A. Comply with manufacturer's written recommendations unless more stringent requirements are indicated or required by Project conditions to ensure satisfactory performance of dampproofing.
 - 1. Apply additional coats if recommended by manufacturer or required to achieve coverages indicated.
 - 2. Allow each coat of dampproofing to cure 24 hours before applying subsequent coats.
 - 3. Apply from finished-grade line to top of footing, extend over top of footing, and down a minimum of 6 inches over outside face of footing.
 - 4. Extend 12 inches onto intersecting walls and footings, but do not extend onto surfaces exposed to view when Project is completed.
 - 5. Install flashings and corner protection stripping at internal and external corners, changes in plane, construction joints, cracks, and where shown as "reinforced", by embedding an 8-inch-wide strip of asphalt-coated glass fabric in a heavy coat of dampproofing. Dampproofing coat required for embedding fabric is in addition to other coats required.
- B. On Concrete Foundations: Apply two brush or spray coats at not less than 1.5 gal./100 sq. ft. for first coat and 1 gal./100 sq. ft. for second coat.
- C. On Unparged Masonry Foundation Walls: Apply primer and two brush or spray coats at not less than 1.5 gal./100 sq. ft. for first coat and 1 gal./100 sq. ft. for second coat.
- D. On Backs of Concrete and Masonry Retaining Walls: Apply one brush or spray coat at not less than 1.25 gal./100 sq. ft.

3.4 INSTALLATION OF PROTECTION COURSE

- A. Install protection course over completed-and-cured dampproofing. Comply with dampproofing material manufacturer's written recommendations for attaching protection course. Support protection course with spot application of trowel-grade mastic where not otherwise indicated.

3.5 CLEANING

- A. Remove dampproofing materials from surfaces not intended to receive dampproofing.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07116

BITUMINOUS DAMPPROOFING FOR ROADWAY BRIDGES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving cut-back asphalt, protective seal coat emulsion, or emulsified- asphalt dampproofing applied to the exterior of below-grade surfaces on Roadway Bridge and Pedestrian Bridge concrete foundations and walls.
- B. For all Roadway Bridge and Pedestrian Bridge Bituminous Dampproofing requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 970.
 - 1. Replace all references to Measurement and Payment with Sub-section 4.1 below.
 - 2. For submittal requirements, including, but not limited to, shop drawings, working drawings, Requests For Information, Non Conformance and testing reports, refer to Section 01300 – SUBMITTALS of the Contract Specifications.

PART 2 – PRODUCTS

Not used.

PART 3 – EXECUTION

Not used.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 07117

MEMBRANE WATERPROOFING AND PROTECTIVE COURSE

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
 - 1. The furnishing and installation of Membrane Waterproofing and Protective Course for Roadway Bridges, Underpasses and Cast-In-Place Concrete Retaining Walls.
- B. For all Roadway Bridge, Underpasses and Cast-In-Place Concrete Retaining Wall Membrane Waterproofing and Protective Course requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 967.
 - 1. Replace all references to Measurement and Payment with Sub-section 4.1 below.
 - 2. For Roadway Bridge and Underpass Membrane Waterproofing and Protective Course submittal requirements, including, but not limited to, shop drawings, working drawings, Requests For Information, and Non Conformance and testing reports, refer to Section 01300 – SUBMITTALS of the Contract Specifications.
 - 3. For additional information regarding Membrane Waterproofing Product and Execution at the Lowell Street Bridge, see sections 2 and 3 below.

PART 2 – PRODUCTS

2.1 PRODUCT INFORMATION FOR MEMBRANE WATERPROOFING AND PROTECTIVE COURSE FOR THE LOWELL STREET BRIDGE

- A. Not used.

PART 3 – EXECUTION

3.1 GENERAL

- A. This Section specifies execution details for Membrane Waterproofing and Protective Course regarding the Lowell Street Bridge.
 - 1. Once the existing Lowell Street Bridge North Abutment stem wall has been removed and the original (1909) abutment is exposed, a Bentonite Waterproofing System shall be applied to the front face of the original abutment. For General Information, and Product Requirements refer to MassDOT Standard Specifications (with Supplemental Specifications) Sections 967 and M9.09.0.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07131

SHEET WATERPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Rubberized-asphalt sheet waterproofing below grade.
 - 2. HDPE sheet waterproofing below grade, for blind-side applications.
- B. Related Work:
 - 1. Section 07115 – BITUMINOUS DAMPPROOFING
 - 2. Section 07141 - COLD FLUID-APPLIED WATERPROOFING.
 - 3. Section 07170 - BENTONITE WATERPROOFING.
 - 4. Section 07270 – AIR AND VAPOR BARRIER SYSTEMS.
 - 5. Section 07423 – RAIN SCREEN SYSTEMS

1.2 PERFORMANCE REQUIREMENTS

- A. Provide waterproofing that prevents the passage of water.

1.3 SUBMITTALS

- A. Product Data: Include manufacturer's written instructions for evaluating, preparing, and treating substrate, technical data, and tested physical and performance properties of waterproofing. Indicate material interactions with substrate that could impair the performance of either item accessories or adjacent.
- B. Shop Drawings: Show locations and extent of waterproofing. Include details for substrate joints and cracks, sheet flashings, penetrations, inside and outside corners, tie-ins with adjoining waterproofing, and other termination conditions.
- C. Samples: For the following products:
 - 1. 12-by-12-inch square of waterproofing and flashing sheet.
 - 2. 12-by-12-inch square of insulation.
 - 3. 4-by-4-inch square of drainage panel.
- D. Installer Certificates: Signed by manufacturers certifying that installers comply with requirements.
- E. Qualification Data: For Installer and for Testing and Inspection Agency.
- F. Product Test Reports: From a qualified independent testing agency indicating and interpreting test results of waterproofing for compliance with requirements, based on comprehensive testing of current waterproofing formulations.

- G. Test Reports: From Testing and Inspection Agency.
- H. Sample Warranty: Copy of special waterproofing manufacturer's and Installer's warranty stating obligations, remedies, limitations, and exclusions before starting waterproofing.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: A qualified installer who is acceptable to waterproofing manufacturer to install manufacturer's products with 5 year experience with similar scope and complexity of work.
- B. Qualifications of Testing and Inspection Agency: Experienced testing and inspection agency acceptable to the Authority.
- C. Source Limitations: Obtain waterproofing materials, protection course, and molded-sheet drainage panels through one source from a single manufacturer.
- D. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1. Review requirements for waterproofing, including surface preparation specified under other Sections, substrate condition and pretreatment, minimum curing period, forecasted weather conditions, special details and sheet flashings, installation procedures, testing and inspection procedures, and protection and repairs.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver liquid materials to Project site in original packages with seals unbroken, labeled with manufacturer's name, product brand name and type, date of manufacture, and directions for storing and mixing with other components.
- B. Store liquid materials in their original undamaged packages in a clean, dry, protected location and within temperature range required by waterproofing manufacturer.
- C. Remove and replace liquid materials that cannot be applied within their stated shelf life.
- D. Store rolls according to manufacturer's written instructions.
- E. Protect stored materials from direct sunlight.

1.6 PROJECT CONDITIONS

- A. Environmental Limitations: Apply waterproofing within the range of ambient and substrate temperatures recommended by waterproofing manufacturer. Do not apply waterproofing to a damp or wet substrate.
 - 1. Do not apply waterproofing in snow, rain, fog, or mist.
- B. Maintain adequate ventilation during preparation and application of waterproofing materials.

1.7 PRE-CONSTRUCTION MEETING

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions

that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

1.8 WARRANTY

- A. Special Manufacturer's Warranty: Written warranty, signed by waterproofing manufacturer agreeing to replace waterproofing material that does not comply with requirements or that does not remain watertight during specified warranty period.
 - 1. Warranty does not include failure of waterproofing due to failure of substrate prepared and treated according to requirements or formation of new joints and cracks in substrate exceeding 1/16 inch in width.
 - 2. Warranty Period: Five years after date of Substantial Completion.
 - 3. Warranty includes removing and reinstalling protection board, drainage panels, and overburden materials.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Rubberized-Asphalt Sheet Waterproofing:
 - a. American Hydrotech, Inc.; VM 75.
 - b. W. R. Grace & Co.; Bituthene.
 - c. Meadows, W. R., Inc.; Mel-Rol.
 - d. Or approved equal.
 - 2. HDPE Sheet Waterproofing:
 - a. Basis of Design: W. R. Grace & Co.; Preprufe 160R for vertical surfaces and Preprufe 300R for horizontal surfaces, or approved equal.
 - b. Provide all accessories associated with Preprufe systems including but not limited to, stainless steel termination bars, flashing, and accessories.

2.2 RUBBERIZED-ASPHALT SHEET WATERPROOFING

- A. Rubberized-Asphalt Sheet: 60-mil-thick, self-adhering sheet consisting of 56 mils of rubberized asphalt laminated to a 4-mil-thick, polyethylene film with release liner on adhesive side.
 - 1. Physical Properties: As follows, measured per standard test methods referenced:
 - a. Tensile Strength: 250 psi minimum; ASTM D 412, Die C, modified.
 - b. Ultimate Elongation: 300 percent minimum; ASTM D 412, Die C, modified.
 - c. Low-Temperature Flexibility: Pass at minus 20 deg F ASTM D 1970.

- d. Crack Cycling: Unaffected after 100 cycles of 1/8-inch (movement; ASTM C 836.
- e. Puncture Resistance: 40 lbf minimum; ASTM E 154.
- f. Hydrostatic-Head Resistance: 150 feet (minimum; ASTM D 5385.
- g. Water Absorption: 0.15 percent weight-gain maximum after 48-hour immersion at 70 deg F; ASTM D 570.
- h. Vapor Permeance: 0.05 perms; ASTM E 96, Water Method.

2.3 HDPE SHEET WATERPROOFING

- A. HDPE Sheet for Vertical Applications: 42-mil-thick, uniform, flexible sheets consisting of 16-mil-thick, HDPE sheet coated with a pressure-sensitive rubber adhesive, a protective adhesive coating, and a release liner.
- B. HDPE Sheet for Horizontal Applications: 56-mil-thick, uniform, flexible sheets consisting of 30-mil-thick, HDPE sheet coated with a pressure-sensitive rubber adhesive, a protective adhesive coating, a detackifying surface treatment, an uncoated self-adhering side lap strip, and a release liner.
- C. Physical Properties: As follows, measured per standard test methods referenced:
 - 1. Tensile Strength, Film: 4000 psi minimum; ASTM D 412.
 - 2. Low-Temperature Flexibility: Pass at minus 10 deg F; ASTM D 1970.
 - 3. Peel Adhesion to Concrete: 5 lbf/in.; ASTM D 903, modified.
 - 4. Lap Adhesion: 2.5 lbf/in.; ASTM D 1876, modified.
 - 5. Hydrostatic-Head Resistance: 231 feet; ASTM D 5385, modified.
 - 6. Vapor Permeance: 0.01 perms; ASTM E 96, Water Method.

2.4 AUXILIARY MATERIALS

- A. General: Furnish auxiliary materials recommended by waterproofing manufacturer for intended use and compatible with sheet waterproofing.
 - 1. Furnish liquid-type auxiliary materials that comply with VOC limits of authorities having jurisdiction.
- B. Primer: Liquid primer recommended for substrate by manufacturer of sheet waterproofing material.
- C. Surface Conditioner: Liquid, waterborne surface conditioner recommended for substrate by manufacturer of sheet waterproofing material.
- D. Sheet Strips: Self-adhering, rubberized-asphalt composite sheet strips of same material and thickness as sheet waterproofing.
- E. Liquid Membrane: Elastomeric, two-component liquid, cold fluid applied, trowel grade or low viscosity.
- F. Substrate Patching Membrane: Low-viscosity, two-component, asphalt-modified coating.
- G. Mastic, Adhesives, and Tape: Liquid mastic and adhesives, and adhesive tapes recommended by waterproofing manufacturer.

1. Detail Tape: Two-sided, pressure-sensitive, self-adhering reinforced tape, 4-1/2 inches wide, with a tack-free protective adhesive coating on one side and release film on self-adhering side.
- H. Metal Termination Bars: Alloy 316 stainless steel bars, approximately 1 by 1/8 inch thick, predrilled at 9-inch centers.
- I. Protection Course: Fan-folded, extruded-polystyrene board insulation, unfaced, nominal thickness 3/8 inch.

2.5 MOLDED-SHEET DRAINAGE PANELS

- A. Nonwoven-Geotextile-Faced, Molded-Sheet Drainage Panel: Manufactured composite subsurface drainage panels consisting of a nonwoven, needle-punched geotextile facing with an apparent opening size not exceeding No. 70 (0.21-mm) sieve laminated to 1 side and a polymeric film bonded to the other side of a 3-dimensional, nonbiodegradable, molded-plastic-sheet drainage core, with a vertical flow rate of 9 to 15 gpm per ft. (112 to 188 L/min. per m).
1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Carlisle Sure-Drain V.
 - b. W. R. Grace Hydroduct 2 or HZ
 - c. Miradri Miradrain 6200 or 6200XL
 - d. Or approved equal

2.6 INSULATION

- A. Board Insulation: Extruded-polystyrene board insulation complying with ASTM C 578, square edged of type, density, and compressive strength indicated below:
1. For vertical applications, Type IV, 1.6-lb/cu. ft. minimum density and 25-psi minimum compressive strength.
 2. For horizontal applications, pedestrian traffic, Type VII, 2.2-lb/cu. ft. minimum density and 60-psi minimum compressive strength.
 3. For horizontal applications, vehicular traffic, Type V, 3-lb/cu. ft. minimum density and 100-psi minimum compressive strength.
 4. Thickness: 2 inches unless indicated otherwise on the Drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements and other conditions affecting performance.
1. For rubberized-asphalt membrane, verify that concrete has cured and aged for minimum time period recommended by waterproofing manufacturer. Verify that concrete is visibly dry and free of moisture. Test for capillary moisture by plastic sheet method according to ASTM D 4263.

2. For HDPE sheet, verify that compacted subgrade is dry, smooth, and sound, ready to receive sheet.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SURFACE PREPARATION

- A. Clean, prepare, and treat substrates according to manufacturer's written instructions. Provide clean, dust-free, and dry substrates for waterproofing application.
- B. Mask off adjoining surfaces not receiving waterproofing to prevent spillage and overspray affecting other construction.
- C. Remove grease, oil, bitumen, form-release agents, paints, curing compounds, and other penetrating contaminants or film-forming coatings from concrete.
- D. Remove fins, ridges, mortar, and other projections and fill honeycomb, aggregate pockets, holes, and other voids.
- E. Prepare, fill, prime, and treat joints, bugholes and cracks in substrates. Remove dust and dirt from joints and cracks according to ASTM D 4258.
- F. Bridge and cover isolation joints, expansion joints and discontinuous deck-to-wall and deck-to-deck joints with overlapping sheet strips.
 1. Invert and loosely lay first sheet strip over center of joint. Firmly adhere second sheet strip to first and overlap to substrate.
- G. Corners: Prepare, prime, and treat inside and outside corners according to ASTM D 6135.
 1. Install membrane strips centered over vertical inside corners. Install 3/4-inch fillets of liquid membrane on horizontal inside corners and as follows:
 - a. At footing-to-wall intersections, extend liquid membrane each direction from corner or install membrane strip centered over corner.
 - b. At plaza deck-to-wall intersections, extend liquid membrane or sheet strips onto deck waterproofing and to finished height of sheet flashing.
- H. Prepare, treat, and seal vertical and horizontal surfaces at terminations and penetrations through waterproofing and at drains and protrusions according to ASTM D 6135.

3.3 RUBBERIZED-ASPHALT SHEET APPLICATION

- A. Install self-adhering sheets according to waterproofing manufacturer's written instructions and recommendations in ASTM D 6135.
- B. Apply primer to substrates at required rate and allow to dry. Limit priming to areas that will be covered by sheet waterproofing in same day. Reprime areas exposed for more than 24 hours.
- C. Apply and firmly adhere sheets over area to receive waterproofing. Accurately align sheets and maintain uniform 2-1/2-inch-minimum lap widths and end laps. Overlap and seal seams and stagger end laps to ensure watertight installation.

1. When ambient and substrate temperatures range between 25 and 40 deg F, install self-adhering, rubberized-asphalt sheets produced for low-temperature application. Do not use low-temperature sheets if ambient or substrate temperature is higher than 60 deg F.
- D. Horizontal Application: Apply sheets from low point to high point of decks to ensure that side laps shed water.
 - E. Apply continuous sheets over sheet strips bridging substrate cracks, construction, and contraction joints.
 - F. Seal exposed edges of sheets at terminations not concealed by metal counterflashings or ending in reglets with mastic or sealant.
 - G. Install sheet waterproofing and auxiliary materials to tie into adjacent waterproofing as applicable.
 - H. Repair tears, voids, and lapped seams in waterproofing not complying with requirements. Slit and flatten fishmouths and blisters. Patch with sheets extending 6 inches beyond repaired areas in all directions.
 - I. Correct deficiencies in or remove sheet waterproofing that does not comply with requirements, repair substrates, reapply waterproofing, and repair sheet flashings.

3.4 HDPE SHEET APPLICATION

- A. Install HDPE sheets according to waterproofing manufacturer's written instructions.
- B. Vertical Applications: Install sheet membrane with HDPE face against substrate. Accurately align sheets and maintain uniform 3-inch-minimum lap widths and end laps. Overlap and seal seams and stagger and tape end laps to ensure watertight installation. Mechanically fasten to substrate.
 1. Securely fasten top termination of membrane with continuous metal termination bar anchored into substrate and cover with detailing tape.
- C. Horizontal Applications: Install sheet membrane with HDPE face against substrate. Accurately align sheets and maintain uniform 3-inch-minimum lap widths and end laps. Overlap and seal seams. Overlap, stagger, and seal end laps with detail tape to ensure watertight installation.
- D. Corners: Seal lapped terminations and cut edges of sheet waterproofing at inside and outside corners with detail tape.
- E. Seal penetrations through sheet waterproofing to provide watertight seal with detail tape patches or wraps and a liquid-membrane troweling.
- F. Install sheet waterproofing and auxiliary materials to produce a continuous watertight tie into adjacent waterproofing.
- G. Repair tears, voids, and lapped seams in waterproofing not complying with requirements. Tape perimeter of damaged or nonconforming area extending 6 inches beyond repaired areas in all directions. Apply a patch of sheet membrane and firmly secure with detail tape.
- H. Correct deficiencies in or remove waterproofing that does not comply with requirements, repair substrates, reapply waterproofing, and repair sheet flashings.

3.5 PROTECTION COURSE INSTALLATION

- A. For sheet membrane, install protection course within 24 hours of waterproofing application, with butted joints over waterproofing membrane before starting subsequent construction operations.
 - 1. Drainage panels may be used in place of a separate protection course to vertical applications when approved by waterproofing manufacturer.

3.6 INSULATION INSTALLATION

- A. Install insulation drainage panels over waterproofed surfaces. Cut and fit to within 3/4 inch of projections and penetrations.
- B. On vertical surfaces, set insulation units in adhesive or tape applied according to manufacturer's written instructions.
- C. On horizontal surfaces, loosely lay insulation units according to manufacturer's written instructions. Stagger end joints and tightly abut insulation units.

3.7 FIELD QUALITY CONTROL

- A. Flood Testing: Flood test each deck area for leaks, according to recommendations in ASTM D 5957, after completing waterproofing but before overlying construction is placed. Install temporary containment assemblies, plug or dam drains, and flood with potable water.
 - 1. Flood to an average depth of 2-1/2 inches with a minimum depth of 1 inch and not exceeding a depth of 4 inches. Maintain 2 inches of clearance from top of sheet flashings.
 - 2. Flood each area for 24 hours.
 - 3. After flood testing, repair leaks, repeat flood tests, and make further repairs until waterproofing installation is watertight. Repair procedures shall be in strict accordance with manufacturer's recommendations.
- B. Engage an independent testing agency to observe flood testing and examine underside of decks and terminations for evidence of leaks during flood testing.

3.8 PROTECTION AND CLEANING

- A. Do not permit foot or vehicular traffic on unprotected membrane.
- B. Protect waterproofing from damage and wear during remainder of construction period.
- C. Protect installed insulation from damage due to ultraviolet light, harmful weather exposures, physical abuse, and other causes. Provide temporary coverings where insulation will be subject to abuse and cannot be concealed and protected by permanent construction immediately after installation.
- D. Clean spillage and soiling from adjacent construction using cleaning agents and procedures recommended by manufacturer of affected construction.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07141

COLD FLUID-APPLIED WATERPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies cold fluid-applied waterproofing for use at green roofs and other applications indicated.
- B. Related Work:
 - 1. Section 05810 – EXPANSION JOINT COVER ASSEMBLIES: Expansion-joint systems.
 - 2. Section 07131 – SHEET WATERPROOFING
 - 3. Section 07550 – MODIFIED BITUMEN BUILT-UP ROOFING

1.2 PERFORMANCE REQUIREMENTS

- A. Provide waterproofing membrane that prevents the passage of water.

1.3 SUBMITTALS

- A. Product Data: Include manufacturer's written instructions for evaluating, preparing, and treating substrate, technical data, and tested physical and performance properties. Indicate material interactions with substrate, accessories, or adjacent materials that could impair the performance of either item.
- B. Shop Drawings: Show locations and extent of waterproofing. Include details for substrate joints and cracks, sheet flashings, penetrations, inside and outside corners, tie-ins to adjoining waterproofing, and other termination conditions.
- C. Sample: 12 by 12 inch sample of waterproofing on typical project substrate.
- D. Installer Certificates: Signed by manufacturers certifying that installers comply with requirements.
- E. Qualification Data: For Installer and for third party Testing and Inspection Agency.
- F. Product Test Reports: From a qualified independent testing agency indicating and interpreting test results of waterproofing for compliance with requirements, based on comprehensive testing of current waterproofing formulations.
- G. Test Reports: From third party Testing and Inspection Agency.
- H. Sample Warranty: Copy of special waterproofing manufacturer's and Installer's warranty stating obligations, remedies, limitations, and exclusions before starting waterproofing.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: A qualified installer with 5 years' experience on similar scope and complexity of work who is authorized, approved, or licensed to install waterproofing manufacturer's products; and who is eligible to receive waterproofing warranty specified.

- B. Testing and Inspection Agency Qualifications: Qualified independent testing agency approved by manufacturer and experienced in observation and inspection of waterproofing systems.
- C. Hold Point - Mockups: Apply 100 square feet of waterproofing to demonstrate substrate surface preparation, crack and joint treatment, corner treatment, thickness, texture, and execution quality.
 - 1. If Engineer determines mockups do not comply with requirements, reapply waterproofing until mockups are approved.
 - 2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
- D. Preinstallation Conference: Conduct conference at Project site to review requirements for waterproofing, including surface preparation specified under other Sections, substrate condition and pretreatment, minimum curing period, forecasted weather conditions, special details and sheet flashings, installation procedures, testing and inspection procedures, and protection and repairs.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver liquid materials to Project site in original containers with seals unbroken, labeled with manufacturer's name, product brand name and type, date of manufacture, and directions for storing and mixing with other components.
- B. Store liquid materials in their original undamaged containers in a clean, dry, protected location and within the temperature range required by waterproofing manufacturer.
- C. Remove and replace liquid materials that cannot be applied within their stated shelf life.
- D. Protect stored materials from direct sunlight.

1.6 PROJECT CONDITIONS

- A. Environmental Limitations: Apply waterproofing within the range of ambient and substrate temperatures recommended by waterproofing manufacturer. Do not apply waterproofing to a damp or wet substrate, or when temperature is below 0 deg F. Do not apply waterproofing in snow, rain, fog, or mist.
- B. Maintain adequate ventilation during application and curing of waterproofing materials.

1.7 WARRANTY

- A. Special Manufacturer's Warranty: Written warranty, signed by waterproofing manufacturer agreeing to repair or replace waterproofing and sheet flashings that do not comply with requirements or that do not remain watertight within specified warranty period.
 - 1. Warranty does not include failure of waterproofing due to failure of substrate prepared and treated according to requirements or formation of new joints and cracks in substrate that exceed 1/8 inch in width.
 - 2. Warranty includes removing and reinstalling protection board, drainage panels, insulation, pedestals, and pavers on plaza decks.

3. Warranty Period: Five years after date of Substantial Completion.

PART 2 - PRODUCTS

2.1 UNMODIFIED POLYURETHANE OR LATEX RUBBER WATERPROOFING MATERIALS

- A. General: Provide waterproofing materials recommended by manufacturer to be compatible with one another and able to develop bond to substrate under conditions of service and application, as demonstrated by waterproofing manufacturer based on testing and field experience.
 1. Two-Component Unmodified Polyurethane or Latex-Rubber Waterproofing: Two component, reinforced polyurethane liquid resin waterproofing membrane with 360 degree needle punched non-woven polyester reinforcing fleece. Products that may be incorporated into the work include, but are not limited, to those manufactured by Kember System America, Inc., Kemperol 2K-PUR.
- B. Primer: Manufacturer's standard, factory-formulated polyurethane or epoxy primer.
- C. Sheet Flashing: 70-mil minimum, composite of the same resin as the field membrane with 165 g/m² fleece reinforcement.
 1. Adhesive: Manufacturer's recommended contact adhesive.
- D. Reinforcing Strip: Manufacturer's recommended fiberglass mesh or polyester fabric.
- E. Sealants and Accessories: Waterproofing manufacturer's recommended sealants and accessories.
 1. Backer Rod: Closed-cell polyethylene foam.
- F. Protection Course at Unmodified Polyurethane or Latex-Rubber Waterproofing: Semirigid sheets of fiberglass or mineral-reinforced-asphaltic core, pressure laminated between two asphalt-saturated fibrous liners and as follows:
 1. Thickness: 1/8 inch nominal.
 2. Adhesive: Rubber-based solvent type recommended by waterproofing manufacturer for type of protection course.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements and other conditions affecting performance.
 1. Verify that concrete has cured and aged for minimum time period recommended by waterproofing manufacturer.
 2. Verify that substrate is visibly dry and free of moisture. Test for capillary moisture by plastic sheet method according to ASTM D 4263.
 3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SURFACE PREPARATION

- A. Clean and prepare substrate according to manufacturer's written recommendations and as specified in sections 3.5, 3.6, or 3.7 as appropriate. Provide clean, dust-free, and dry substrate for waterproofing application.
- B. Mask off adjoining surfaces not receiving waterproofing to prevent spillage or overspray affecting other construction.
- C. Close off deck drains and other deck penetrations to prevent spillage and migration of waterproofing fluids.
- D. Remove grease, oil, bitumen, form-release agents, paints, curing compounds, and other penetrating contaminants or film-forming coatings from concrete.
 - 1. Abrasive blast clean concrete surfaces uniformly to expose top surface of fine aggregate according to ASTM D 4259 with a self-contained, recirculating, blast-cleaning apparatus. Remove material to provide a sound surface free of laitance, glaze, efflorescence, curing compounds, concrete hardeners, or form-release agents. Remove remaining loose material and clean surfaces according to ASTM D 4258.
- E. Remove fins, ridges, and other projections and fill honeycomb, aggregate pockets, and other voids with materials as recommended by manufacturer for non-reactive with waterproofing.

3.3 PREPARATION AT TERMINATIONS AND PENETRATIONS

- A. Prepare vertical and horizontal surfaces at terminations and penetrations through waterproofing and at expansion joints, drains, and sleeves according to ASTM C 898 and manufacturer's written instructions.
- B. Prime substrate, unless otherwise instructed by waterproofing manufacturer.
- C. Apply a double thickness of waterproofing and embed a joint reinforcing strip in preparation coat when recommended by waterproofing manufacturer.
 - 1. Provide sealant cants around penetrations and at inside corners of deck-to-wall butt joints when recommended by waterproofing manufacturer.

3.4 JOINT AND CRACK TREATMENT

- A. Prepare, treat, rout, and fill joints and cracks in substrate according to ASTM C 898 and waterproofing manufacturer's written instructions. Remove dust and dirt from joints and cracks complying with ASTM D 4258 before coating surfaces.
 - 1. Comply with ASTM C 1193 for joint-sealant installation.
 - 2. Apply bond breaker between sealant and preparation strip.
 - 3. Prime substrate and apply a single thickness of preparation strip extending a minimum of 3 inches along each side of joint. Apply a double thickness of waterproofing and embed a joint reinforcing strip in preparation coat.
- B. Install sheet flashing and bond to deck and wall substrates where indicated or required according to waterproofing manufacturer's written instructions. Extend sheet flashings onto perpendicular surfaces and other work penetrating substrate according to ASTM C 898.

3.5 UNMODIFIED POLYURETHANE OR LATEX RUBBER WATERPROOFING APPLICATION

- A. Apply waterproofing according to ASTM C 898 and manufacturer's written instructions.
- B. Start installing waterproofing in presence of manufacturer's technical representative.
- C. Apply primer over prepared substrate.
- D. Mix materials and apply waterproofing by spray, roller, notched squeegee, trowel, or other application method suitable to slope of substrate.
 - 1. Apply one or two coats of waterproofing to obtain a seamless membrane free of entrapped gases, with an average dry film thickness of 60 mils and a minimum dry film thickness of 50 mils at any point.
 - 2. Apply waterproofing to prepared wall terminations and vertical surfaces.
 - 3. Verify wet film thickness of waterproofing every 100 sq. ft.
- E. Install protection course with butted joints over nominally cured membrane before starting subsequent construction operations.

3.6 FIELD QUALITY CONTROL

- A. Adhesion Tests: Conduct in accordance with ASTM D4541 to confirm adequate surface preparation. Conduct a minimum of 3 tests and one additional for every 1000 square feet installed.
- B. Membrane Thickness: Check every 100 square feet using a gauge pin standard comb-type thickness gauge.
- C. Coverage Rate: Monitored by checking quantity of materials used against the area covered.
- D. Any additional testing required by system manufacture to ensure product will meet performance criteria listed in Section 2.
- E. Flood Testing: Flood test each deck area for leaks, according to recommendations in ASTM D 5957, after completing waterproofing but before overlying construction is placed. Install temporary containment assemblies, plug or dam drains, and flood with potable water.
 - 1. Flood to an average depth of 2-1/2 inches with a minimum depth of 1 inch and not exceeding a depth of 4 inches. Maintain 2 inches of clearance from top of sheet flashings.
 - 2. Flood each area for 24 hours.
 - 3. After flood testing, repair leaks, repeat flood tests, and make further repairs until waterproofing installation is watertight. Repair procedures shall be in strict accordance with manufacturer's recommendations.
- F. Engage an independent testing agency to observe flood testing and examine underside of decks and terminations for evidence of leaks during flood testing.

3.7 CURING, PROTECTING, AND CLEANING

- A. Cure waterproofing according to manufacturer's written recommendations, taking care to prevent contamination and damage during application stages and curing. Do not permit foot or vehicular traffic on unprotected membrane.
- B. Install 2 or more layers of asphaltic hardboard as required to achieve a minimum of 3/4" thickness. Stagger the panel joints.
- C. Protect waterproofing from damage and wear during remainder of construction period.
- D. Clean spillage and soiling from adjacent construction using cleaning agents and procedures recommended by manufacturer of affected construction.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07142

HOT FLUID-APPLIED WATERPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies hot fluid-applied waterproofing for bridge decks, underground building areas and other applications indicated on the Drawings.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 01420 – MOCK-UPS
 - 2. Section 07131 – SHEET WATERPROOFING.
 - 3. Section 07141 - COLD FLUID-APPLIED WATERPROOFING
 - 4. Section 07170 - BENTONITE WATERPROOFING

1.2 PERFORMANCE REQUIREMENTS

- A. Provide waterproofing that prevents the passage of water and complies with physical requirements in Canadian General Standards Board publication CAN/CGSB-37.50, "Hot Applied, Rubberized Asphalt for Roofing and Waterproofing".

1.3 SUBMITTALS

- A. Product Data: Include manufacturer's written instructions for evaluating, preparing, and treating substrate, technical data, and tested physical and performance properties.
- B. Shop Drawings: Show locations and extent of waterproofing. Include details for substrate joints and cracks, sheet flashings, penetrations, inside and outside corners, tie-ins to adjoining waterproofing, and other termination conditions.
- C. Installer Certificates: Signed by manufacturers certifying that installers comply with requirements.
- D. Qualification Data: For Installer and for Testing and Inspection Agency.
- E. Product Test Reports: From a qualified independent testing agency indicating and interpreting test results of waterproofing for compliance with requirements, based on comprehensive testing of current waterproofing formulations.
- F. Test Reports: From Testing and Inspection Agency.
- G. Sample Warranty: Copy of special waterproofing manufacturer's and Installer's warranty stating obligations, remedies, limitations, and exclusions before starting waterproofing.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: A qualified installer who is authorized, approved, or licensed to install waterproofing manufacturer's product; and who is eligible to receive waterproofing warranty specified.

- B. Mockups: Apply 100 square feet of waterproofing to demonstrate surface preparation, crack and joint treatment, corner treatment, thickness, texture, and execution quality.
 - 1. If Engineer determines mockups do not comply with requirements, reapply waterproofing until mockups are approved.
 - 2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
- C. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1. Review requirements for waterproofing, including surface preparation specified under other Sections, substrate condition and pretreatment, minimum curing period, forecasted weather conditions, special details and sheet flashings, installation procedures, testing and inspection procedures, and protection and repairs.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver liquid materials to Project site in original containers with seals unbroken, labeled with manufacturer's name, product brand name and type, date of manufacture, and directions for storing and mixing with other components.
- B. Store liquid materials in their original undamaged containers in a clean, dry, protected location and within the temperature range required by waterproofing manufacturer.
- C. Remove and replace liquid materials that cannot be applied within their stated shelf life.
- D. Protect stored materials from direct sunlight.

1.6 PROJECT CONDITIONS

- A. Environmental Limitations: Apply waterproofing within the range of ambient and substrate temperatures recommended by waterproofing manufacturer. Do not apply waterproofing to a damp or wet substrate, or when temperature is below 0 deg F. Do not apply waterproofing in snow, rain, fog, or mist.
- B. Maintain adequate ventilation during application and curing of waterproofing materials.

1.7 WARRANTY

- A. Special Manufacturer's Warranty: Written warranty, signed by waterproofing manufacturer agreeing to repair or replace waterproofing and sheet flashings that do not comply with requirements or that do not remain watertight within specified warranty period.
 - 1. Warranty does not include failure of waterproofing due to failure of substrate prepared and treated according to requirements or formation of new joints and cracks in substrate that exceed 1/8 inch in width.
 - 2. Warranty includes removing and reinstalling protection board, drainage panels, insulation, pedestals, and pavers on plaza decks.
 - 3. Warranty Period: Five years after date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
1. American Hydrotech, Inc.; Monolithic Membrane 6125
 2. Carlisle Corporation, Carlisle Coatings & Waterproofing Div.; CCW-500
 3. T. C. Miradri; Miraseal 9100
 4. Monsey Bakor; Elasto-Seal 790-11
 5. Tremco; Tremproof 150

2.2 MEMBRANE

- A. Single-component; 100 percent solids; hot fluid-applied, rubberized asphalt with the following properties measured per applicable test methods in CAN/CGSB-37.50:
1. Flash Point: Not less than 260 deg C or not less than 25 deg C above manufacturer's maximum recommended application temperature.
 2. Cone Penetration: 110 maximum at 25 deg C, and 200 maximum at 50 deg C.
 3. Flow: 3 mm maximum at 60 deg C.
 4. Toughness: Not less than 5.5 J.
 5. Ratio of Toughness to Peak Load: Not less than 0.040.
 6. Adhesion Rating: Pass.
 7. Water-Vapor Permeance: 1.7 ng/Pa x s x sq. m.
 8. Water Absorption: 0.35-g maximum mass gain, or 0.18-g maximum mass loss.
 9. Pinholing: Not more than one pinhole.
 10. Low-Temperature Flexibility: No cracking.
 11. Crack Bridging Capability: No cracking, splitting, or loss of adhesion.
 12. Heat Stability: Comply with requirements for penetration, flow, low-temperature flexibility, and viscosity when heated for five hours at manufacturer's recommended application temperature.
 13. Viscosity Test: 2 to 15 seconds.

2.3 AUXILIARY MATERIALS

- A. Primer: ASTM D 41, asphaltic primer.
- B. Elastomeric Flashing Sheet: 50-mil-minimum, nonstaining, uncured sheet neoprene with manufacturer's recommended contact adhesives and predrilled metal termination bars and anchors, with the following physical properties as measured per standard test methods referenced:
1. Tensile Strength: 1,400 psi minimum; ASTM D 412, Die C.

2. Elongation: 300 percent minimum; ASTM D 412.
 3. Tear Resistance: 125 psi minimum; ASTM D 624, Die C.
 4. Brittleness: Does not break at minus 30 deg F; ASTM D 2137.
- C. Sealants and Accessories: Waterproofing manufacturer's recommended sealants and accessories.
- D. Reinforcing Fabric: Manufacturer's recommended spun-bonded polyester fabric.
- E. Separator Sheet: ASTM D 4397, polyethylene sheet, minimum 4 mils thick.
- F. Protection Course: Semirigid sheets of fiberglass or mineral-reinforced-asphaltic core, pressure laminated between two asphalt-saturated fibrous liners and as follows:
1. Thickness: 1/8 inch, nominal, for vertical applications, 1/4 inch, nominal, elsewhere.
 2. Adhesive: Rubber-based solvent type recommended by waterproofing manufacturer for type of protection course.

2.4 MOLDED-SHEET DRAINAGE PANELS

- A. Nonwoven-Geotextile-Faced, Molded-Sheet Drainage Panel: Manufactured composite subsurface drainage panels consisting of a nonwoven, needle-punched geotextile facing with an apparent opening size not exceeding No. 70 sieve laminated to 1 side and a polymeric film bonded to the other side of a 3-dimensional, nonbiodegradable, molded-plastic-sheet drainage core, with a vertical flow rate of 9 to 15 gpm per ft.
1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Carlisle Sure-Drain V
 - b. W. R. Grace Hydroduct 2 or HZ
 - c. Miradri Miradrain 6200 or 6200XL

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer and all parties concerned present, for compliance with requirements and other conditions affecting performance.
1. Verify that concrete has cured and aged for minimum time period recommended by waterproofing manufacturer.
 2. Verify that substrate is visibly dry and free of moisture. Test for capillary moisture by plastic sheet method according to ASTM D 4263.
 3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Clean and prepare substrate according to manufacturer's written instructions. Provide clean, dust-free, and dry substrate for waterproofing application.
- B. Mask off adjoining surfaces not receiving waterproofing to prevent spillage and overspray affecting other construction.
- C. Close off deck drains and other deck penetrations to prevent spillage and migration of waterproofing fluids.
- D. Remove grease, oil, form-release agents, paints, curing compounds, and other penetrating contaminants or film-forming coatings from concrete.
 - 1. Abrasive blast clean concrete surfaces uniformly to expose top surface of fine aggregate according to ASTM D 4259 with a self-contained, recirculating, blast-cleaning apparatus. Remove material to provide a sound surface free of laitance, glaze, efflorescence, curing compounds, concrete hardeners, or form-release agents. Remove remaining loose material and clean surfaces according to ASTM D 4258.
- E. Remove fins, ridges, and other projections and fill honeycombs, aggregate pockets, and other voids.

3.3 JOINTS, CRACKS, AND TERMINATIONS

- A. Prepare and treat substrates to receive waterproofing membrane, including joints and cracks, deck drains, corners, and penetrations according to CAN/CGSB-37.51, "Application of Rubberized Asphalt, Hot-Applied, for Roofing and Waterproofing", and waterproofing system manufacturer's written instructions.
 - 1. Rout and fill joints and cracks in substrate. Before filling, remove dust and dirt according to ASTM D 4258.
 - 2. Embed reinforcing fabric into a layer of hot, rubberized asphalt. Extend reinforcing fabric a minimum of 6 inches on each side of joints and cracks and beyond deck drains, corners, and penetrations.
- B. At expansion joints and discontinuous deck-to-wall or deck-to-deck joints, bridge joints with elastomeric flashing sheet extended a minimum of 6 inches on each side of joints and adhere to substrates in a layer of hot, rubberized asphalt.

3.4 FLASHING INSTALLATION

- A. Install flashing sheets at terminations of waterproofing membrane according to CAN/CGSB-37.51, "Application of Rubberized Asphalt, Hot-Applied, for Roofing and Waterproofing", and waterproofing system manufacturer's written instructions.
- B. Prime substrate with asphalt primer.
- C. Install elastomeric flashing sheet and adhere to deck and wall substrates in a layer of hot, rubberized asphalt.
- D. Extend flashing sheet up walls or parapets a minimum of 8 inches above plaza deck pavers and a minimum of 6 inches onto deck to be waterproofed unless greater coverage is indicated on

the Drawings.

- E. Install termination bars and mechanically fasten to top of flashing sheet at terminations and perimeter of roofing.

3.5 MEMBRANE APPLICATION

- A. Apply rubberized asphalt according to CAN/CGSB-37.51, "Application of Rubberized Asphalt, Hot-Applied, for Roofing and Waterproofing", and manufacturer's written instructions.
- B. Heat rubberized asphalt in an oil- or air-jacketed melter with mechanical agitator specifically designed for heating rubberized-asphalt waterproofing.
- C. Start application with manufacturer's technical representative present.
- D. Apply primer, at manufacturer's recommended rate, over prepared substrate and allow to dry.
- E. Reinforced Membrane: Apply waterproofing to substrates and adjoining surfaces indicated. Spread hot fluid-applied, rubberized asphalt to a thickness of 90 mils; embed reinforcing fabric, overlapping sheets 2 inches; and spread another 125-mil-thick layer to provide a uniform, reinforced, seamless membrane 215 mils thick.
- F. Apply waterproofing over prepared joints and up wall terminations and vertical surfaces to heights indicated or required by manufacturer.
- G. Cover waterproofing with separator sheet with overlapped joints while rubberized asphalt is still hot and before membrane is subject to traffic. Install protection course with overlapped joints over separator sheet.

3.6 MOLDED-SHEET DRAINAGE PANEL INSTALLATION

- A. Place and secure molded-sheet drainage panels to substrate according to manufacturer's written instructions. Use adhesives that do not penetrate waterproofing. Lap edges and ends of geotextile to maintain continuity. Protect installed molded-sheet drainage panels during subsequent construction. For vertical applications, install board insulation used as a protection course before installing drainage panels.

3.7 FIELD QUALITY CONTROL

- A. Flood Testing: Flood test each deck area for leaks, according to recommendations in ASTM D 5957, after completing waterproofing but before overlying construction is placed. Install temporary containment assemblies, plug or dam drains, and flood with potable water.
 - 1. Flood to an average depth of 2-1/2 inches with a minimum depth of 1 inch and not exceeding a depth of 4 inches. Maintain 2 inches of clearance from top of sheet flashings.
 - 2. Flood each area for 24 hours.
 - 3. After flood testing, repair leaks, repeat flood tests, and make further repairs until waterproofing installation is watertight.
- B. Engage an independent testing agency to observe flood testing and examine underside of decks and terminations for evidence of leaks during flood testing.

3.8 CURING, PROTECTING, AND CLEANING

- A. Cure waterproofing according to manufacturer's written recommendations, taking care to prevent contamination and damage during application stages and curing. Do not permit foot or vehicular traffic on unprotected membrane.
- B. Protect waterproofing from damage and wear during remainder of construction period.
- C. Clean spillage and soiling from adjacent construction using cleaning agents and procedures recommended by manufacturer of affected construction.
- D. Obtain approval of the Engineer for both the source of potable water for flood testing and the method of disposal. In no case shall water be disposed of in an uncontrolled fashion.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07160

CRYSTALLINE WATERPROOFING

PART 1 - GENERAL

1.1 SUMMARY

- A. Section includes crystalline waterproofing for application with concrete.
- B. Related Sections:
 - 1. Section 03300 - CAST IN PLACE CONCRETE.
 - 2. Section 07920 - JOINT SEALANTS.

1.2 PERFORMANCE REQUIREMENTS

- A. Provide waterproofing that prevents passage of water under hydrostatic pressure and complies with physical requirements specified as demonstrated by testing performed by independent testing agency of manufacturer's current waterproofing formulation.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated. Include material descriptions and installation instructions for crystalline waterproofing. Indicate material interactions with substrate, accessories, or adjacent materials that could impair the performance of either item.
- B. Qualification Data: For firms and persons specified in "Quality Assurance" Article to demonstrate their capabilities and experience.
- C. Product Certificates: For waterproofing, patching, and plugging materials, from manufacturer.
- D. Product Test Reports: Based on evaluation of comprehensive tests performed by manufacturer and witnessed by a qualified independent testing agency, for crystalline waterproofing.
- E. Field quality-control reports.

1.4 QUALITY ASSURANCE

- A. Qualification of Installer: A qualified installer who is authorized, approved, or licensed to install waterproofing manufacturer's products; and who is eligible to receive waterproofing warranty specified.
- B. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1. Review requirements for waterproofing, including surface preparation specified under other Sections, substrate condition and pretreatment, minimum curing period, forecasted weather conditions, special details and sheet flashings, installation procedures, testing and inspection procedures, and protection and repairs

1.5 PROJECT CONDITIONS

- A. Weather Limitations: Proceed with application only when existing and forecasted weather conditions permit crystalline waterproofing to be performed according to manufacturer's written instructions.
- B. Proceed with waterproofing work only after pipe sleeves, vents, curbs, inserts, drains, and other projections through the substrate to be waterproofed have been completed. Proceed only after substrate defects, including honeycombs, voids, and cracks, have been repaired to provide a sound substrate free of forming materials, including reveal inserts.
- C. Ambient Conditions: Proceed with waterproofing work only if temperature is maintained at 40 deg F(4.4 deg C) or above during work and cure period, and space is well ventilated and kept free of water.

1.6 WARRANTY

- A. Submit written warranty signed by manufacturer and Installer agreeing to repair or replace waterproofing, sheet flashings, and other components of waterproofing system that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 WATERPROOFING MATERIALS

- A. Crystalline Waterproofing: Prepackaged, blend of portland cement, specially treated sand, and active chemicals that, when mixed with water and applied, penetrates into concrete and concrete unit masonry and reacts chemically with the byproducts of cement hydration in the presence of water to develop crystalline growth within substrate capillaries to produce an impervious, dense, waterproof substrate; that has VOC content complying with limits of authorities having jurisdiction; with properties meeting or exceeding the criteria specified below.
 - 1. Available Products: Subject to compliance with requirements, provide one of the following:
 - a. Xypex Chemical Corporation; Xypex
 - b. AQUAFIN, Inc.; AQUAFIN-1C.
 - c. Vandex USA LLC; Vandex Super/Super White.
 - d. Or approved equal.
 - 2. Water Permeability: Maximum zero for water at 30 feet when tested according to CE CRD- C 48.
 - 3. Compressive Strength: Minimum 4000 psi at 28 days when tested according to ASTM C 109/C 109M.
- B. Crystalline Waterproofing Additive: Crystalline type that chemically controls and permanently fixes a non-soluble crystalline structure throughout the capillary voids of the concrete which causes the concrete to become sealed against the penetration of liquids and protects the concrete from deterioration due to harsh environmental conditions.

1. Available Products: Subject to compliance with requirements, provide one of the following:
 - a. Kryton International Inc.
 1. Krystol Internal Membrane (KIM)
 2. Krystol Waterstop Grout
 - b. Xypex Chemical Corporation
 1. Xypex Admix C-500 or Xypex Admix C-1000.

2.2 ACCESSORY MATERIALS

- A. Patching Compound: Factory-premixed cementitious repair mortar, crack filler, or sealant recommended by waterproofing manufacturer for filling and patching tie holes, honeycombs, reveals, and other imperfections; compatible with substrate and other materials indicated; and VOC content complying with limits of authorities having jurisdiction.
- B. Plugging Compound: Factory-premixed cementitious compound with hydrophobic properties and recommended by waterproofing manufacturer; resistant to water and moisture but vapor permeable for all standard applications (vertical, overhead, and horizontal surfaces not exposed to vehicular traffic); compatible with substrate and other materials indicated; and VOC content complying with limits of authorities having jurisdiction.
- C. Portland Cement: ASTM C 150, Type I.
- D. Sand: ASTM C 144.
- E. Water: Potable.

2.3 MIXES

- A. Crystalline Waterproofing: Add prepackaged dry ingredients to water according to manufacturer's written instructions. Mix together with mechanical mixer or by hand to required consistency.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Applicator present, for suitable conditions where waterproofing is to be applied.
- B. Proceed with application only after unsatisfactory conditions have been corrected.
- C. Notify Architect in writing of active leaks or defects that would affect system performance.

3.2 PREPARATION

- A. Protect other work from damage caused by cleaning, preparation, and application of waterproofing.
- B. Provide temporary enclosure to ensure adequate ambient temperatures and ventilation conditions for application.

- C. Do not allow waterproofing, patching, and plugging materials to enter reveals or annular spaces intended for resilient sealants or gaskets, such as joint spaces between pipes and pipe sleeves.
- D. Stop active water leaks with plugging compound according to waterproofing manufacturer's written instructions.
- E. Repair damaged or unsatisfactory substrate with patching compound according to manufacturer's written instructions.
 - 1. At holes and cracks in substrate, remove loosened chips and cut reveal with sides perpendicular to surface, not tapered, and approximately 1 inch deep. Fill reveal with patching compound flush with surface.
- F. Surface Preparation: Comply with waterproofing manufacturer's written instructions to remove efflorescence, chalk, dust, dirt, mortar spatter, grease, oils, paint, curing compounds, and form-release agents to ensure that waterproofing bonds to surfaces.
 - 1. Clean concrete surfaces according to ASTM D 4258.
 - 2. Concrete Joints: Clean reveals according to waterproofing manufacturer's written instructions.

3.3 APPLICATION

- A. General: Comply with waterproofing manufacturer's written instructions for application and curing.
 - 1. Saturate surface with water for several hours prior to application and maintain damp condition until applying waterproofing. Remove standing water.
 - 2. Apply waterproofing to surfaces indicated on Drawings.
 - 3. Number of Coats: Number required for specified water permeability.
 - 4. Application Method: Brush or spray. Apply to ensure that each coat fills voids and is in full contact with substrate or previous coat.
 - 5. Dampen surface between coats.
- B. Final Coat Finish: Smooth.
- C. Waterproofing admixture shall be added to concrete mix at time of batching.
- D. Curing: Moist-cure waterproofing for three days immediately after final coat has set, followed by air drying, unless otherwise recommended in writing by manufacturer.

3.4 FIELD QUALITY CONTROL

- A. After installation and prior to covering waterproofing system, arrange for system manufacturer's technical personnel to inspect waterproofing installation and submit report to Construction Manager.
 - 1. Notify Construction Manager and Owner 48 hours in advance of date and time of inspection.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07162

SPRAY-ON WATERPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: The Design-Builder shall furnish and install all materials, tools, and equipment required to install spray elastomer waterproofing system to suitable concrete, masonry, miscellaneous metal, and other surfaces. Default thickness is 80 mils (2 mm) at any location on the deck to ensure adequate coverage of substrate irregularities. Work shall also include the installation of an integral pre-molded/preformed deck joint system with the spray applied waterproofing. Joint system shall maintain the integrity of the waterproof system and allow for movement as required by design. In addition, an Asphaltic Protection Board shall be provided on top of waterproofing membrane prior to placement of ballast.
- B. References: The publications listed below (latest revision applicable) form a part of this specification to the extent referenced herein. The publications are referred to within the text by the designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) Test Methods:

- ASTM C 836-00 Standard Specification for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course
- ASTM D 2240 Standard Test Method for Rubber Property—Durometer Hardness ASTM D 638 Standard Test Method for Tensile Properties of Plastics
- ASTM D 4060 Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
- ASTM E 96 Standard Test Methods for Water Vapor Transmission of Materials
- ASTM D 4541 Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
- ASTM D 4787 Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates
- ASTM D 6132 Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Applied Organic Coatings Using an Ultrasonic Gage
- ASTM D 1005 Standard Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

1.2 PERFORMANCE REQUIREMENTS

- A. Provide waterproofing membrane that prevents the passage of water.
- B. Provide pre-molded/preformed deck joint system that is compatible with the waterproofing membrane. Joint system shall be manufactured by the same firm that produces the membrane and provide for a minimum movement of 75% of the joint width.

- C. Provide Asphaltic Protection Board that is compatible with the waterproofing membrane.

1.3 SUBMITTALS

- A. The Design-Builder shall submit the following Product Data comprising:
 - 1. Product data sheets and manufacturer's installation specification, including shelf life, storage requirements, mixing and application details and allowable application temperatures and moisture content.
 - 2. Temperature and moisture content
 - 3. MSDS sheets for all products used in the work and any protective clothing, gloves, respirators or other personal protective equipment required for safe installation
 - 4. Substrate preparation details
 - 5. Two (2) samples of the proposed membrane, each eight (8) inches (200mm) square. One sample shall include color, texture and thickness of the proposed membrane system. A separate sample shall demonstrate those characteristics plus the non-skid characteristics of exposed waterproofing for use in areas not covered.
 - 6. Shop Drawings: Show locations and extent of waterproofing. Include details for substrate joints and cracks, sheet flashings, penetrations, inside and outside corners, tie-ins to adjoining waterproofing, and other termination conditions.
 - 7. Installer Certificates: Signed by Manufacturer(s) certifying that installers comply with the requirements of the Manufacture and have been trained by the Manufacture for the installation of the proposed membrane material.
 - 8. Qualification Data: For Installer and for Testing and Inspection Agency.
 - 9. Product Test Reports: From a qualified independent testing agency indicating and interpreting test results of waterproofing for compliance with requirements, based on comprehensive testing of current waterproofing formulations.
 - 10. Test Reports: From Testing and Inspection Agency.
 - 11. Sample Warranty: Copy of special waterproofing manufacturer's and Installer's warranty stating obligations, remedies, limitations, and exclusions before starting waterproofing.

1.4 QUALITY ASSURANCE

- A. All items to be provided under this Section shall be furnished only by manufacturers having a minimum of five (5) years' experience in the manufacture of similar products and systems and shall demonstrate that those products have been installed in environments similar to the proposed installation on elevated structure on the Massachusetts Bay Transportation Authority. Provide a record of at least five (5) previous, separate, similar successful installations in the last five (5) years.
- B. The manufacturer shall be a primary blender with proprietary formulations, an authorized installer program and capacity to provide field technical services as required.

- C. Design-Builder shall offer a 3 year unlimited warranty on all spray-on waterproofing products against defects in materials, workmanship and installation.
- D. If a certification course is available from the manufacturer, the Design-Builder shall have a minimum of two (2) supervisory personnel with currently approved certification from the manufacturer.
- E. The Design-Builder shall schedule a pre-installation conference to review the installation schedule, shut- down details, restricted access procedures, proposed equipment and staffing requirements, mixing and delivery methods, proposed dry film thickness, worker protection, and any safety issues related to the installation. The MBTA and their designates shall be invited to participate in this meeting.
- F. The Design-Builder shall develop a Mockup of the proposed waterproofing system. Mockup shall be applied over an area of 100 square feet to demonstrate surface preparation, crack and joint treatment, corner treatment, thickness, texture, expansion joint installation and execution quality.
 - 1. If MBTA determines mockups do not comply with requirements, reapply waterproofing until mockups are approved.
 - 2. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
- G. The Design-Builder shall schedule a field visit to inspect the surface preparation, equipment set-up and application procedures at each installation location prior to waterproofing installation. The MBTA and their designates shall be invited to participate in this meeting.

1.5 PRODUCT DELIVERY AND STORAGE

- A. Manufactured materials shall be delivered in original, unbroken pallets, packages, containers, or bundles bearing the label of the manufacturer and location of manufacture. All chemical components shall be crated or boxed separately and noted as such to facilitate their movement to a dry indoor storage facility.
- B. All materials or components shall be carefully handled to prevent them and their packaging from damage and shall be stored in dry indoor storage facilities within the temperature range prescribed by the manufacturer until they are required at the project site.
- C. Any products or components exposed to weather or temperatures outside the manufacturer’s allowable range, damaged by shipment or jobsite handling or with damaged or incomplete packaging or labeling shall be replaced at Design-Builder’s expense and removed from the project and project storage sites.

PART 2 - PRODUCTS

2.1 MANUFACTURER

- A. All components of the spray-on waterproofing and deck joint system shall be manufactured by a single company to assure all constituents are compatible and intended for use as a complete waterproofing system.

2.2 GENERAL

A. Acceptable products include the following:

1. Eliminator Waterproofing Membrane Stirling Lloyd Product, Inc.
152 Rockwell Road
Newington, CT 06111
2. Bridge Deck Membrane Bridge Preservation LLC
Box 32336
Kansas City, MO 64171
3. Or MBTA approved equal

B. The membrane shall be 100% solids rapid curing elastomer, installed by spray and shall meet the following physical properties based on the test conducted at a membrane thickness of 80 mils (2mm):

<u>Property of Cured Product</u>	<u>Test Method</u>	<u>Required Value</u>
Dynamic Crack Bridging	ASTM C 836	Pass @ 10 cycles 1/8" (3.2mm) -15°F (-26°C)
Solids Content	---	100%
Hardness	ASTM D 2240	50D
Elongation	ASTM D 638	> 130%
Tensile Strength	ASTM D 638	> 1400 psi
Tabor Abrasion (grams loss, 1000 gm sample, 1000 rev., H-22)	ASTM D 4060	< 0.75 grams
Moisture Vapor Transmission	ASTM E 96	< 0.20 perm
Gel Time	---	< 10 minutes
CureTime	---	< 30 minutes
Open to Light Traffic	---	1 hour

C. Primer shall be as specified by the waterproofing membrane manufacturer.

D. Spray equipment shall be suitable for use with the product specified and approved by the waterproofing membrane manufacturer in writing.

E. The waterproofing shall not be orange, red, yellow or any bright color. Pastel shades of the banned colors may be submitted for consideration by the MBTA, but the MBTA is under no obligation to accept colors that may dilute the effect of using warning colors in worker safety.

F. Asphaltic Protective Board, Provide a protection board that meets the requirements of AREMA Chapter 8, Section 29.10, Paragraph 29.10.3, Asphaltic Panels.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Prior to the installation of primer or spray-on membrane, the Design-Builder shall inspect the substrate preparation with the MBTA's representative. The substrate preparation shall be approved prior to primer or spray-on membrane installation.

3.2 PREPARATION

- A. Provide clean, sound concrete substrate.
- B. Repair any spalls or other defects with rapid curing concrete patch material.
- C. Prepare, treat, rout, and fill cracks in substrate according to ASTM C 898 and waterproofing manufacturer's written instructions. Remove dust and dirt from cracks complying with ASTM D 4258 before coating surfaces.
 - 1. Comply with ASTM C 1193 for joint-sealant installation.
 - 2. Apply bond breaker between sealant and preparation strip.
 - 3. Prime substrate and apply a single thickness of preparation strip extending a minimum of 3 inches along each side of crack. Apply a double thickness of waterproofing and embed a joint reinforcing strip in preparation coat if manufacture recommends it.
- D. Shot blast concrete to remove laitance and other contamination and provide suitable blast profile equal to not less than 60 grit sandpaper and not more than ¼".
- E. Test prepared surface using Elcometer adhesion testing (ASTM D 4541). Minimum allowable pull strength is 150 psi.
- F. Mask surfaces that are not to be waterproofed prior to spray applications.

3.3 INSTALLATION

- A. Spray or roll primer at a rate of 160-200 square feet per gallon, or as per manufacturer's instructions and approval by MBTA, over surfaces to receive waterproof coating system. Allow primer to go tack-free before spraying waterproofing membrane.
- B. Concrete and masonry surfaces may be damp. Broom away all ponded water prior to installation.
- C. Reapply primer if in place more than twelve 12 hrs. hours prior to application of waterproofing.
- D. Spray waterproofing base coat over primed deck surface at a minimum rate of twenty 20 square feet per gallon to achieve a minimum thickness of 80 mils.
- E. Retouch waterproofing membrane coating by filling low spots or areas with inadequate thickness.
- F. Spray additional waterproofing base coats to achieve specified system thickness. Retouch as required.
- G. Repair any damaged areas prior to placement of asphaltic protection board, by removing damaged membrane and re-applying waterproofing to the specified thickness using above methods.

3.4 FIELD QUALITY CONTROL

- A. Since the waterproofing membrane typically gels too rapidly to allow wet film testing, use ultrasonic test equipment or destructive testing to determine stroke per gallon method to assure proper film thickness.
1. Perform one (1) dry film thickness test per two hundred fifty (250) track feet of track bed area treated. These tests may be either ultrasonic or destructive testing and shall be witnessed by the MBTA's representative.
 2. Adhesion Tests, Conduct in accordance with ASTM D4541 to confirm adequate surface preparation. Conduct a minimum of 3 tests and one additional for every 100 track feet installed.
 3. If destructive testing is utilized, the sample removed shall be square and between one (1") inch and two (2") inches per side. The minimum thickness shall be measured per ASTM D 1005.
 4. Flood Testing: Flood test each deck area for leaks, according to recommendations in ASTM D5957, after completing waterproofing but before overlying construction is placed. Install temporary containment assemblies, plug or dam drains, and flood with potable water.
 - a. Flood to an average depth of 2-1/2 inches with a minimum depth of 1 inch and not exceeding a depth of 4 inches. Maintain 2 inches of clearance from top of sheet flashings.
 - b. Flood each area for 24 hours.
 - c. After flood testing, repair leaks, repeat flood tests, and make further repairs until waterproofing installation is watertight. Repair procedures shall be in strict accordance with manufacturer's recommendations.
 - d. Engage an independent testing agency to observe flood testing and examine underside of decks and terminations for evidence of leaks during flood testing.
 5. Repair areas damaged by destructive testing by re-spraying with membrane material or filling with special two-component gun-grade material provided by the manufacturer.
 6. If ultrasonic testing is used, it shall comply with the requirements of ASTM D 6132.
 7. As an additional check, spray equipment may be calibrated and tested to a "spray pass per gallon" of product sprayed, but this shall not replace ultrasonic or destructive testing methods.
 8. Maintain spray and other installation equipment in proper operating condition throughout installation. Provide adequate reserve equipment as required.
 9. The absence of pinholes shall be verified in accordance with ASTM D 4787.
- B. CLEANING
1. Spills and overspray shall be cleaned as they occur.

2. Consult manufacturer's literature and MSDA sheets for proper cleaning products and methods.
3. Clean the site to MBTA's satisfaction prior to Substantial Completion.

C. PROTECTION

1. Install asphaltic protection boards in accordance with the manufacture recommendations.
2. Protect all installed work until ballast has been placed and MBTA has approved of Substantial Completion.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07170

BENTONITE WATERPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies bentonite panel waterproofing for use under slab on grade construction of the elevator and/or escalator pits or as requested by the Engineer.
- B. Related Work:
 - 1. Section 07115 – BITUMINOUS DAMPPROOFING
 - 2. Section 07920 – JOINT SEALANTS Joint sealers.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include product specifications and manufacturer's written installation instructions.
- B. Shop Drawings: Show installation details for interface with other work.
- C. Samples: For each of the following products, in sizes indicated:
 - 1. Waterproofing: 6 inches square.
 - 2. Flexible Flashing Membrane: 6 inches square.
 - 3. Protection Board: 6 inches square.
 - 4. Drainage Mat: 6 inches square.
- D. Material Certificates: For each type of bentonite waterproofing, signed by manufacturers.
- E. Preconstruction Test Reports: For water samples taken at Project site along with recommendations resulting from these tests.
- F. Installer Certificates: Signed by manufacturers certifying that installers comply with requirements.
- G. Qualification Data: For Installer and for Testing and Inspection Agency.
- H. Product Test Reports: From a qualified independent testing agency indicating and interpreting test results of waterproofing for compliance with requirements, based on comprehensive testing of current waterproofing formulations.
- I. Sample Warranty: Copy of special waterproofing manufacturer's and Installer's warranty stating obligations, remedies, limitations, and exclusions before starting waterproofing.

1.3 QUALITY ASSURANCE

- A. Source Limitations: Obtain bentonite waterproofing system through one source from a single manufacturer. Obtain accessory products used with bentonite waterproofing from sources acceptable to bentonite waterproofing manufacturer.

- B. Preconstruction Testing: Engage a qualified independent testing agency to test water for compliance with requirements.
 - 1. Obtain water samples from Project site at approximate locations where waterproofing will be installed and test for acids, alkalis, brine, or other contaminants that may inhibit performance of waterproofing materials.
 - 2. Comply with manufacturer's written instructions for testing.
- C. Mockups: Build mockups to set quality standards for fabrication and installation.
 - 1. Approval of mockups is also for other material and construction qualities specifically approved by Engineer in writing.
 - 2. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless such deviations are specifically approved by Engineer in writing.
- D. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials to Project site in manufacturer's original unopened and undamaged containers.
- B. Store materials in a dry, well-ventilated space.
- C. Remove and replace bentonite materials that have been prematurely exposed to moisture.

1.5 PROJECT CONDITIONS

- A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit bentonite waterproofing to be installed according to manufacturer's written instructions and warranty requirements.
 - 1. Do not apply waterproofing materials to surfaces where ice or frost is visible. Do not apply bentonite waterproofing materials in areas with standing water.
 - 2. Placing of bentonite clay products in panel or composite form on damp surfaces is allowed if approved in writing by manufacturer.

1.6 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of bentonite waterproofing system that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Water penetrating the building or structure resulting from substrate cracking of up to 1/8 inch.
 - b. Deteriorated or displaced waterproofing materials.
 - 2. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 GEOTEXTILE/BENTONITE SHEETS

- A. Geotextile/Bentonite Waterproofing: Minimum of 1.1 lb/sq. ft. of bentonite clay granules between 2 layers of geotextile polypropylene fabric, one woven and one nonwoven, needlepunched and heat fused together.
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. CETCO; Voltex.
 - b. Carlisle Coatings & Waterproofing Inc.; CCW Clay Mat.
 - c. MiraDRI Moisture Protection Products, TC MiraDRI; MiraCLAY.
 - d. Tremco; Paraseal
 - e. Or approved equal.
- B. Contaminant-Resistant Geotextile/Bentonite Waterproofing: Minimum of 1.2 lb/sq. ft. of bentonite clay granules specially formulated for use in saltwater or contaminated ground-water, between 2 layers of geotextile polypropylene fabric, one woven and one nonwoven, needlepunched and heat fused together.
 - 1. Available Products:
 - a. CETCO VOLTEX DS-CR
 - b. Carlisle coatings: for contaminant resistant
 - c. TREMCO; for contaminant resistant

2.2 INSTALLATION ACCESSORIES

- A. Molded-Sheet Drainage Panels: Prefabricated, composite drainage panels, manufactured with a permeable geotextile facing laminated to a molded-plastic, three-dimensional sheet drainage core.
- B. Termination Bar: Mastic tape shall be used for all terminations whether shown on the Contract Drawings or not.
- C. Fasteners: Case-hardened nails or hardened-steel, powder-actuated fasteners. Depending on manufacturer's written requirements, provide 1/2- or 1-inch-diameter washers under fastener heads.
- D. Sealants: As recommended in writing by waterproofing manufacturer. Comply with requirements specified in Section 07920 – Joint Sealants.
- E. Tapes: As recommended in writing by waterproofing manufacturer for joints between sheets or panels.
- F. Adhesive: Water-based adhesive used to secure membrane to both vertical and horizontal surfaces.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for substrate preparations affecting performance of bentonite waterproofing.

1. For the record, prepare written report, endorsed by Installer, listing conditions detrimental to performance of bentonite waterproofing.
 2. Do not proceed with installation until unsatisfactory conditions have been corrected.
- B. Verify that substrate is complete and that all work that will penetrate waterproofing is complete and rigidly installed. Verify locations of waterproofing termination.

3.2 PREPARATION

- A. Coordinate work in the vicinity of waterproofing to ensure proper conditions for installing the waterproofing system and to prevent damage to waterproofing after installation.
- B. Formed Concrete Surfaces: Remove fins and projections. Fill voids, rock pockets, form-tie holes, and other defects greater than 1/8 with bentonite mastic or cementitious patching material according to manufacturer's written instructions.
- C. Horizontal Concrete Surfaces: Remove debris, standing water, oily substances, mud, and similar substances that could impair the bonding ability of concrete or the effectiveness of waterproofing. Fill voids, cracks greater than 1/8 inch, honeycomb areas, and other defects with bentonite mastic or cementitious patching material according to manufacturer's written instructions.
- D. Excavation Support and Protection or Stable Excavation: If water is seeping, use plastic sheets or other suitable means to prevent wetting the bentonite waterproofing. Fill minor gaps and spaces 1/8 inch wide or wider with wood, metal, concrete, or other appropriate filling material. Cover or fill large voids and crevices with cement mortar according to manufacturer's written instructions.

3.3 INSTALLATION, GENERAL

- A. Install waterproofing and accessories according to manufacturer's written instructions, standard details, and recommended practices.
1. Apply linear joint-sealing tubes, bentonite mastic, or both at changes of plane, construction joints in substrate, projections, and penetrations.
 2. Apply granular bentonite around penetrations in horizontal surfaces according to manufacturer's written instructions.
- B. Static Construction Joints: Protect construction joints with bentonite preformed waterstop flexible strips. Either place concrete directly over flexible strips or press strips into preformed cavities. Comply with manufacturer's written instructions where joint waterproofing is not otherwise indicated.
- C. Apply granular bentonite continuously at base of wall waterproofing (on footing, against wall) according to manufacturer's written instructions.
- D. Protect waterproofing from damage and wetting before and during subsequent construction operations. Repair punctures, tears, and cuts according to manufacturer's written instructions.
- E. Apply sealants to comply with requirements specified in Division 7 Section "Joint Sealants" and with manufacturer's written instructions.

3.4 GEOTEXTILE/BENTONITE PANEL INSTALLATION

- A. General: Install a continuous layer of waterproofing sheets with woven geotextile side directly against concrete to be waterproofed. Lap ends and edges a minimum of 4 inches on horizontal and vertical substrates. Stagger end joints between sheets a minimum of 24 inches. Fasten seams by stapling to adjacent sheet or nailing to substrate.
- B. Below Structural Slabs-on-Grade: Place waterproofing sheets on compacted substrate with woven geotextile side up with ends and edges lapped and stapled.
 - 1. Install a layer of waterproofing sheets under footings, grade beams, and pile caps; or continue waterproofing through key joints between footings and foundation walls, and extend a minimum of 8 inches up or beyond perimeter slab forms.
- C. Concrete Walls: Starting at bottom of wall, apply waterproofing sheets horizontally with primary backing side against wall. Secure with powder-actuated fasteners or case-hardened, steel-cap masonry nails; spaced according to manufacturer's written instructions. Extend to bottom of footing, grade beam, or wall and secure as recommended in writing by manufacturer.
 - 1. Termination at Grade: Fasten top edge of waterproofing sheets to wall and protect top edge with sheet metal counterflashing. Cover waterproofing with a lapped course of plastic protection sheets if backfilling does not proceed immediately. Before backfilling, install a layer of protection board.
- D. Excavation Support and Protection (Permanent Shoring): Encase tieback rods, nuts, and plates, using bentonite mastic and waterproofing sheets, according to waterproofing manufacturer's written instructions for each configuration.
 - 1. Install a layer of waterproofing sheets, with ends and edges lapped and nailed to shoring. Cover waterproofing with plastic protection sheets if needed for protection from precipitation; remove plastic sheets before placing concrete.
 - 2. Inspect and repair waterproofing after reinforcing steel has been placed. Coordinate and control concrete placement to avoid damage to waterproofing.
- E. Horizontal Roofs, Plazas, and between Slabs: Starting at lowest point, install a layer of waterproofing sheets, with ends and edges lapped a minimum of 4 inches, fastening every 18 to 24 inches to hold material in place.
 - 1. Terminations at Vertical Surfaces: Provide fillet or cant at intersection of horizontal and vertical substrates. Extend waterproofing to top of curb or to a minimum of 6 inches above plane of waterproofing; secure top edge with sheet metal flashing.
 - 2. Cover waterproofing with a plastic slip-sheet.

3.5 FIELD QUALITY CONTROL

- A. Inspection: Arrange for manufacturer's representative to inspect completed installation and provide written report that installation complies with manufacturer's written instructions. Remove and replace applications of bentonite waterproofing where inspection indicates that it does not comply with specified requirements.
- B. Perform additional testing and inspecting, at Contractor's expense, to determine compliance of replaced or additional work with specified requirements.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07190

WATER REPELLENTS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies water-repellent coatings for the following surfaces not required to have anti-graffiti coating specified in Section 09861:
 - 1. Concrete vertical surfaces.
 - 2. Concrete horizontal surfaces.
 - 3. Concrete unit masonry (unpainted and unglazed).
 - 4. Stonework.

- B. Related Work:
 - 1. Section 03300 – CAST-IN_PLACE CONCRETE.
 - 2. Section 04800 - MASONRY
 - 3. Section 07920 – JOINT SEALANTS
 - 4. Section 09861 – ANTI GRAFFITI COATINGS.

1.2 PERFORMANCE REQUIREMENTS

- A. Performance Testing: Provide water repellents that comply with test-performance requirements indicated, as evidenced by reports of tests performed by manufacturer by a qualified independent testing agency on manufacturer's standard products applied to substrates simulating those on Project using same application methods to be used for Project.

- B. Absorption: Minimum 90 percent reduction of absorption after 24 hours in comparison of treated and untreated specimens.
 - 1. Stone: ASTM C 97.
 - 2. Concrete Unit Masonry: ASTM C 140.
 - 3. Hardened Concrete: ASTM C 642.

- C. Permeability: Minimum 80 percent water-vapor transmission in comparison of treated and untreated specimens, per ASTM D 1653.

- D. Water Penetration and Leakage through Masonry: Minimum 90 percent reduction in leakage rate in comparison of treated and untreated specimens, per ASTM E 514.

- E. Durability: Maximum 5 percent loss of water repellency after 2500 hours of weathering in comparison to specimens before weathering, per ASTM G 154.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated.

1. Include recommendations for method of application, primer, coverage or thickness and protection course. Indicate material interactions with substrate, accessories, or adjacent materials that could impair the performance of either item.
 2. Include manufacturer's printed statement of VOC content.
 3. Include manufacturer's standard colors.
- B. Samples: For each type and color of water repellent and substrate indicated, 12 by 12 inches in size, with specified water-repellent treatment applied to half of each Sample.
- C. Manufacturer Certificates: Signed by manufacturers certifying that water repellents comply with requirements.
- D. Qualifications: Installer. A qualified installer who is authorized, approved or licensed to install water repellent manufactured products and is eligible to provide the warranty specified.
- E. Warranty: Special warranty specified in this Section.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: An employer of workers trained and approved by manufacturer.
- B. Test Application: Apply a finish sample for each type of water repellent and substrate required. Duplicate finish of approved sample.
1. Locate each test application as directed by Engineer.
 2. Size: 10 square feet.
 3. Final approval by Engineer of color and water-repellent application will be from test applications.

1.5 PROJECT CONDITIONS

- A. Limitations: Proceed with application only when the following existing and forecasted weather and substrate conditions permit water repellents to be applied according to manufacturers' written instructions and warranty requirements:
1. Ambient temperature is above 40 deg F.
 2. Concrete surfaces and mortar have cured for more than 28 days.
 3. Concrete or masonry walls are not treated prior to 30 days after building close-in.
 4. Rain or snow is not predicted within 24 hours.
 5. Application proceeds more than 24 hours after surfaces have been wet.
 6. Substrate is not frozen, or surface temperature is above 40 deg F.
 7. Windy conditions do not exist that may cause water repellent to be blown onto vegetation or surfaces not intended to be treated.

1.6 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace materials that fail to maintain water repellency specified in Part 1 "Performance

Requirements" Article within specified warranty period.

1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PENETRATING WATER REPELLENTS

- A. Silane/Siloxane-Blend, Penetrating Water Repellent: Clear, silane and siloxane blends with 3.3 lb/gal. or less of VOCs.
 1. Available Products:
 - a. Anti-Hydro International, Inc.; Aridox 40 VOC.
 - b. Hydrozo, a division of ChemRex; Enviroseal 7 or Hydrozo 100.
 - c. Pecora Corporation; 910W.
 - d. ProSoCo, Inc.; SL 100 Water Repeller.
 - e. Or approved equal.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Clean substrate of substances that might interfere with penetration or performance of water repellents.

Test for moisture content, according to water-repellent manufacturer's written instructions, to ensure that surface is dry enough.

 1. Cast-in-Place Concrete Section 03300: Remove oil, curing compounds, laitance, and other substances that could prevent adhesion or penetration of water repellents.
- B. Test for pH level, according to water-repellent manufacturer's written instructions, to ensure chemical bond to silicate minerals.
- C. Protect adjoining work, including sealant bond surfaces, from spillage or blow-over of water repellent.

Cover adjoining and nearby surfaces of aluminum and glass if there is the possibility of water repellent being deposited on surfaces. Cover live plants and grass.
- D. Coordination with Sealants: Do not apply water repellent until sealants for joints adjacent to surfaces receiving water-repellent treatment have been installed and cured.
 1. Water-repellent work may precede sealant application only if sealant adhesion and compatibility have been tested and verified using substrate, water repellent, and sealant materials identical to those used in the work.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATION

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect the

substrate before application of water repellent and to instruct Applicator on the product and application method to be used.

- B. Apply a heavy-saturation spray coating of water repellent on surfaces indicated for treatment using low-pressure spray equipment to achieve application rate recommended by manufacturer. Prepare a test area to determine proper application rate as recommended by manufacturer. Comply with manufacturer's written instructions for using airless spraying procedure, unless otherwise indicated. Thoroughly mix prior to application.

3.3 CLEANING

- A. Immediately clean water repellent from adjoining surfaces and surfaces soiled or damaged by water- repellent application as work progresses. Repair damage caused by water-repellent application. Comply with manufacturer's written cleaning instructions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07210

BUILDING INSULATION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies perimeter insulation under slabs-on-grade and perimeter foundation wall insulation and batt insulation of the following types:
 - 1. Extruded polystyrene insulation at perimeter walls and slabs.
 - 2. Glass fiber, mineral wool, and foil-faced polyisocyanurate insulation at designated exterior walls.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 04800 - MASONRY: Insulation installed in cavity walls and masonry cells.
 - 3. Section 07550 – MODIFIED BITUMINOUS BUILT UP ROOFING
 - 4. Section 09260 - GYPSUM BOARD ASSEMBLIES: Acoustic insulation in gypsum board assemblies.
 - 5. Division 15 - PLUMBING: Plumbing insulation.
 - 6. Division 15 - HVAC: Mechanical insulation.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include installation instructions and accessories for installation.
- B. Exterior Wall Certification: Submit manufacturer's certification that exterior wall insulation as designed in the assemblies indicated on the Contract Drawings has been tested to meet the requirements of NFPA 285 and passed.

1.3 QUALITY ASSURANCE

- A. Source Limitations: Obtain each type of building insulation through one source from a single manufacturer.
- B. Fire Test Performance for Insulation: Passes NFPA 285, Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load Bearing Wall Assemblies Containing Combustible Components. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
- C. Protect insulation materials from physical damage and from deterioration by moisture, soiling, and other sources. Store inside and in a dry location. Comply with manufacturer's written instructions for handling, storing, and protecting during installation.

D. Protect plastic insulation as follows:

1. Do not expose to sunlight, except to extent necessary for period of installation and concealment.
2. Protect against ignition at all times. Do not deliver plastic insulating materials to Project site before installation time.
3. Complete installation and enclosure of plastic materials as rapidly as possible in each area of construction.
4. Or approved equal.

1.4 PRE-CONSTRUCTION MEETINGS

A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 FOAM-PLASTIC BOARD INSULATION

- A. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
1. DiversiFoam Products.
 2. Dow Chemical Company.
 3. Owens Corning.
- B. Extruded-Polystyrene Board Insulation: ASTM C 578, Type IV, with maximum flame-spread of 75 and smoke-developed 450.
- C. High-Compressive Strength Extruded Polystyrene Board Below Slabs at radiant heating flooring in the Vehicle Maintenance Facility topping slab : ASTM C 578, Type V, 100-psi minimum compressive strength; maximum flame-spread and smoke-developed indexes of 25 and 450, respectively, per ASTM E 84.
- D. Factory Mutual approved when installed as described in the current edition of the FM Approval Guide

2.2 GLASS-FIBER BLANKET INSULATION

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. Johns Manville.
 2. Knauf Insulation.
 3. Owens Corning.

- B. Unfaced, Glass-Fiber Blanket Insulation: ASTM C 665, Type I; with maximum flame-spread and smoke-developed indexes of 25 and 50, respectively, per ASTM E 84; passing ASTM E 136 for combustion characteristics.

2.3 MINERAL-WOOL BOARD

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Roxul Inc.
 - 2. Fibrex Insulations Inc.
 - 3. Isolatek International.
 - 4. Owens Corning; Thermafiber.
- B. Unfaced, Mineral-Wool Board Insulation: ASTM C 612, Type IVB; with maximum flame-spread and smoke-developed indexes of 15 and zero, respectively, per ASTM E 84; passing ASTM E 136 for combustion characteristics.
 - 1. Nominal density of 4 lb/cu. ft. Types IA and IB, thermal resistivity of 4 deg F x h x sq. ft./Btu x in. at 75 deg F minimum.
 - 2. Fiber Color: Natural, except darkened where visible through joints in cladding.
- C. Attachment to Substrate: Manufacturer's recommended mechanical attachment clip spindle.

2.4 FOIL-FACED POLYISOCYANURATE BOARD

- A. Foil-Faced, Polyisocyanurate Board Insulation: ASTM C 1289, Type I, Class 1 or 2, with maximum flame-spread and smoke-developed indexes of 25 and 450, respectively, per ASTM E 84; 25-psi minimum compressive strength.
- B. Factory Mutual approved when installed as described in the current edition of the FM Approval Guide

2.5 AUXILIARY INSULATING MATERIALS

- A. Adhesive for Bonding Insulation: Product with demonstrated capability to bond insulation securely to substrates indicated without damaging insulation and substrates.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements of Sections in which substrates and related work are specified and for other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Clean substrates of substances harmful to materials, including removing projections capable of puncturing materials or of interfering with insulation attachment.

3.3 INSTALLATION GENERAL

- A. Comply with insulation manufacturer's written instructions applicable to products and application indicated.
- B. Install insulation that is undamaged, dry, and unsoiled and that has not been left exposed at any time to ice, rain, and snow.
- C. Extend insulation in thickness indicated to envelop entire area to be insulated. Cut and fit tightly around obstructions and fill voids with insulation. Remove projections that interfere with placement.

3.4 INSTALLATION OF PERIMETER AND UNDER-SLAB INSULATION

- A. On vertical surfaces, set insulation units in adhesive applied according to manufacturer's written instructions. Use adhesive recommended by insulation manufacturer. If not otherwise indicated, extend insulation a minimum of 48 inches below exterior grade line.
- B. On horizontal surfaces, loosely lay insulation units according to manufacturer's written instructions. Stagger end joints and tightly abut insulation units.

3.5 INSTALLATION OF CAVITY-WALL INSULATION

- A. Fit courses of insulation between wall ties (if applicable) and other obstructions, with edges butted tightly in both directions. Press units firmly against inside substrates indicated. Fill gaps with compatible insulating material.
- B. Mechanically attach cavity insulation per manufacturer's instructions. Fit insulation with edges butted tightly in both directions. Do not compress insulation. Maintain cavity width of dimension indicated between insulation and cladding material.

3.6 INSTALLATION OF GLASS-FIBER INSULATION

- A. Glass-Fiber Blanket Insulation:
 - 1. Use insulation widths and lengths that fill the cavities formed by framing members. If more than one length is required to fill the cavities, provide lengths that will produce a snug fit between ends.
 - 2. Place insulation in cavities formed by framing members to produce a friction fit between edges of insulation and adjoining framing members.
 - 3. Maintain 3-inch clearance of insulation around recessed lighting fixtures not rated for or protected from contact with insulation.

3.7 PROTECTION

- A. Protect installed insulation from damage due to harmful weather exposures, physical abuse, and other causes. Provide temporary coverings or enclosures where insulation is subject to abuse and cannot be enclosed and protected by permanent construction immediately after installation.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07215

CLOSED CELL SPRAYED FOAM INSULATION

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies spray polyurethane foam insulation with intumescent thermal barrier.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 - 2. Section 04800 - MASONRY for insulation installed in cavity walls and masonry cells.
 - 3. Section 07131 – SHEET WATERPROOFING.
 - 4. Section 07141 – COLD FLUID-APPLIED WATERPROOFING for insulated drainage panels installed with waterproofing.
 - 5. Section 07550 – MODIFIED BITUMENT BUILT-UP ROOFING for insulation specified as part of roofing construction.

1.2 SUBMITTALS

- A. Product Data: For the type of product indicated. Include product specifications and manufacturers written instructions for installation.
- B. Exterior Wall Certification: Submit manufacturer's certification that exterior wall insulation as designed in the assemblies indicated on the Contract Drawings has been tested to meet the requirements of NFPA 285 and passed.
- C. Manufacturer's Certificates: Certify that product meet or exceed specified requirements.

1.3 QUALITY ASSURANCE

- A. Installer's Qualifications: Installer with at least five years of experience in successfully installing insulation on projects of similar type and complexity.
- B. Fire Test Performance for Insulation: Passes NFPA 285, Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load Bearing Wall Assemblies Containing Combustible Components.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Protect insulation materials from physical damage and from deterioration due to moisture, direct sunlight, and other sources. Store inside and in a dry location. Comply with manufacturer's written instructions for handling, storing, and protecting during installation.

1.5 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under

this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 SPRAY POLYURETHANE FOAM INSULATION

- A. Closed-Cell Polyurethane Foam Insulation: ASTM C 1029, Type II, with maximum flame-spread and smoke-developed indexes of 25 and 450, respectively, per ASTM E 84.
 - 1. Basis-of-Design: Heatlok Soy 200+ by Demilec with 11 mils BlazeLok water-based intumescent coating or equal by BASF, Dow Chemical or equal.
 - 2. Core Density: ASTM D 1622, minimum 2.0 lb/cu. ft.
 - 3. Thermal Resistance: ASTM C 518, minimum of 6.2 deg F x h x sq. ft./Btu x in. at 75 deg F (43 K x m/W at 24 deg C).
 - 4. Compressive Strength: ASTM D 1621, minimum 20 psi.
 - 5. Closed Cell Content: ASTM D, minimum 90 percent.
 - 6. Water Absorption: ASTM D 2842, maximum 2.5 percent.
 - 7. Water Vapor Permeability: ASTM E 96, maximum 2.5 perm/inch.
- B. Primer: Follow manufacturer's recommendation for surfaces conditions.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Clean substrates of substances which are harmful to insulation.
- B. Cover adjacent areas to protect from overspray.
- C. Apply required primers for special conditions as recommended by manufacturer.

3.2 INSTALLATION

- A. Apply sprayed foam insulation in accordance with ASTM C1029 and with insulation manufacturer's written instructions applicable to products and applications indicated.
- B. Do not apply insulation until installation of pipes, ducts, conduits, wiring, and electrical outlets in walls is completed and windows, electrical boxes, and other items not indicated to receive insulation are masked. After insulation is applied, make flush with face of studs by using method recommended by insulation manufacturer.
- C. Apply insulation to uniform monolithic density without voids.
- D. Avoid formation of sub-layer air pockets.

- E. Miscellaneous Voids: Install insulation in miscellaneous voids and cavity spaces where required to prevent gaps in insulation.

3.3 FIELD QUALITY CONTROL

- A. Conduct field inspection and testing in accordance with manufacturers and Contractors instructions for verification of insulation and density.

3.4 CLEANING

- A. Remove overspray from non-prescribed surfaces without causing damage to surfaces.
- B. Remove protective covers from adjacent surfaces.

3.5 PROTECTION

- A. Protect installed products until completion of project per manufacturer's instructions.
- B. Repair or replace damaged products as required.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07220

ROOF DECK INSULATION

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies roof deck insulation.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 07550 - MODIFIED BITUMEN BUILT-UP ROOFING
 - 3. Section 07600 - FLASHING AND SHEET METAL

1.2 REFERENCES

ASTM A-167-94a	Specification for Stainless and Heat-Resisting Chromium Nickel Steel Plate, Sheet and Strip
ASTM A-653	Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvanized) by the Hot-Dip Process
ASTM B-29	Pig Lead
ASTM B-32	Solder Metal
ASTM C-165-95	Test Method for Measuring Compressive Properties of Thermal Insulation
ASTM C-208-95	Specifications for Cellulosic Fiber Insulating Board
ASTM C-209-92	Test Method for Cellulosic Fiber Insulating Board
ASTM C-272-91	Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM C-518-91	Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
ASTM D-5	Test Method for Penetration of Bituminous Materials
ASTM D-36	Test Method for Softening Point of Bitumen (Ring and Ball Apparatus)
ASTM D-312	Specification for Asphalt Used in Roofing
ASTM D-412-92	Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers-Tension
ASTM D-1621-94	Test Method for Compressive Properties of Rigid Cellular Plastics
ASTM D-1622	Test Method for Apparent Density of Rigid Cellular Plastics
ASTM D-1863	Specification for Mineral Aggregate Used on Built-Up Roofs

ASTM D-2126-94	Test Method for Response off Rigid Cellular Plastics to Thermal Humid Aging
ASTM D-2178	Standard Specification for Asphalt Glass Felts used in Roofing and Waterproofing
ASTM D-4601-94	Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing
ASTM D-5147	Sampling and Testing Modified Bituminous Sheet Material
CISPI	Cast Iron Soil Pipe Institute, Washington, D.C.
NRCA	National Roofing Contractors Association, Chicago, IL
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SDI	Steel Deck Institute, St. Louis, Missouri
SPIB	Southern Pine Inspection Bureau, Pensacola, Florida
FS HH-I-1972	Insulation Board, Polyisocyanurate
FS LLL-1-535B	Insulation Board, Thermal (Fiberboard) FM Global Factory Mutual Global Standards

1.3 SUBMITTALS

- A. Product Data: Provide manufacturer's specification data sheets for each product.
- B. Provide approval letters from insulation manufacturer for use of their insulation within this particular roofing system type.
- C. Provide a sample of each insulation type.
- D. Certification
 - 1. Submit roof manufacturer's certification that insulation adhesive furnished is acceptable to roof manufacturer.
 - 2. Submit roof manufacturer's certification that insulation furnished is acceptable to roofing manufacturer as a component of roofing system and is eligible for roof manufacturer's system warranty.
- E. FM Global Forms: Submit copy of FM Global Form 2688 prior to installation of roofing system. This form is available by the BMTA

1.4 DELIVERY, STORAGE AND HANDLING

- A. Deliver products to site with seals and labels intact, in manufacturer's original containers, dry and undamaged.
- B. Store all insulation materials in a manner to protect them from the wind, sun and moisture damage prior to and during installation. Any insulation that has been exposed to any moisture shall be removed from the project site.
- C. Keep materials enclosed in a water tight, ventilated enclosure (i.e. tarpaulins).
- D. Store materials off the ground. Any warped, broken or wet insulation boards shall be removed

from the site.

1.5 QUALITY ASSURANCE

- A. FM Approvals Listing: Provide roofing, base flashings, and component materials that comply with requirements in FM Approvals 4450 and FM Approvals 4470 as part of a membrane roofing system, and that are listed in FM Approvals' "RoofNav" for Class 1 or noncombustible construction, as applicable. Identify materials with FM Approvals markings. Obtain FM acceptance of system proposed for use prior to ordering materials.
 - 1. Roofing System:
 - a. Fire/Windstorm Classification: In accordance with FM recommendations.
 - b. Roofing shall meet FM Global requirements for rating in the field of the roof, perimeter and corners.
 - c. Provide additional securement as required in FMG Data Sheet 1-29.
 - d. Hail Resistance: MH and in accordance with FM recommendations.
 - e. Provide "RoofNav" assembly number corresponding to an FM approved roof assembly. Refer to www.roofnav.com for information and Form 2688.
- B. Fire Classification, ASTM E-108
- C. Submit certification that the roof system furnished meets local or nationally recognized building codes for fire Class A and/or wind resistance.
- D. Contractor shall have minimum 5 years experience installing items on work of similar scope and complexity.

1.6 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 PRODUCTS

2.1 APPROVED EQUIVALENT

- A. Contractor must submit any product not specified a minimum five days before the bid date to Engineer in order for product to be considered for approval. The Engineer will notify Contractor in writing of decision to accept or reject request.

2.2 INSULATION MATERIALS

- A. Provide thicknesses of insulation as indicated. provide combination of types and thicknesses to provide a complete system.
 - 1. Rigid Polyisocyanurate Roof Insulation

- a. Qualities: Rigid, closed cell polyisocyanurate foam core bonded to heavy-duty glass fiber mat facers.
 - 1. Thickness: 3 in.
 - 2. R-Value: Minimum 18.5
 - 3. Board Size: 4' x 8'
 - b. Source
 - 1. E'NRG'Y-2 By NRG Barriers, Inc.
 - 2. Ultra Gard Gold II by Schuller Roofing Systems
 - 3. GAFTEMP Isotherm R by GAF
 - 4. Approved Equivalent
 - c. Insulation board shall meet the following requirements
 - 1. UL, WH or FM listed under Roofing Systems
 - 2. Federal Specification HH-I-1972, Class 1
 - d. Physical Properties
 - 1. Dimensional Stability ASTM D-2126 2% max.
 - 2. Compressive Strength ASTM D-1621 25 psi min.
 - 3. Vapor Permeability ASTM E-96 1 perm max.
 - 4. Foam Core DensityASTM D-1622 2.0 pcf min.
 - 5. Water Absorption ASTM C-209 <1%
 - 6. R-Factor HR per inch
 - 7. Thickness ASTM C-518 5.6 (Design Value)
2. Tapered Polyisocyanurate Roof Insulation (drain sumps only)
- a. Qualities: Factory Tapered, closed cell polyisocyanurate foam core bonded to heavy-duty glass fiber mat facers.
 - 1. Taper Thickness: Minimum 1 in. at low points.
 - 2. Tapered Slope: 1/4 in. per foot.
 - 3. Average R-Value: Minimum 10.0.
 - b. Source
 - 1. E'NRG'Y-2 by NRG Barriers, Inc.
 - 2. Ultra Gard Gold II by Schuller Roofing Systems
 - 3. GAFTEMP Isotherm R by GAF
 - 4. Approved Equivalent
 - c. Insulation board shall meet the following requirements
 - 1. FM listed under Roofing Systems
 - 2. Federal Specification HH-I-1972, Class 1
3. High Density Fiberboard Roof Insulation

- a. Qualities: Rigid, composed of interlocking fibers factory blended treated with asphalt on the topside.
 - 1. Board Size: 4' x 4'
 - 2. Thickness: Minimum ½ in.
- b. Source
 - 1. Celotex
 - 2. Temple Inland
 - 3. GAF Building Materials Corporation
 - 4. Approved Equivalent
- c. Insulation board shall meet the following requirements
 - 1. FM listed under Roofing Systems.
 - 2. Federal Specification LLL-I-535-B.
- d. Physical Properties

1. Dry Density	ASTM C-208	17.5 pcf.
2. Compressive Strength	ASTM C-165	45 psi min.
3. Linear Expansion	ASTM C-208,209	0.5% max.
4. Foam Core Density	ASTM C-1622	2.0 pcf min.
5. Water Absorption	ASTM C-208	10% max.
6. R-Factor HR per inch	ASTM C-518	2.5 (Design Value)
7. Thickness		

2.3 RELATED MATERIALS

- A. Fiber Cant and Tapered Edge Strips: Performed rigid insulation units of sizes/shapes indicated, matching insulation board or of perlite or organic fiberboard, as per the approved manufacturer.
 - 1. Acceptable Manufacturers
 - a. The Garland Company, Inc.
 - b. Celotex
 - c. Johns-Manville Roofing Systems
 - d. International Permalite, Inc.
 - e. Or approved equal.
- B. Protection Board: Pre-molded semi-rigid asphalt composition board ½ in.
- C. Roof Board Joint Tape: 6” wide glass fiber mat with adhesive compatible with insulation board facers.
- D. Fasteners and Adhesives: Comply with FM Global requirements according to the wind rating for each building. The wind rating will be covered under 07550 - MODIFIED BITUMEN BUILT-UP ROOFING, typically 18-24-32 and 12 inches on center, but subject to change from FM Global.
- E. Single component insulation adhesive.

1. Performance Requirements:
 - a. Tensile Strength (ASTM D-412-92).... 250 psi
 - b. Density (ASTM D-1875-90) 8.5 lbs/gal
 - c. Viscosity (ASTM D-2556-93a)..... 2,000-60,000 cP
 - d. Peel Strength (ASTM D-903)17 lb/in
 - e. Flexibility (ASTM D-816-12) Pass @ -70°F

PART 3 EXECUTION

3.1 INSPECTION OF SURFACES

- A. Roofing contractor shall be responsible for preparing an adequate substrate to receive insulation.
 1. Verify that work, which penetrates roof deck, has been completed.
 2. Verify that wood nailers are properly and securely installed.
 3. Examine surfaces for defects, rough spots, ridges, depressions, foreign material, moisture, and unevenness.
 4. Do not proceed until defects are corrected.
 5. Do not apply insulation until substrate is sufficiently dry.
 6. Broom clean substrate immediately prior to application.
 7. Use additional insulation to fill depressions and low spots that would otherwise cause ponding water.
 8. Verify that temporary roof has been completed.

3.2 INSTALLATION

- A. Mechanical Attachment: Install insulation and protection board with mechanical fasteners all the way through to the metal decking.
 1. All boards shall be cut and fitted where the roof deck intersects a vertical surface. The boards shall be cut to fit a minimum of ¼” away from the vertical surface.
 2. Fasten insulation according to requirements of FM's "Approval Guide" for specified Windstorm Resistance Classification and the insulation and roofing system manufacturers' written instructions.
- A. Fasten insulation according to requirements of FM's "Approval Guide" for specified Windstorm Resistance Classification and the insulation and roofing system manufacturers' written instructions.
- B. Spacing pattern of fasteners shall be as per manufacturer’s recommendations to meet the FM requirements. Placement of any fastener from edge of insulation board shall be a minimum of three inches, and a maximum of six (6) inches.

3.3 CLEANING

- A. Remove debris and cartons from roof deck. Leave insulation clean and dry, ready to receive roofing membrane.

PART 4 MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07270

AIR AND VAPOR BARRIER SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies fluid-applied, vapor-retarding membrane air barriers.
- B. Related Work:
 - 1. Section 04800 – MASONRY: masonry substrate for air and vapor barrier system and insulation in cavity wall installed over air and vapor barrier system.
 - 2. Section 07550 - MODIFIED BITUMEN BUILT-UP ROOFING: connection to roof air and vapor barriers.

1.2 DEFINITIONS

- A. Air Barrier Assembly: The collection of air barrier materials and auxiliary materials applied to an opaque wall or soffit, including joints and junctions to abutting construction, to control air movement through the wall.

1.3 PERFORMANCE REQUIREMENTS

- A. General: Air barrier shall be capable of performing as a continuous vapor-retarding air barrier and as a liquid-water drainage plane flashed to discharge to the exterior incidental condensation or water penetration. Air barrier assemblies shall be capable of accommodating substrate movement and of sealing substrate expansion and control joints, construction material changes, penetrations, and transitions at perimeter conditions without deterioration and air leakage exceeding specified limits.
- B. Air Barrier Assembly Air Leakage: Not to exceed 0.03 cfm/sq. ft. of surface area at 1.57 lbf/sq. ft., ASTM E 283.

1.4 PRECONSTRUCTION TESTING

- A. Mockup Testing: Air barrier assemblies shall comply with performance requirements indicated, as evidenced by reports based on mockup testing by a qualified testing agency.
 - 1. Contractor shall engage a qualified testing agency.
 - 2. Quantitative Air Leakage Testing: Testing of the mockup for air leakage will be conducted not to exceed the test pressure differential, positive and negative, indicated in "Performance Requirements" Article for air barrier assembly air leakage when tested according to ASTM E 283.
 - 3. Notify Engineer a minimum of seven days in advance of the dates and times when mockup testing will take place.

1.5 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under

this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

1.6 SUBMITTALS

- A. Product Data: Include manufacturer's written instructions for evaluating, preparing, and treating substrate; technical data; and tested physical and performance properties of air barrier.
- B. Shop Drawings: Show locations and extent of air barrier. Include details for substrate joints and cracks, counterflashing strip, penetrations, inside and outside corners, terminations, and tie-ins with adjoining construction.
 - 1. Include details of interfaces with other materials that form part of air barrier.
 - 2. Include details of mockups.
- C. Product Certificates: For air barriers, certifying compatibility of air barrier and accessory materials with Project materials that connect to or that come in contact with air barrier; signed by product manufacturer.
- D. Qualification Data: For Applicator.
- E. Product Test Reports: Based on evaluation of comprehensive tests performed by a qualified testing agency, for air barriers.
- F. Exterior Wall Certification: Submit manufacturer's certification that air vapor barrier as designed in the assemblies indicated on the Contract Drawings has been tested to meet the requirements of NFPA 285 and passed.

1.7 QUALITY ASSURANCE

- A. Applicator Qualifications: A firm experienced in applying air barrier materials similar in material, design, and extent to those indicated for this Project, whose work has resulted in applications with a record of successful in-service performance.
- B. Mockups: Before beginning installation of air barrier, build mockups of exterior wall assembly 150 sq. ft., incorporating backup wall construction, external cladding, window, door frame and sill, insulation, and flashing to demonstrate surface preparation, crack and joint treatment, and sealing of gaps, terminations, and penetrations of air barrier membrane.
 - 1. Coordinate construction of mockup to permit inspection by Contractor's testing agency of air barrier before external insulation and cladding is installed.
 - 2. Include junction with roofing membrane, building corner condition, and foundation wall intersection.
 - 3. If the Engineer determines mockups do not comply with requirements, reconstruct mockups and apply air barrier until mockups are approved.
 - 4. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

- C. Preinstallation Conference: Conduct conference at Project site.
 - 1. Include installers of other construction connecting to air barrier, such as roofing, waterproofing, architectural precast concrete, masonry, joint sealants, windows, glazed curtain walls, and door frames.
 - 2. Review air barrier requirements including surface preparation, substrate condition and pretreatment, minimum substrate curing period, forecasted weather conditions, special details and sheet flashings, mockups, installation procedures, sequence of installation, testing and inspecting procedures, and protection and repairs.

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Store liquid materials in their original undamaged packages in a clean, dry, protected location and within temperature range required by air barrier manufacturer.
- B. Remove and replace liquid materials that cannot be applied within their stated shelf life.
- C. Store rolls according to manufacturer's written instructions.
- D. Protect stored materials from sunlight.

1.9 PROJECT CONDITIONS

- A. Environmental Limitations: Apply air barrier within the range of ambient and substrate temperatures recommended by air barrier manufacturer. Protect substrates from environmental conditions that affect performance of air barrier. Do not apply air barrier to a damp or wet substrate or during snow, rain, fog, or mist.

PART 2 - PRODUCTS

2.1 VAPOR-RETARDING MEMBRANE AIR BARRIER

- A. Fluid-Applied, Vapor-Retarding Membrane Air Barrier: Synthetic polymer membrane.
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Synthetic Polymer Membrane:
 - 1. Grace, W. R., & Co. - Conn.; Perm-A-Barrier Liquid.
 - 2. Henry Company; Air-Bloc 32.
 - 3. Rubber Polymer Corporation, Inc.; Rub-R-Wall Airtight.
 - 4. Or approved equal
 - 2. Physical and Performance Properties:
 - a. Membrane Air Permeance: Not to exceed 0.004 cfm/sq. ft. of surface area at 1.57-lbf/sq. ft. pressure difference; ASTM E 2178.
 - b. Ultimate Elongation: 500 percent minimum; ASTM D 412, Die C.
 - c. Vapor Permeance: 0.1 perm (5.8 ng/Pa x s x sq. m); ASTM E 96/E 96M.

2.2 AUXILIARY MATERIALS

- A. General: Auxiliary materials recommended by air barrier manufacturer for intended use and compatible with air barrier. Liquid-type auxiliary materials shall comply with VOC limits of authorities having jurisdiction.
- B. Primer: Liquid waterborne or solvent-borne primer recommended for substrate by manufacturer of air barrier material.
- C. Counterflashing Strip: Modified bituminous 40-mil-thick, self-adhering sheet consisting of 32 mils of rubberized asphalt laminated to an 8-mil-thick, cross laminated polyethylene film with release liner backing.
- D. Butyl Strip at Termination with EPDM or TPO Roofing Membrane: Vapor-retarding, 30- to 40-mil- thick, self adhering; polyethylene-film-reinforced top surface laminated to layer of butyl adhesive, with release liner backing.
- E. Modified Bituminous Strip To Cover Cracks and Joints and Terminate Air Barrier to Compatible Roofing Membrane: Vapor-retarding, 40-mil-thick, smooth-surfaced, self-adhering; consisting of 36 mils of rubberized asphalt laminated to a 4-mil- polyethylene film with release liner backing.
- F. Termination Mastic: Cold fluid-applied elastomeric liquid; trowel grade.
- G. Substrate Patching Membrane: Manufacturer's standard trowel-grade substrate filler.
- H. Adhesive and Tape: Air barrier manufacturer's standard adhesive and pressure-sensitive adhesive tape.
- I. Stainless-Steel Sheet: ASTM A 240/A 240M, Type 304, 0.0187 inch thick, and Series 300 stainless- steel fasteners.
- J. Sprayed Polyurethane Foam Sealant to Fill Gaps at Penetrations and Openings: 1- or 2-component, foamed-in-place, polyurethane foam sealant, 1.5 to 2.0 lb/cu. ft. density; flame spread index of 25 or less according to ASTM E 162; with primer and noncorrosive substrate cleaner recommended by foam sealant manufacturer.
- K. Modified Bituminous Transition Strip to Seal Air Barrier Terminations with Glazing Systems: Vapor- retarding, 40-mil-thick, smooth-surfaced, self-adhering; consisting of 36 mils of rubberized asphalt laminated to a 4-mil-thick polyethylene film with release liner backing.
- L. Elastomeric Flashing Sheet to Seal Air Barrier Terminations with Glazing Systems: ASTM D 2000, 2BC415 to 3BC620, minimum 50- to 65-mil-thick, cured sheet neoprene with manufacturer's recommended contact adhesives and lap sealant with stainless-steel termination bars and fasteners.
- M. Preformed Silicone-Sealant Extrusion to Seal Air Barrier Terminations with Glazing Systems: Manufacturer's standard system consisting of cured low-modulus silicone extrusion, sized to fit opening widths, with a single-component, neutral-curing, Class 100/50 (low-modulus) silicone sealant for bonding extrusions to substrates.

- 1. Available Products: Subject to compliance with requirements, products that may

be incorporated into the Work include, but are not limited to, the following:

- a. Dow Corning Corporation, 123 Silicone Seal.
 - b. GE Silicone, UltraSpan US1100.
 - c. Pecora Corporation, Sil-Span.
 - d. Tremco, Incorporated, Spectrem EZ Seal.
 - e. Or approved equal.
- N. Joint Sealant: ASTM C 920, single-component, neutral-curing silicone; Class 100/50 (low-modulus), Grade NS, Use NT related to exposure, and, as applicable to joint substrates indicated, Use O. Comply with Section 07920 - JOINT SEALANTS.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements and other conditions affecting performance.
1. Verify that substrates are sound and free of oil, grease, dirt, excess mortar, or other contaminants.
 2. Verify that concrete has cured and aged for minimum time period recommended by air barrier manufacturer.
 3. Verify that concrete is visibly dry and free of moisture. Test for capillary moisture by plastic sheet method according to ASTM D 4263.
 4. Verify that masonry joints are flush and completely filled with mortar.
 5. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SURFACE PREPARATION

- A. Clean, prepare, and treat substrate according to manufacturer's written instructions. Provide clean, dust-free, and dry substrate for air barrier application.
- B. Mask off adjoining surfaces not covered by air barrier to prevent spillage and overspray affecting other construction.
- C. Remove grease, oil, bitumen, form-release agents, paints, curing compounds, and other penetrating contaminants or film-forming coatings from concrete.
- D. Remove fins, ridges, mortar, and other projections and fill honeycomb, aggregate pockets, holes, and other voids in concrete with substrate-patching membrane.
- E. Remove excess mortar from masonry ties, shelf angles, and other obstructions.
- F. Prepare, fill, prime, and treat joints and cracks in substrates. Remove dust and dirt from joints and cracks according to ASTM D 4258. Install modified bituminous strips and center over treated construction and contraction joints and cracks exceeding a width of 1/16 inch.
- G. Bridge and cover isolation joints expansion joints and discontinuous deck-to-wall and deck-to-deck joints with overlapping modified bituminous strips.

- H. At changes in substrate plane, apply sealant or termination mastic beads at sharp corners and edges to form a smooth transition from one plane to another.
- I. Cover gaps in substrate plane and form a smooth transition from one substrate plane to another with stainless-steel sheet mechanically fastened to structural framing to provide continuous support for air barrier.

3.3 JOINT TREATMENT

- A. Concrete and Masonry: Prepare, treat, rout, and fill joints and cracks in substrate according to ASTM C 1193 and air-barrier manufacturer's written instructions. Remove dust and dirt from joints and cracks complying with ASTM D 4258 before coating surfaces.
 - 1. Prime substrate and apply a single thickness of air-barrier manufacturer's recommended preparation coat extending a minimum of 3 inches (75 mm) along each side of joints and cracks. Apply a double thickness of fluid air-barrier material and embed a joint reinforcing strip in preparation coat.
- B. Gypsum Sheathing: Fill joints greater than 1/4 inch (6 mm) with sealant according to ASTM C 1193 and air-barrier manufacturer's written instructions. Apply first layer of fluid air-barrier material at joints. Tape joints with joint reinforcing strip after first layer is dry. Apply a second layer of fluid air-barrier material over joint reinforcing strip.
- C. Exterior wall assemblies: treat joints between panels of metal studs with sheet metal cladding according to instructions of 07920.

3.4 INSTALLATION

- A. Apply fluid air-barrier material to form a seal with strips and transition strips and to achieve a continuous air barrier according to air-barrier manufacturer's written instructions. Apply fluid air-barrier material within manufacturer's recommended application temperature ranges.
- B. Prepare, treat, and seal vertical and horizontal surfaces at terminations and penetrations with termination mastic and according to ASTM D 6135.
- C. Apply primer to substrates at required rate and allow to dry. Limit priming to areas that will be covered by air barrier sheet in same day. Reprime areas exposed for more than 24 hours. Prime glass-fiber-surfaced gypsum sheathing with number of prime coats needed to achieve required bond, with adequate drying time between coats.
- D. Apply and firmly adhere modified bituminous sheets horizontally over area to receive air barrier sheets. Accurately align sheets and maintain a uniform 2-1/2-inch-minimum lap widths and end laps. Overlap and seal seams and stagger end laps to ensure airtight installation.
 - 1. Apply sheets in a shingled manner to shed water without interception by any exposed sheet edges.
 - 2. Roll sheets firmly to enhance adhesion to substrate.
- E. Apply continuous modified bituminous sheets over modified bituminous strips bridging substrate cracks, construction, and contraction joints.
- F. Seal strips and transition strips around masonry reinforcing or ties and penetrations with

termination mastic.

- G. Seal top of non-metallic through-wall flashings to air barrier sheet with an additional 6-inch-wide strip.
- H. Seal exposed edges of metallic sheets at seams, cuts, penetrations, and terminations not concealed by metal counterflashings or ending in reglets with termination mastic.
- I. Install air barrier sheets and auxiliary materials to form a seal with adjacent construction and to maintain a continuous air barrier.
 - 1. Coordinate the installation of air barrier with installation of roofing membrane and base flashing to ensure continuity of air barrier with roofing membrane.
 - 2. Install compatible strip on roofing membrane or base flashing so that a minimum of 3 inches of coverage is achieved over both substrates.
- J. Connect and seal exterior wall air barrier membrane continuously to roofing membrane air barrier, concrete below-grade structures, floor-to floor construction, exterior glazing and window systems, glazed curtain-wall systems, storefront systems, exterior louvers, exterior door framing, and other construction used in exterior wall openings using accessory materials.
- K. Wall Openings: Prime concealed perimeter frame surfaces of windows, curtain walls, storefronts, and doors. Apply membrane specified below so that a minimum of 3 inches of coverage is achieved over both substrates. Maintain 3 inches of full contact over firm bearing to perimeter frames with not less than 1 inch of full contact.
 - 1. Modified Bituminous Transition Strip: Roll firmly to enhance adhesion.
 - 2. Elastomeric Flashing Sheet: Apply adhesive to wall, frame, and flashing sheet. Install flashing sheet and termination bars, fastened at 6 inches o.c. Apply lap sealant over exposed edges and on cavity side of flashing sheet.
 - 3. Preformed Silicone-Sealant Extrusion: Set in full bed of silicone sealant applied to walls, frame, and membrane.
- L. Fill gaps in perimeter frame surfaces of windows, curtain walls, storefronts, doors, and miscellaneous penetrations of air barrier membrane with foam sealant.
- M. At end of each working day, seal top edge of membrane to substrate with termination mastic.
- N. Apply joint sealants forming part of air barrier assembly within manufacturer's recommended application temperature ranges. Consult manufacturer when sealant cannot be applied within these temperature ranges.
- O. Repair punctures, voids, and deficient lapped seams in air barrier. Slit and flatten fishmouths and blisters. Patch with air barrier sheet extending 6 inches beyond repaired areas in all directions.
- P. Do not cover air barrier until it has been tested and inspected by Contractor's testing agency.
- Q. Correct deficiencies in or remove air barrier that does not comply with requirements; repair substrates and reapply air barrier components.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Contractor shall engage a qualified testing agency to perform tests and inspections and prepare test reports.
- B. Inspections: Air barrier materials and installation are subject to inspection for compliance with requirements. Inspections may include the following:
 - 1. Continuity of air barrier system has been achieved throughout the building envelope with no gaps or holes.
 - 2. Continuous structural support of air barrier system has been provided.
 - 3. Masonry and concrete surfaces are smooth, clean and free of cavities, protrusions, and mortar droppings.
 - 4. Site conditions for application temperature and dryness of substrates have been maintained.
 - 5. Maximum exposure time of materials to UV deterioration has not been exceeded.
 - 6. Surfaces have been primed.
 - 7. Laps in sheet materials have complied with the minimum requirements and have been shingled in the correct direction (or mastic applied on exposed edges), with no fishmouths.
 - 8. Termination mastic has been applied on cut edges.
 - 9. Strips and transition strips has been firmly adhered to substrate.
 - 10. Compatible materials have been used.
 - 11. Transitions at changes in direction and structural support at gaps have been provided.
 - 12. Connections between assemblies (membrane and sealants) have complied with requirements for cleanliness, preparation and priming of surfaces, structural support, integrity, and continuity of seal.
 - 13. All penetrations have been sealed.
- C. Tests: Testing to be performed will be determined by Contractor's testing agency from among the following tests:
 - 1. Qualitative Testing: Air barrier assemblies will be tested for evidence of air leakage according to ASTM E 1186.
 - 2. Quantitative Air Leakage Testing: Testing not to exceed the test pressure differential, positive and negative, indicated in "Performance Requirements" Article for air barrier assembly air leakage according to ASTM E 283.
- D. Remove and replace deficient air barrier components and retest as specified above.

3.6 CLEANING AND PROTECTION

- A. Protect air barrier system from damage during application and remainder of construction period, according to manufacturer's written instructions.
 - 1. Protect air barrier from exposure to UV light and harmful weather exposure as required by manufacturer. Remove and replace air barrier exposed to these conditions for more than 30 days.
 - 2. Protect air barrier from contact with creosote, uncured coal-tar products, TPO, EPDM, flexible PVC membranes, and sealants not approved by air barrier manufacturer.

- B. Clean spills, stains, and soiling from adjacent construction that would be exposed in the completed work using cleaning agents and procedures recommended by manufacturer of affected construction.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07420

METAL WALL PANEL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Factory-formed and assembled insulated metal wall panels.
 2. Honeycomb-core metal wall panels.
 3. Metal plate wall panels.
 4. Standing seam metal wall panels.
 5. Bullet-resistant fiberglass panels behind metal wall panel systems at locations indicated.
- B. Related Work:
1. Section 01800, SUSTAINABILITY REQUIREMENTS
 2. Section 05411, LIGHT GAUGE METAL FRAMING.
 3. Section 07210, BUILDING PERIMETER INSULATION.
 4. Section 07270, AIR AND VAPOR BARRIER
 5. Section 07422, TRANSLUCENT WALL PANELS.
 6. Section 07423, RAIN SCREEN SYSTEMS.
 7. Section 07600, FLASHING AND SHEET METAL
 8. Section 07920, JOINT SEALANTS
 9. Section 08801, GLASS AND GLAZING
 10. Section 08910, GLAZED METAL FRAMED CURTAIN WALLS
 11. Section 09900, PAINTING
- C. Drawing Coordination: Refer to the Drawings for the following keynotes for this Section:
1. W-12 STAINLESS STEEL PANEL, 316, ANGEL HAIR FINISH
 2. W-13 STAINLESS STEEL PANEL, 316, #4 FINISH (PANEL & TRIM)
 3. W-14 STAINLESS STEEL PANEL, PERFORATED, 316, #4 FINISH
 4. W-15 STAINLESS STEEL PANEL, HONEYCOMB PANEL, 316, #4 FINISH
 5. W-16 STAINLESS STEEL PANEL SYSTEM, PICKLED/PASSIVATED FINISH
 6. W-18 ALUMINUM FORMED PANEL SYSTEM - PAINTED/PERFORATED
 7. W-24 PORCELAIN ENAMEL PANEL – GALVANIZED STEEL
 8. W-25 316 STAINLESS STEEL PANEL - PERFORATED & FINISHED WITH ANGEL HAIR FINISH
 9. W-32 ALUMINUM PERFORATED PAINTED PANEL

- 10. W-34 ALUMINUM FORMED PANEL, NON PERFORATED
- 11. W-35 ALUMINUM PAINTED INSULATED METAL PANEL
- 12. W-36 ZINC STANDING SEAM

D. For all painted metal panels, contractors price shall include (6) six custom colors in addition to the standard panel colors for each type of panel.

1.2 DEFINITION

A. Metal Wall Panel Assembly: Metal wall panels, attachment system components, miscellaneous metal framing, and accessories necessary for a complete weathertight wall system.

1.3 PERFORMANCE REQUIREMENTS

A. General Performance: Metal wall panel assemblies shall comply with performance requirements without failure due to defective manufacture, fabrication, installation, or other defects in construction.

B. Delegated Design: Design metal wall panel assembly, including comprehensive engineering analysis prepared under the supervision of and signed and sealed by a qualified professional engineer licensed in the Commonwealth of MA, using performance requirements and design criteria indicated.

C. Structural Performance: Provide metal wall panel assemblies capable of withstanding the effects of the following loads and stresses within limits and under conditions indicated, based on testing according to ASTM E 330:

- 1. Wind Loads: Determine loads based on the following minimum design wind pressures, whichever is more stringent:
 - a. Uniform pressure of 20 lbf/sq. ft., acting inward or outward.
 - b. In accordance with FM Global data sheet 1-28 and safety factors as applicable.

2. Deflection Limits: Metal-faced composite wall panel assemblies shall withstand wind loads with horizontal deflections no greater than 1/180 of the span.

D. Air Infiltration: Air leakage through assembly of not more than 0.06 cfm/sq. ft. (0.3 L/s per sq. m) of wall area when tested according to ASTM E 283 at a static-air-pressure difference of 6.24 lbf/sq. ft. (300 Pa).

E. Water Penetration: No water penetration when tested according to ASTM E 331 at the test-pressure difference of 6.24 lbf/sq. ft. (300 Pa)

F. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes by preventing buckling, opening of joints, overstressing of components, failure of joint sealants, failure of connections, and other detrimental effects. Base calculations on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.

- 1. Temperature Change (Range): Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C) ambient; 180 deg F (100 deg C) material surfaces.

G. Galvanic reactions: dissimilar metals shall be separated by neoprene, bituminous paint or similar substance. This shall not be visible to public in final configuration.

- H. All exterior metal panels shall be designed and comply with the requirements of FM Global 1-28 requirements.

1.4 SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each type of panel and accessory.
- B. Shop Drawings: Show fabrication and installation layouts of metal wall panels; details of edge conditions, joints, panel profiles, corners, anchorages, attachment system, trim, flashings, closures, and accessories; and special details. Distinguish among factory-, shop-, and field-assembled work.
 - 1. Accessories: Include details of the following items, at a scale of not less than 1-1/2 inches per 12 inches (1:10):
 - a. Flashing and trim.
 - b. Anchorage systems.
- C. Samples For Verification: For each type of exposed finish required, prepare samples of size indicated below:
 - 1. Metal Wall Panels: 12 inches (300 mm) long by actual panel width. Include fasteners, closures, and other metal-faced composite wall panel accessories.
 - 2. Trim and Closures: 12 inches (300 mm) long. Include fasteners and other exposed accessories.
 - 3. Accessories: 12-inch-(300-mm-) long samples for each type of accessory.
- D. Delegated-Design Submittal: For wall panel assembly indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation; as stated in 1.4.B.
- E. Coordination Drawings: Exterior elevations, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Wall panels and attachments.
 - 2. Subgirts and/or furring and hat channels.
 - 3. Wall-mounted items including doors, windows, louvers, and lighting fixtures.
 - 4. Penetrations of wall by pipes and utilities.
 - 5. Adjacent construction.
- F. Qualification Data: For Installer, and professional engineer. Installed shall be trained or certified by manufacturer, installer and engineer shall have min. 5 years experience performing work of similar scope and complexity.
- G. Compatibility and Adhesion Test Reports: From sealant manufacturer, indicating the following:
 - 1. Materials forming joint substrates and joint-sealant backings have been tested for compatibility and adhesion with joint sealants.

2. Interpretation of test results and written recommendations for primers and substrate preparation needed for adhesion.
- H. Product Test Reports: Based on evaluation of comprehensive tests performed by a qualified testing agency, for each product.
 - I. Maintenance Data: For metal wall panels to include in maintenance manuals.
 - J. Warranties: Samples of special warranties.

1.5 QUALITY ASSURANCE:

- A. Installer Qualifications: An employer of workers trained and approved by manufacturer.
- B. Testing Agency Qualifications: Qualified according to ASTM E 329 for testing indicated.
- C. Source Limitations: Obtain each type of metal wall panel from single source from single manufacturer.
- D. Preconstruction Compatibility and Adhesion Testing: Submit samples of materials that will contact joint sealants to joint-sealant manufacturers for testing indicated in subparagraphs below:
 1. Use manufacturer's standard test methods to determine whether priming and other specific joint preparation techniques are required to obtain rapid, optimum adhesion of joint sealants to joint substrates.
 - a. Perform tests under environmental conditions replicating those that will exist during installation.
 2. Submit no fewer than nine pieces of each type of material, including joint substrates, shims, joint-sealant backings, secondary seals, and miscellaneous materials.
 3. Schedule enough time for testing and analyzing results to prevent delaying the Work.
 4. For materials failing tests, obtain joint-sealant manufacturer's written instructions for corrective measures, including use of specially formulated primers.
- E. Fire-Resistance Ratings: Where indicated, provide metal-faced composite wall panels identical to those of assemblies tested for fire resistance per ASTM E 119 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 1. Indicate design designations from UL's "Fire Resistance Directory" or from the listings of another qualified testing agency.
- F. Mockups: Build full scale, free standing mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for fabrication and installation.
 1. Provide metal panel work required to complete exterior wall mock-up; including supports, attachments, and accessories.
 2. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Engineer specifically approves such deviations in writing.

1.6 PROJECT CONDITIONS

- A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit assembly of metal wall panels to be performed according to manufacturer's written instructions and warranty requirements.
- B. Field Measurements: Verify locations of structural members and wall opening dimensions by field measurements before metal wall panel fabrication and indicate measurements on Shop Drawings.

1.7 COORDINATION

- A. Coordinate metal wall panel assemblies with rain drainage work, flashing, trim, and construction of studs, soffits, and other adjoining work to provide a leakproof, secure, and noncorrosive installation.

1.8 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of metal wall panel assemblies that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures, including rupturing, cracking, or puncturing.
 - b. Deterioration of metals and other materials beyond normal weathering.
 - 2. Warranty Period: Two years from date of Substantial Completion.
- B. Special Warranty on Panel Finishes: Manufacturer's standard form in which manufacturer agrees to repair finish or replace metal wall panels that show evidence of deterioration of factory-applied finishes within specified warranty period.
 - 1. Exposed Panel Finish: Deterioration includes, but is not limited to, the following:
 - a. Color fading more than 5 Hunter units when tested according to ASTM D 2244.
 - b. Chalking in excess of a No. 8 rating when tested according to ASTM D 4214.
 - c. Cracking, checking, peeling, or failure of paint to adhere to bare metal.
 - 2. Finish Warranty Period: 20 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 METAL-FACED INSULATED WALL PANELS

- A. Metal panels for fabrication of wall panels shall be a factory insulated, shop assembled laminated aluminum panels for exterior walls complete with associated trim. Acceptable products include:
 - 1. Designwall 2000; Kingspan Benchmark, Columbus, OH
 - 2. Centria, Boston, MA
 - 3. Protean, Burnsville, MN
 - 4. Or approved equal

- B. General: Provide factory-formed and -assembled metal wall panels fabricated from two metal facing sheets and insulation core foamed in place during fabrication, and with joints between panels designed to form weathertight seals. Include accessories required for weathertight installation
 - 1. Fire-Retardant Core: Noncombustible, with the following surface-burning characteristics as determined by testing identical products per ASTM E 84 by UL or another testing and inspecting agency acceptable to authorities having jurisdiction:
 - a. Flame-Spread Index: 25 or less.
 - b. Smoke-Developed Index: 450 or less.
- C. Aluminum-Faced Insulated Wall Panels: Formed with 0.040-inch- thick, coil-coated aluminum sheet facings.
 - 1. Panel Thickness: 3 inch (R21) and 4 inch (R30), at areas indicated on the Drawings.
 - 2. Surface Texture: Smooth:
 - 3. Width: As indicated on the Drawings.
 - 4. Core Insulation: One of the following.
 - a. Shall be formed isocyanurate, nominal density 2.0 pcf with minimum shear strength of 24 psi.
 - b. Shall be expanded polystyrene (EPS), Report #NER-479, nominal density 1.0 pcf with minimum shear strength of 20 psi.
- D. Attachment System Components: Formed from extruded aluminum.
 - 1. Include manufacturer's standard panel stiffeners, panel clips and anchor channels.

2.2 MISCELLANEOUS METAL FRAMING

- A. Miscellaneous Metal Framing, General: ASTM C 645, cold-formed metallic-coated steel sheet, ASTM A 653/A 653M, G60 (Z180) hot-dip galvanized.
- B. Subgirts: Manufacturer's standard C-or Z-shaped sections 0.064-inch (1.63-mm) nominal thickness.
- C. Zee Clips: 0.079-inch (2.01-mm) nominal thickness.
- D. Base or Sill Angles or Channels: 0.079-inch (2.01-mm) nominal thickness.
- E. Hat-Shaped, Rigid Furring Channels:
 - 1. Nominal Thickness: As required to meet performance requirements.
- F. Cold-Rolled Furring Channels: Minimum 1/2-inch-(13-mm-) wide flange. Nominal Thickness: As required to meet performance requirements.
 - 1. Furring Brackets: Adjustable, corrugated-edge type of steel sheet with nominal thickness of 0.040 inch (1.02 mm).
 - 2. Tie Wire: ASTM A 641/A 641M, Class 1 zinc coating, soft temper, 0.062-inch-(1.57mm-) diameter wire, or double strand of 0.048-inch-(1.22-mm-) diameter wire.

- G. Fasteners for Miscellaneous Metal Framing: Of type, material, size, corrosion resistance, holding power, and other properties required to fasten miscellaneous metal framing members to substrates.

2.3 MISCELLANEOUS MATERIALS

- A. Aluminum Extrusions: ASTM B 221 (ASTM B 221M), alloy and temper recommended by manufacturer for type of use and finish indicated.
- B. Fasteners: Self-tapping screws, bolts, nuts, self-locking rivets and bolts, end-welded studs, and other suitable fasteners designed to withstand design loads. Provide exposed fasteners with heads matching color of metal wall panels by means of plastic caps or factory-applied coating. Provide EPDM, PVC, or neoprene sealing washers.

2.4 ACCESSORIES

- A. Wall Panel Accessories: Provide components required for a complete metal wall panel assembly including trim, copings, fasciae, mullions, sills, corner units, clips, flashings, sealants, gaskets, fillers, closure strips, and similar items. Match material and finish of metal wall panels unless otherwise indicated.
- B. Flashing and Trim: Provide flashing and trim as required to seal against weather and to provide finished appearance. Locations include, but are not limited to, bases, drips, sills, jambs, corners, end walls, framed openings, rakes, fasciae, parapet caps, soffits, reveals, and fillers. Finish flashing and trim with same finish system as adjacent metal wall panels.

2.5 FABRICATION

- A. General: Fabricate and finish metal wall panels and accessories at the factory to greatest extent possible, by manufacturer's standard procedures and processes, as necessary to fulfill indicated performance requirements demonstrated by laboratory testing. Comply with indicated profiles and with dimensional and structural requirements.
- B. Fabricate metal wall panels in a manner that eliminates condensation on interior side of panel and with joints between panels designed to form weathertight seals.
- C. Metal Wall Panels: Factory form panels in a continuous process. Trim and square edges of sheets with no displacement of face sheets or protrusion of core material.
 - 1. Form panel lines, breaks, and angles to be sharp and true, with surfaces free from warp and buckle.
 - 2. Fabricate panels with sharply cut edges, with no displacement of face sheets or protrusion of core material.
 - 3. Fabricate panels with panel stiffeners, as required to comply with deflection limits, attached to back of panels with structural silicone sealant or bond tape.
 - 4. Dimensional Tolerances:
 - a. Length: Plus 1/8 inch.
 - b. Width: Plus 1/8 inch.
 - c. Thickness: Plus or minus 0.008 inch (0.2 mm).
 - d. Panel Bow: 0.8 percent maximum of panel length or width.

- e. Squareness: 0.2 inch (5 mm) maximum.
- D. Sheet Metal Accessories: Fabricate flashing and trim to comply with recommendations in SMACNA's "Architectural Sheet Metal Manual" that apply to design, dimensions, metal, and other characteristics of item indicated.
- 1. Form exposed sheet metal accessories that are without excessive oil canning, buckling, and tool marks and that are true to line and levels indicated, with exposed edges folded back to form hems.
 - 2. Seams for Aluminum: Fabricate nonmoving seams with flat-lock seams. Form seams and seal with epoxy seam sealer. Rivet joints for additional strength.
 - 3. Sealed Joints: Form nonexpansion but movable joints in metal to accommodate elastomeric sealant to comply with SMACNA standards.
 - 4. Conceal fasteners and expansion provisions. Exposed fasteners are not allowed on faces of accessories exposed to view.
 - 5. Fabricate cleats and attachment devices from same material as accessory being anchored or from compatible, noncorrosive metal recommended by metal wall panel manufacturer.
 - a. Size: As recommended by SMACNA's "Architectural Sheet Metal Manual" or metal wall panel manufacturer for application, but not less than thickness of metal being secured.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances, metal wall panel supports, and other conditions affecting performance of the Work.
- 1. Examine wall framing to verify that girts, angles, channels, studs, and other structural panel support members and anchorage have been installed within alignment tolerances required by metal wall panel manufacturer.
 - 2. Examine wall sheathing to verify that sheathing joints are supported by framing or blocking and that installation is within flatness tolerances required by metal-faced composite wall panel manufacturer.
 - 3. Verify that sheet waterproofing has been installed over sheathing or backing substrate to prevent air infiltration or water penetration.
- B. Examine roughing-in for components and systems penetrating metal-faced composite wall panels to verify actual locations of penetrations relative to seam locations of panels before panel installation.
- C. For the record, prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Miscellaneous Framing: Install subgirts, base angles, sills, furring, and other miscellaneous wall panel support members and anchorage according to ASTM C 754 and metal-faced composite wall panel manufacturer's written instructions.

3.3 METAL PANEL INSTALLATION

- A. General: Install metal panels according to manufacturer's written instructions in orientation, sizes, and locations indicated. Install panels perpendicular to supports unless otherwise indicated. Anchor metal panels and other components of the Work securely in place, with provisions for thermal and structural movement.
 - 1. Shim or otherwise plumb substrates receiving metal panels.
 - 2. Flash and seal metal panels at perimeter of all openings. Fasten with self-tapping screws. Do not begin installation until air- or water-resistive barriers and flashings that will be concealed by metal panels are installed.
 - 3. Install screw fasteners in predrilled holes.
 - 4. Locate and space fastenings in uniform vertical and horizontal alignment.
 - 5. Install flashing and trim as metal panel work proceeds.
 - 6. Locate panel splices over, but not attached to, structural supports. Stagger panel splices and end laps to avoid a four-panel lap splice condition.
 - 7. Align bottoms of metal panels and fasten with blind rivets, bolts, or self-tapping screws. Fasten flashings and trim around openings and similar elements with self-tapping screws.
 - 8. Provide weathertight escutcheons for pipe- and conduit-penetrating panels.
- B. Fasteners: Use stainless-steel fasteners approved by panel manufacturer for the applicable requirements.
- C. Metal Protection: Where dissimilar metals contact each other or corrosive substrates, protect against galvanic action as recommended in writing by metal panel manufacturer.
- D. Joint Sealers: Install gaskets, joint fillers, and sealants where indicated and where required for weathertight performance of metal wall panel assemblies. Provide types of gaskets, fillers, and sealants indicated by metal panel manufacturer; or, if not indicated, provide types recommended by metal wall panel manufacturer.
 - 1. Seal metal wall panel end laps with double beads of tape or sealant, full width of panel. Seal side joints where recommended by metal wall panel manufacturer.
 - 2. Prepare joints and apply sealants to comply with requirements in Section 079200 "Joint Sealants."

3.4 INSULATED METAL WALL PANEL INSTALLATION

- A. General: Apply continuous ribbon of sealant to panel joint on concealed side of insulated metal wall panels as vapor seal; apply sealant to panel joint on exposed side of panels for weather seal.
 - 1. Fasten foamed-insulation-core metal wall panels to supports with fasteners at each lapped joint at location and spacing and with fasteners recommended by manufacturer.

2. Apply panels and associated items true to line for neat and weathertight enclosure. Avoid "panel creep" or application not true to line.
 3. Provide metal-backed washers under heads of exposed fasteners on weather side of insulated metal wall panels.
 4. Locate and space exposed fasteners in uniform vertical and horizontal alignment. Use proper tools to obtain controlled uniform compression for positive seal without rupture of washer.
 5. Provide sealant tape at lapped joints of insulated metal wall panels and between panels and protruding equipment, vents, and accessories.
 6. Apply a continuous ribbon of sealant tape to panel side laps and elsewhere as needed to make panels weathertight.
 7. Apply snap-on battens to exposed-fastener, insulated-core metal wall panel seams to conceal fasteners.
- B. Foamed-Insulation-Core Metal Wall Panels: Fasten metal wall panels to supports with concealed clips at each joint at location and spacing and with fasteners recommended by manufacturer. Fully engage tongue and groove of adjacent panels.
1. Install clips to supports with self-tapping fasteners.

3.5 ACCESSORY INSTALLATION

- A. General: Install accessories with positive anchorage to building and weathertight mounting and provide for thermal expansion. Coordinate installation with flashings and other components.
1. Install components required for a complete metal wall panel assembly including trim, copings, corners, seam covers, flashings, sealants, gaskets, fillers, closure strips, and similar items.
- B. Flashing and Trim: Comply with performance requirements, manufacturer's written installation instructions, and SMACNA's "Architectural Sheet Metal Manual." Provide concealed fasteners, and set units true to line and level as indicated. Install work with laps, joints, and seams that will be permanently watertight and weather resistant.
1. Install exposed flashing and trim that is without excessive oil canning, buckling, and tool marks and that is true to line and levels indicated, with exposed edges folded back to form hems. Install sheet metal flashing and trim to fit substrates and to result in waterproof and weather-resistant performance.
 2. Expansion Provisions: Provide for thermal expansion of exposed flashing and trim. Space movement joints at a maximum of 10 feet (3 m) with no joints allowed within 24 inches (610 mm) of corner or intersection. Where lapped expansion provisions cannot be used or would not be sufficiently weather resistant and waterproof, form expansion joints of intermeshing hooked flanges, not less than 1 inch (25 mm) deep, filled with mastic sealant (concealed within joints).
- C. Bullet-Resistant Fiberglass: Install in accordance with manufacturer's instructions and in proper relationship with adjacent construction. Provide continuous coverage.

3.6 ERECTION TOLERANCES

- A. Installation Tolerances: Contractor to shim and align metal wall panel units within installed tolerance of 1/4 inch in 20 feet (6 mm in 6 m), nonaccumulative, on level, plumb, and location lines as indicated and within 1/8-inch (3-mm) offset of adjoining faces and of alignment of matching profiles.

3.7 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified independent testing agency to perform field tests and inspections.
- B. Water-Spray Test: After installation, test area of assembly as directed by Architect for water penetration according to AAMA 501.2.
- C. Metal wall panels will be considered defective if they do not pass test and inspections.
- D. Additional tests and inspections, at Contractor's expense, are performed to determine compliance of replaced or additional work with specified requirements.
- E. Prepare test and inspection reports.

3.8 CLEANING

- A. Remove temporary protective coverings and strippable films, if any, as metal wall panels are installed unless otherwise indicated in manufacturer's written installation instructions. On completion of metal wall panel installation, clean finished surfaces as recommended by panel manufacturer. Maintain in a clean condition during construction.
- B. After metal wall panel installation, clear weep holes and drainage channels of obstructions, dirt, and sealant.
- C. Replace metal wall panels that have been damaged or have deteriorated beyond successful repair by finish touchup or similar minor repair procedures.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07423

RAIN SCREEN SYSTEMS

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies metal rain screen wall panels and ultra high performance concrete (UHPC) rain screen panels.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 05411 – LIGHT GAUGE METAL FRAMING
 - 3. Section 07210 – BUILDING INSULATION
 - 4. Section 07131 – SHEET WATERPROOFING
 - 5. Section 07270 – AIR AND VAPOR BARRIER SYSTEMS
 - 6. Section 07600 – FLASHING AND SHEET METAL
 - 7. Section 07920 – JOINT SEALANTS
 - 8. Section 08801 – GLASS AND GLAZING

1.2 DEFINITION

- A. Metal Plate Wall Panel Assembly: Metal plate wall panels, attachment system components, miscellaneous metal framing, and accessories necessary for a complete weathertight wall system based on AAMA CW-RS-1.

1.3 PERFORMANCE REQUIREMENTS

- A. General Performance: Metal wall panel assemblies shall comply with performance requirements without failure due to defective manufacture, fabrication, installation, or other defects in construction.
- B. Delegated Design: Design metal wall panel assembly, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
- C. Design, Fabricate, and erect a dry joint, pressure equalized rainscreen metal wall panel system without the use of sealants, gaskets, or butyl tape in accordance with AAMA 508.
- D. Pressure Equalization Cycling: ASTM E 1233, 5 to 25 psf for 100 three-second cycles at 0.08 seconds or less.
- E. Structural Performance: Provide metal wall panel assemblies capable of withstanding the effects of the following loads and stresses within limits and under conditions indicated, based on testing according to ASTM E 330:
 - 1. Wind Loads: Determine loads based on the following minimum design wind pressures whichever is more stringent:
 - a. Uniform pressure of 30 lbf/sq. ft. (1436 Pa), acting inward or outward.

- b. In accordance with FM Global data sheet 1-28 and safety factors as applicable.
- 2. Deflection Limits: Metal wall panel assemblies shall withstand wind loads with horizontal deflections no greater than $L/360$ of the span.
- F. Air Infiltration: Air leakage through assembly of not more than 0.13 cfm/sq. ft. of wall area when tested according to ASTM E 283 at a static-air-pressure difference of 1.57 lbf/sq. ft..
- G. Water Penetration: No water penetration when tested according to ASTM E 331 at the test-pressure difference of 6.24 lbf/sq. ft. (300 Pa)
- H. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes by preventing buckling, opening of joints, overstressing of components, failure of joint sealants, failure of connections, and other detrimental effects. Base calculations on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.
 - 1. Temperature Change (Range): Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C) ambient; 180 deg F (100 deg C) material surfaces.
- I. All exterior metal panels shall be designed and comply with the requirements of FM Global 1-28 requirements.

1.4 SUBMITTALS

- A. Product Data: For each type of product:
 - 1. Include construction details, material descriptions,, dimensions of individual components and profiles, and finishes for each type of panel and accessory.
 - 2. Exterior Wall Certification: Submit manufacturer's certification that exterior wall composite metal panels as designed in the assemblies indicated on the Contract Drawings has been tested to meet the requirements of NFPA 285 and passed.
- B. Drawings: Show fabrication and installation layouts of metal wall panels; details of edge conditions, joints, panel profiles, corners, anchorages, attachment system, trim, flashings, closures, and accessories; and special details.
 - 1. Accessories: Include details of the following items, at a scale of not less than 1-1/2 inches per 12 inches (1:10):
- C. For Verification: For each type of exposed finish required, prepare samples of size indicated below:
 - 1. Metal Wall Panels: 12 inches (300 mm) long by actual panel width. Include fasteners, closures, and other metal-faced composite wall panel accessories.
- D. Qualification Data: For Installer, and professional engineer.
- E. Product Test Reports: Based on evaluation of comprehensive tests performed by a qualified testing agency, for each product.
- F. Maintenance Data: For metal wall panels to include in maintenance manuals.
- G. Warranties: Samples of special warranties.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: An employer of workers trained and approved by manufacturer, with 5 years of experience of work of similar scope and complexity.
- B. Mockups: Build mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for fabrication and installation.
 - 1. Provide metal panel work required to complete exterior wall mock-up; including supports, attachments, and accessories.
 - 2. Water-Spray Test: Conduct water-spray test of mockup of metal panel assembly, testing for water penetration according to AAMA 501.2.
 - 3. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Engineer specifically approves such deviations in writing.

1.6 PROJECT CONDITIONS

- A. Weather Limitations: Proceed with installation only when existing and forecasted weather conditions permit assembly of metal wall panels to be performed according to manufacturer's written instructions and warranty requirements.
- B. Field Measurements: Verify locations of structural members and wall opening dimensions by field measurements before metal wall panel fabrication and indicate measurements on Shop Drawings.

1.7 COORDINATION

- A. Coordinate metal wall panel assemblies with rain drainage work, flashing, trim, and construction of studs, soffits, and other adjoining work to provide a leakproof, secure, and noncorrosive installation.

1.8 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of metal wall panel assemblies that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures, including rupturing, cracking, or puncturing.
 - b. Deterioration of metals and other materials beyond normal weathering.
 - 2. Warranty Period: Two years from date of Substantial Completion.
- B. Special Warranty on Panel Finishes: Manufacturer's standard form in which manufacturer agrees to repair finish or replace metal wall panels that show evidence of deterioration of factory-applied finishes within specified warranty period.
 - 1. Finish Warranty Period: 20 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 METAL RAIN SCREEN WALL PANELS

- A. Metal Rain Screen Wall Panels: Provide factory-formed, metal plate wall panels fabricated from single sheets of metal formed into profile for installation method indicated. Include attachment assembly components, and accessories required for weathertight system.
1. Dri-Design (basis of design)
 2. North Clad
 3. Metalwerks
- B. Zinc Alloy Plate Panels: Alloy and temper as recommended by manufacturer for application, Architecturally Rolled Zinc, Type 1, ASTM B 69.
1. Panel Thickness: 0.059 inch (1.5 mm).
 2. Tensile Strength: ASTM B 69, 14 to 38 ksi.
 3. Hardness: ASTM E 18, 54 to 74 tested with Rockwell tester for 15T scale.
 4. Panel Depth: 1-1/4 inch.
 5. Panel Size: As indicated on drawings.
 6. Panel Joints: As indicated on drawings.
 7. Finish and Color:
 - a. Lechmere Station: Quartz-zinc
 - b. Union Square Station: Quartz-zinc
- C. Zinc Composite Panels: Alloy and temper as recommended by manufacturer for application, Architecturally Rolled Zinc, Type 1, ASTM B 69.
1. Basis-of-Design: Alcoa, Reynobond ZCM or equal, dry joint system.
 2. Panel Thickness: 0.7 mm, fire-retardant core
 3. Panel Size: As indicated on drawings.
 4. Panel Joints: As indicated on drawings.
 5. Fire Test Performance for Metal Panels as part of an exterior wall assembly: Assembly passes NFPA 285, Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-LoadBearing Wall Assemblies Containing Combustible Componen
- D. Attachment System Components: Rainscreen-principle system, supplied or approved by rainscreen manufacturer.

2.2 MISCELLANEOUS MATERIALS

- A. Miscellaneous Metal Subframing and Furring: ASTM C 645, cold-formed, metallic-coated steel sheet, ASTM A 653/A 653M, G90 (Z275 hot-dip galvanized) coating designation or ASTM A 792/A 792M, Class AZ50 (Class AZM150) aluminum-zinc-alloy coating designation unless

otherwise indicated. Provide manufacturer's standard sections as required for support and alignment of metal panel system.

- B. Panel Accessories: Provide components required for a complete, weathertight panel system including trim, copings, fasciae, mullions, sills, corner units, clips, flashings, sealants, gaskets, fillers, closure strips, and similar items. Match material and finish of metal panels unless otherwise indicated.
- C. Flashing and Trim: Provide flashing and trim formed from same material as metal panels as required to seal against weather and to provide finished appearance. Locations include, but are not limited to, bases, drips, sills, jambs, corners, endwalls, framed openings, rakes, fasciae, parapet caps, soffits, reveals, and fillers. Match finish flashing and trim with same finish system as adjacent metal panels.
- D. Panel Fasteners: Self-tapping screws designed to withstand design loads. Provide exposed fasteners with heads matching color of metal panels by means of plastic caps or factory-applied coating. Provide EPDM or PVC sealing washers for exposed fasteners.
 - 1. For Zinc Alloy Metal Panels: Stainless steel fasteners, as approved by rainscreen manufacturer.
- E. Weather Barriers: Refer to Section 07131, "Sheet Waterproofing."

2.3 FABRICATION

- A. General: Fabricate and finish metal wall panels and accessories at the factory to greatest extent possible, by manufacturer's standard procedures and processes, as necessary to fulfill indicated performance requirements demonstrated by laboratory testing. Comply with indicated profiles and with dimensional and structural requirements.
- B. Fabricate metal wall panels in a manner that eliminates condensation on interior side of panel and with joints between panels designed to form weathertight seals.
- C. Sheet Metal Accessories: Fabricate flashing and trim to comply with recommendations in SMACNA's "Architectural Sheet Metal Manual" that apply to design, dimensions, metal, and other characteristics of item indicated.
 - 1. Form exposed sheet metal accessories that are without excessive oil canning, buckling, and tool marks and that are true to line and levels indicated, with exposed edges folded back to form hems.
 - 2. Conceal fasteners and expansion provisions where possible. Exposed fasteners are not allowed on faces of accessories exposed to view.
 - 3. Fabricate cleats and attachment devices from same material as accessory being anchored or from compatible, noncorrosive metal. These attachment devices shall be supplied or recommended by metal-faced composite wall panel manufacturer.
 - a. Size: As recommended by SMACNA's "Architectural Sheet Metal Manual" or metal-faced composite wall panel manufacturer for application, but not less than thickness of metal being secured.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances, metal wall panel supports, and other conditions affecting performance of the Work.
 - 1. Examine wall framing to verify that girts, angles, channels, studs, and other structural panel support members and anchorage have been installed within alignment tolerances required by metal wall panel manufacturer.
 - 2. Examine wall sheathing to verify that sheathing joints are supported by framing or blocking and that installation is within flatness tolerances required by metal wall panel manufacturer.
 - 3. Verify that air- or water-resistive barriers have been installed over sheathing or backing substrate to prevent air infiltration or water penetration.
- B. Examine roughing-in for components and systems penetrating metal wall panels to verify actual locations of penetrations relative to seam locations of panels before panel installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Miscellaneous Framing: Install subgirts, base angles, sills, furring, and other miscellaneous wall panel support members and anchorage according to ASTM C 754 and metal-faced composite wall panel manufacturer's written instructions.

3.3 METAL PANEL INSTALLATION

- A. General: Install metal panels according to manufacturer's written instructions in orientation, sizes, and locations indicated. Install panels perpendicular to supports unless otherwise indicated. Anchor metal panels and other components of the Work securely in place, with provisions for thermal and structural movement.
 - 1. Shim or otherwise plumb substrates receiving metal panels.
 - 2. Flash and seal metal panels at perimeter of all openings. Fasten with self-tapping screws. Do not begin installation until air- or water-resistive barriers and flashings that will be concealed by metal panels are installed.
 - 3. Install screw fasteners in predrilled holes.
 - 4. Locate and space fastenings in uniform vertical and horizontal alignment.
 - 5. Install flashing and trim as metal panel work proceeds.
 - 6. Locate panel splices over, but not attached to, structural supports. Stagger panel splices and end laps to avoid a four-panel lap splice condition.
 - 7. Align bottoms of metal panels and fasten with blind rivets, bolts, or self-tapping screws. Fasten flashings and trim around openings and similar elements with self-tapping screws.
 - 8. Provide weathertight escutcheons for pipe- and conduit-penetrating panels.

- B. Metal Protection: Where dissimilar metals will contact each other or corrosive substrates, protect against galvanic action as recommended by metal-faced composite wall panel manufacturer.
- C. Attachment Assembly, General: Install attachment assembly required to support metal plate wall panels and to provide a complete weathertight wall system, including subgirts, perimeter extrusions, tracks, drainage channels, panel clips, and anchor channels.
 - 1. Include attachment to supports, panel-to-panel joinery, panel-to-dissimilar-material joinery.
- D. Rainscreen-Principle Installation: Install using manufacturer's standard assembly with vertical channel that provides support and secondary drainage assembly, draining at base of wall. Notch vertical channel to receive support pins. Install vertical channels supported by channel brackets or adjuster angles and at locations, spacings, and with fasteners recommended by manufacturer. Attach metal plate wall panels by inserting horizontal support pins into notches in vertical channels and into flanges of panels. Leave horizontal and vertical joints with open reveal.
 - 1. Install metal plate wall panels to allow individual panels to be installed and removed without disturbing adjacent panels.
 - 2. Do not apply sealants to joints unless otherwise indicated.
- E. Accessory Installation: Install accessories with positive anchorage to building and weathertight mounting, and provide for thermal expansion. Coordinate installation with flashings and other components.
- F. Flashing and Trim: Comply with performance requirements, manufacturer's written installation instructions, and SMACNA's "Architectural Sheet Metal Manual." Provide concealed fasteners where possible, and set units true to line and level as indicated. Install work with laps, joints, and seams that are permanently watertight.
 - 1. Install exposed flashing and trim that is without buckling and tool marks and that is true to line and levels indicated, with exposed edges folded back to form hems. Install sheet metal flashing and trim to fit substrates and to result in waterproof performance.
 - 2. Expansion Provisions: Provide for thermal expansion of exposed flashing and trim. Space movement joints at a maximum of 10 feet (3 m) with no joints allowed within 24 inches (605 mm) of corner or intersection. Where lapped expansion provisions cannot be used or would not be sufficiently waterproof, form expansion joints of intermeshing hooked flanges, not less than 1 inch (25 mm) deep, filled with mastic sealant (concealed within joints).

3.4 ERECTION TOLERANCES

- A. A. Installation Tolerances: Contractor to shim and align metal wall panel units within installed tolerance of 1/4 inch in 20 feet (6 mm in 6 m), nonaccumulative, on level, plumb, and location lines as indicated and within 1/8-inch (3-mm) offset of adjoining faces and of alignment of matching profiles.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified independent testing agency to perform field tests and inspections.
- B. Water-Spray Test: After installation, test area of assembly as directed by Architect for water penetration according to AAMA 501.2.
- C. Metal wall panels will be considered defective if they do not pass test and inspections.

- D. At the Contractor's expense, additional tests and inspections, via the testing agency above, will be performed to determine compliance of replaced or additional work with specified requirements.
- E. Prepare test and inspection reports.

3.6 CLEANING

- A. Remove temporary protective coverings and strippable films, if any, as metal wall panels are installed unless otherwise indicated in manufacturer's written installation instructions. On completion of metal wall panel installation, clean finished surfaces as recommended by panel manufacturer. Maintain in a clean condition during construction.
- B. After metal wall panel installation, clear weep holes and drainage channels of obstructions, dirt, and sealant.
- C. Replace metal wall panels that have been damaged or have deteriorated beyond successful repair by finish touchup or similar minor repair procedures.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07550

MODIFIED BITUMEN BUILT-UP ROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies modified bitumen built-up roofing systems in cold process, with fascia and flashing, miscellaneous caulking and damproofing necessary to satisfactorily complete the entire work.
- B. Related Work: None
- C. These specifications have been reviewed by Factory Mutual Global for compliance with standards and procedures according to Roof NAV assembly number 231414-224944-0 and 133087-2249-0 for built up roof on steel deck.
- D. Refer to FM Global property Loss Prevention Data Sheet 1-28 for ratings of roof covering system. Based on initial review by FM Global, the following ratings have been identified for the following structures:
 - 1. Lechmere Station:
 - a. System as approved per location; the roof of the north access structure and south egress stair structure area shall require a roof with an I-75/I-120/I-165 wind rating in the field, perimeter and corners respectively.
 - 2. East Somerville:
 - a. System as approved per location; the roof of the Bike Storage Building will require a roof with an I-60/I-90/I-135 wind rating in the field, perimeter and corners.
 - 3. Traction Power substations:
 - a. System as approved per location.
 - 4. College Avenue
 - 5.
 - a. System as approved per location; station structure area shall require a roof with an I-75/I-120/I-165 wind rating in the field, perimeter and corners respectively.
 - 6. Vehicle Maintenance Facility:
 - a. System as approved per location.

1.2 REFERENCES

- A. American Society of Civil Engineers (ASCE): ASCE 7-98, Minimum Design Loads for Buildings and Other Structures.
- B. American Society for Testing and Materials (ASTM):

1. ASTM D451, Test Method for Sieve Analysis of Granular Mineral Surfacing for Asphalt Roofing Products.
2. ASTM D1079, Terminology Relating to Roofing, Waterproofing and Bituminous Materials.
3. ASTM D1227, Specification for Emulsified Asphalt Used as a Protective Coating for Roofing.
4. ASTM D1863, Specification for Mineral Aggregate Used as a Protective Coating for Roofing.
5. ASTM D4586, Specification for Asphalt Roof Cement.
6. ASTM D2824, Specification for Aluminum-Pigmented Asphalt Roof Coating.
7. ASTM D5147, Test Method for Sampling and Testing Modified Bituminous Sheet Materials.
8. ASTM D6162, Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Combination of Polyester and Glass Fiber Reinforcements.
9. ASTM D6163, Specification for Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Glass Fiber Reinforcements.
10. ASTM E108, Test Methods for Fire Test of Roof Coverings.

C. National Roofing Contractors Association (NRCA):

1. Roofing and Waterproofing Manual.

1.3 SYSTEM DESCRIPTION

- A. FM Approvals Listing: Provide roofing, base flashings, and component materials that comply with requirements in FM Approvals 4450 and FM Approvals 4470 as part of a membrane roofing system, and that are listed in FM Approvals' "RoofNav" for Class 1 or noncombustible construction, as applicable. Identify materials with FM Approvals markings. Obtain FM acceptance of system proposed for use prior to ordering materials.

1. Roofing System:

- a. Fire/Windstorm Classification: In accordance with FM recommendations.
- b. Roofing shall meet FM Global requirements for rating in the field of the roof, perimeter and corners.
- c. Provide additional securement as required in FMG Data Sheet 1-29.
- d. Hail Resistance: MH and in accordance with FM recommendations.
- e. Provide "RoofNav" assembly number corresponding to an FM approved roof assembly. Refer to www.roofnav.com for information and Form 2688.

- B. It is the intent of this specification to install a long-term, quality roof system that meets or exceeds all current NRCA guidelines as stated in the most recent edition of the NRCA Roofing and Waterproofing Manual.

1.4 SUBMITTALS

- A. Provide submittals in accordance with Volume 2 Technical Provisions Subsection 2.8.
- B. Product Data: Provide manufacturer's technical product data for each type of roofing product specified. Include data substantiating that materials comply with specified requirements.

- C. Samples: Submit two (2) samples of each product specified.
- D. Manufacturer's Certificate: Certify that roof system furnished is approved by Factory Mutual in accordance with ASTM E108, Class A for external fire and meets local or nationally recognized building codes.
- E. Manufacturer's Certificate: Certify that the roof system is adhered properly to meet or exceed the requirements of FM Global.
- F. Manufacturer's Certificate: Certify that materials are manufactured in the United States and conform to requirements specified herein, are chemically and physically compatible with each other, and are suitable for inclusion within the total roof system specified herein.
- G. Manufacturer's Certificate: Submit a certified copy of the roofing manufacturer's ISO 9001 compliance certificate.
- H. Test Reports: Submit test reports, prepared by an independent testing agency, for all modified bituminous sheet roofing, indicating compliance with ASTM D5147.
- I. Submit a copy of an unexecuted manufacturer's 30-year single source warranty for review. This warranty shall include modified bituminous roofing. Warranty shall cover wind speeds up to 90 mph.
- J. Manufacturer providing warranty will include a list of ten (10) completed projects of similar scope and complexity with contact information for reference within a 50 mile distance. Projects will include daily job site inspections and be a minimum of five (5) years old.
- K. Submit a sample of roof coating for review.

1.5 QUALIFICATIONS

- A. Manufacturer of the modified bitumen roof membrane shall have a minimum [10] years experience in the manufacturing of modified bitumen roof membranes and have ISO 9001 certification.
- B. Installer: Company specializing in modified bituminous roofing installation with a minimum 5 years' experience and certified by roofing system manufacturer as qualified to install manufacturer's roofing materials.
- C. Installer's Field Supervision: Maintain a full-time Supervisor/Foreman on job site during all phases of roofing work and at any time roofing work is in progress. Maintain proper supervision of workmen. Maintain a copy of the specifications in the possession of the Supervisor/Foremen and on the roof at all times.
- D. Insurance Certification: Assist DB Entity in preparation and submittal of roof installation acceptance certification as may be necessary in connection with fire and extended coverage insurance on roofing and associated work.

1.6 PRE-INSTALLATION CONFERENCE

- A. Pre-Roofing Conference: Convene a pre-roofing conference approximately two (2) weeks before scheduled commencement of modified bituminous roofing system installation and associated work.
- B. Require attendance of installer of each component of associated work, installers of deck or substrate construction to receive roofing work, installers of rooftop units and other work in and around roofing

which must precede or follow roofing work (including mechanical work if any), DB Entity, roofing system manufacturer's representative, and other representatives directly concerned with performance of the Work, including (where applicable) DB Entity's insurers, testing agencies and governing authorities.

C. Objectives of conference to include:

1. Review foreseeable methods and procedures related to roofing work.
2. Tour representative areas of roofing substrates (decks), inspect and discuss condition of substrate, roof drains, curbs, penetrations and other preparatory work performed by others.
3. Review structural loading limitations of deck and inspect deck for loss of flatness and for required attachment.
4. Review roofing system requirements (Refer to Contract Documents).
5. Review required submittals both completed and yet to be completed.
6. Review and finalize construction schedule related to roofing work and verify availability of materials, installer's personnel, equipment and facilities needed to make progress and avoid delays.
7. Review required inspection, testing, certifying and material usage accounting procedures.
8. Review weather and forecasted weather conditions and procedures for inclement conditions.
9. Record discussion of conference including decisions and agreements (or disagreements) reached and furnish copy of record to each party attending. If substantial disagreements exist at conclusion of conference, determine how disagreements will be resolved and set date for reconvening conference.
10. Review notification procedures for weather or non-working days.

1.7 DELIVERY, STORAGE AND HANDLING

- A. Deliver products to site with seals and labels intact, in manufacturer's original containers, dry and undamaged.
- B. Store and handle roofing sheets in a dry, well-ventilated, weather-tight place to ensure no possibility of significant moisture exposure. Store rolls of felt and other sheet materials on pallets or other raised surface. Stand all roll materials on end. Cover roll goods with a canvas tarpaulin or other breathable material (not polyethylene).
- C. Do not leave unused materials on the roof overnight or when roofing work is not in progress unless protected from weather and other moisture sources.
- D. It is the responsibility of the DB Entity to secure all material and equipment on the job site. If any material or equipment is stored on the roof, the DB Entity must make sure that the integrity of the deck is not compromised at any time. Damage to the deck caused by the DB Entity will be the sole responsibility of the DB Entity and will be repaired or replaced at his expense.

1.8 MANUFACTURER'S INSPECTIONS

- A. When the project is in progress, the roofing system manufacturer will provide the following:
 1. Keep the MBTA contacts informed as to the progress and quality of the work as observed.
 2. Provide daily job site inspections including documented weekly progress reports including pho-

tos.

3. Report to the designated personal in writing any failure or refusal of the DB Entity to correct unacceptable practices called to the DB Entity's attention. Confirm after completion that manufacturer has observed no applications procedures in conflict with the specifications other than those that may have been previously reported
4. The presence of the manufacturer's representative shall in no way be construed as the manufacturer or the representative as having any responsibility or oversight of the DB Entity's employees for safety issues. The sole purpose of the manufacturer's representative is to ensure the specified materials are applied in a manner consistent with this specification.

1.9 PROJECT CONDITIONS

- A. Weather Condition Limitations: Do not apply roofing membrane during inclement weather or when a 40% chance of precipitation is expected.
- B. Do not apply roofing insulation or membrane to damp deck surface.
- C. Do not expose materials vulnerable to water or sun damage in quantities greater than can be weather-proofed during same day.

1.10 SEQUENCING AND SCHEDULING

- A. Sequence installation of modified bituminous sheet roofing with related units of work specified in other sections to ensure that roof assemblies including roof accessories, flashing, trim and joint sealers are protected against damage from effects of weather, corrosion and adjacent construction activity.
- B. Fully complete all modified bituminous membrane roofing field assembly work each day. Phased construction will not be accepted.

1.11 WARRANTY

- A. Upon completion of installation, and acceptance by the Owner, the manufacturer will supply to the Owner a 30-year water tight roofing system warranty.
- B. Installer will submit a minimum of a two (2) year warranty to the membrane manufacturer with a copy directly to Owner.
- C. Membrane manufacturer will provide an annual inspection for the life of the warranty.

1.12 PRODUCT OPTIONS AND SUBSTITUTIONS

- A. Any material submitted as an equal to the specified material must include a list of three (3) projects where the proposed material has been used in a similar roofing system as that which is specified and is located within a fifty mile radius from the location of the project. In addition, the three projects must be at least three (3) years old and be available for inspection by the MBTA.
- B. Any deficiencies in performance, warranty terms or improper submittal procedure will constitute grounds for immediate rejection of substitution.
- C. Single ply EPDM and or PVC roof membrane system will not be considered as equals to the specified system and will be immediately rejected.

- D. No modified bitumen membrane will be considered unless it can meet or exceed the performance characteristics described in Article 2.4 of this Section

PART 2 - PRODUCTS

2.1 PERFORMANCE STANDARD

- A. When a performance standard is specified it shall be indicative of a standard required.
- B. Any item or materials submitted as a substitution to the performance specified must comply in all respects as to the quality and performance specified. The MBTA shall be the sole judge as to whether or not an item submitted as a substitute is truly equal. Should the DB Entity choose to submit a substitute product, he shall assume all monetary or other risk involved, should the MBTA find the substitution unacceptable.

2.2 DESCRIPTION

- A. Modified bituminous roofing work including but not limited to:
 - 1. Base Ply and Base Flashing Ply: Will be one ply of approved ASTM D 6163 Type I, 80 mil SBS (Stryrene-Butadiene-Styrene) rubber modified base sheet.
 - 2. Cold Bitumen Membrane Inner Ply Adhesive: The standard bitumen will consist of a V.O.C. free, non-asbestos containing cold applied adhesive.

Performance Requirements:

- a. Flash Point 400°F (232°C) (ASTM D 93)
 - b. Density @ 77°F (25°C) , 11.2 lbs./gal. (1.11 g/m3) (ASTM D 1475)
 - c. Non-Volatile 100% (ASTM D 4586)
 - d. Slope Limitations 3:12
 - e. Viscosity @ 73.4 ± 2°F 25,000 - 30,000 cP (23 ± 2°C) Brookfield HADT T-bar; Spindle A; 10 RPM
 - f. VOC, 0 g/l
- 3. Modified Membrane/Top Flashing Ply: 160 mil SBS (Stryrene-Butadiene-Styrene) and SIS (Stryrene-Isoprene-Styrene) rubber modified membrane incorporating recycled content and reinforced with a strong fiberglass and polyester composite scrim.
 - 4. Surfacing: Two coats of specified coating, manufacturer approved.
 - 5. Insulation Adhesive Performance Requirements: Two component, foam adhesive as recommended by insulation manufacturer and approved by FM indicated ratings.
 - a. Tensile Strength (ASTM D412), 250 psi
 - b. Density (ASTM D1875), 8.5 lbs./gal.
 - c. Viscosity (ASTM D2556), 16,000 to 24,000 cP.
 - d. 2`Peel Strength (ASTM D903), 17 lb/in.

- e. 3`Flexibility (ASTM D816), Pass @ -70°F

2.3 BITUMINOUS MATERIALS

- A. Asphalt Primer: V.O.C. compliant, ASTM D41.
- B. Asphalt Roofing Mastic: V.O.C. compliant, ASTM D2822, Type II.
- C. Cold Applied Membrane Adhesive: Performance Requirements:
 - 1. Flash Point , 400°F (232°C) (ASTM D 93)
 - 2. Density @ 77°F (25°C), 11.2 lbs./gal. (1.11 g/m3) (ASTM D 1475)
 - 3. Non-Volatile 100% (ASTM D 4586)
 - 4. Slope Limitations 3:12
 - 5. Viscosity @ 73.4 ± 2°F 25,000 - 30,000 cP (23 ± 2°C) Brookfield HADT T-bar; Spindle A; 10 RPM
 - 6. VOC 0 g/l
- D. Brush Grade Flashing Adhesive Performance Requirements:
 - 1. Non-Volatile Content, ASTM D-4479, 70 min.
 - 2. Density, ASTM D-1475, 8.6 lb./gal.
 - 3. V.O.C., ASTM D-3960, 295 g/l max.
 - 4. Flash Point, ASTM D-93, 100°F

2.4 SHEET MATERIALS

- A. Type I Base Sheet:
 - 1. Tensile Strength, MD 100 lbf./in. , XD 100 lbf./
 - 2. Tear Strength, MD 110 lbf., XD 110 lbf
 - 3. Elongation, MD 2.5%, XD 2.5%
 - 4. Low Temp Flex passes -20°F (-28.8°C)
 - 5. Recycled Content pre-consumer 27%
 - 6. Finished membrane meets and/or exceeds ASTM D 6163, TYPE I
 - 7. Test Method ASTM D 5147 is tested at *2 in./min. @ 73.4 ± 3.6°F (50 mm/min. @ 23 ± 2°C)
- B. Modified Membrane Independent Test Properties/Top Modified Flashing Ply:
 - 1. ASTM D-6162, Type III minimum performance characteristics.
 - 2. Tensile Strength (ASTM D-5147) 2 in/min. @ 73.4 °F, MD 700 lbf/in, CMD 750 lbf/in
 - 3. Tear Strength (ASTM D-5147) 2 in/min. @ 73.4 °F, MD 1300 lbf, CMD 1400 lbf
 - 4. Elongation at Maximum Tensile (ASTM D-5147) 2 in/min. @ 73.4 °F, MD 6%, CMD 6%

5. Low Temperature Flexibility (ASTM D-5147) Passes -30°F (-34°C)
6. Thickness, 160mm

2.5 SURFACINGS

A. White coating

1. ASTM D 4798 - No deterioration over 1,000 hours per ASTM G 26 test requirements
2. Non-Volatile (ASTM D 1644), 66% min
3. Density @ 77°F (25°C) (ASTM D 1475), 12 lb./gal (1.43g/cm³)
4. Elongation (ASTM D 2370), 100% minimum
5. Tensile Strength (ASTM D 2370), 200 psi minimum
6. VOC, <50 g/l
7. Reflectance, 0.84
8. Emittance, 0.91
9. SRI, 106

B. Grey Coating

1. ASTM D 4798 - No deterioration over 1,000 hours per ASTM G 26 test requirements
2. Non-Volatile (ASTM D 1644), 66% min
3. Density @ 77°F (25°C) (ASTM D 1475), 12 lb./gal (1.43g/cm³)
4. Elongation (ASTM D 2370), 100% minimum
5. Tensile Strength (ASTM D 2370), 200 psi minimum
6. VOC, <50 g/l

2.6 RELATED MATERIALS

A. Roof Insulation: as required to meet Energy Code requirements.

B. Two component, foam adhesive as recommended by insulation manufacturer and approved by FM indicated ratings.

1. Tensile Strength (ASTM D412), 250 psi
2. Density (ASTM D1875), 8.5 lbs./gal.
3. Viscosity (ASTM D2556), 16,000 to 24,000 cP.
4. 2`Peel Strength (ASTM D903), 17 lb/in.
5. 3`Flexibility (ASTM D816), Pass @ -70°F

C. Nails and Fasteners: Non-ferrous metal or galvanized steel, except that hard copper nails shall be used with copper; aluminum or stainless steel nails shall be used with aluminum; and stainless steel nails shall be used with stainless steel. Fasteners shall be self-clinching type of penetrating type as recommended by the manufacturer of the deck material. Nails and fasteners shall be flush-driven through flat metal discs of not less than one (1) inch diameter. Omit metal discs when one-piece composite nails or

fasteners with heads not less than one (1) inch diameter are used.

- D. Metal Discs: Flat discs or caps of zinc-coated sheet metal not lighter than twenty eight (28) gauge and not less than one (1) inch in diameter. Form discs to prevent dishing. Bell or cup shaped caps are not acceptable.
- E. Zinc Transitions, gravel stops, and flashings: sheet metal as required for a complete and warrantable roofing system installation.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that deck surfaces and project conditions are ready to receive work of this section.
- B. Verify that deck is supported and secured to structural members.
- C. Verify that deck is clean and smooth, free of depressions, projections or ripples, and is properly sloped to drains.
- D. Verify that adjacent roof members do not vary more than ¼” in height.
- E. Verify that deck surfaces are dry and free of snow or ice.
- F. Confirm that moisture content does not exceed twelve (12) percent by moisture meter tests.
- G. Verify that openings, curbs, pipes, conduit, sleeves, ducts, and other items, which penetrate the roof, are set solidly, and that wood cant strips and wood nailing strips are set in place.
- H. Coordinate work with sheet metal roofing edge conditions as required.

3.2 GENERAL INSTALLATION REQUIREMENTS

- A. Cooperate with manufacturer, inspection and test agencies engaged or required to perform services in connection with installing the roof system
- B. Insurance/Code Compliance: Where required by code, install and test the roofing system to comply with governing regulation and specified insurance requirements.
- C. Protect other work from spillage of roofing materials and prevent materials from entering or clogging drains and conductors. Replace or restore other work damaged by installation of the modified bituminous roofing system.
- D. Coordinate installing roofing system components so that insulation and roofing plies are not exposed to precipitation or left exposed overnight. Provide cut-offs at end of each day’s work to cover exposed ply sheets and insulation with two (2) plies of #15 organic roofing felt with joints and edges sealed with roofing cement. Remove cut-offs immediately before resuming work.
- E. Cold applied membrane adhesive coverage rates for interply application (2.5) two and a half gallons per 100 square feet (plus or minus 25% on total job average basis.)

- F. Substrate Joint Penetrations: Prevent bitumen from penetrating substrate joints or damaging roofing system components.
- G. Apply roofing materials as specified by manufacturer's instructions.
 - 1. Keep roofing materials dry before and during application.
 - 2. Do not permit phased construction.
 - 3. Complete application of roofing plies, modified sheet and flashing in a continuous operation.
 - 4. Begin and apply only as much roofing in one day as can be completed that same day.
- H. Cut-Offs (Waterstops): At end of each day's roofing installation, protect exposed edge of incomplete work, including ply sheets and insulation. Provide temporary covering of two (2) plies of #15 organic roofing felt set in flashing adhesive.

3.3 BASE PLY INSTALLATION

- A. Base Plies: Install (2) two base sheets in 2.5 gallons per ply per square of bitumen shingled uniformly to achieve two plies throughout over the prepared substrate. Shingle in proper direction to shed water on each large area of roofing. Prior to installation, cut sheets into 18' lengths and allow to relax.
- B. Lap ply sheet ends eight (8) inches. Stagger end laps twelve (12) inches minimum.
- C. Lightly broom in base plies to assure complete adhesion.
- D. Extend plies two (2) inches beyond top edges of cants at wall and roof projections and equipment bases.
- E. Install base flashing ply to all perimeter and projection details.
- F. Allow the two plies of base sheet to cure at least thirty minutes before installing the modified membrane. However, the modified membrane must be installed the same day as the base plies.

3.4 MODIFIED MEMBRANE APPLICATION

- A. The modified membrane shall then be solidly bonded to the base layers with specified cold adhesive at the rate of 2.5 gallons per 100 square feet. Two hours prior to installation, cut sheets into 18' lengths and allow to relax.
- B. The modified membrane roll must push a puddle of asphalt in front of it with asphalt slightly visible at all side laps. Exercise care during application to eliminate air entrapment under the membrane.
- C. Subsequent rolls of modified shall be installed across the roof as above with a minimum of 4" side laps and 8" end laps. The end laps shall be staggered. The modified membrane shall be laid in the same direction as the underlayers but the laps shall not coincide with the laps of the base layers.
- D. For best results, allow the cold adhesive to set for five to ten minutes before installing the top layer of modified membrane.
- E. Extend membrane 2" beyond top edge of all cants in full moppings of the cold adhesive as shown on the drawings.

3.5 FLASHING MEMBRANE INSTALLATION

- A. Seal all curb, wall and parapet flashings with an application of mastic and mesh on a daily basis. Do not permit conditions to exist that will allow moisture to enter behind, around or under the roof or flashing membrane.
- B. Prepare all walls, penetrations, expansion joints [and where shown on the drawings] to be flashed with asphalt primer at the rate of one hundred (100) square feet per gallon. Allow primer to dry tack free.
- C. Install pressure treated wood nailers on the existing parapet wall to prepare for installation of new coping caps.
- D. Use the modified membrane as the flashing membrane. Adhere to the underlying base flashing ply with specified asphalt unless otherwise noted in these specifications. Nail off at a minimum of eight (8) inches o.c. from the finished roof at all vertical surfaces.
- E. Solidly adhere the entire sheet of flashing membrane to the substrate.
- F. Seal all vertical laps of flashing membrane with a three-course application of trowel-grade mastic and fiberglass mesh.
- G. Coordinate counter flashing, cap flashings, expansion joints, and similar work with modified bitumen roofing work.
- H. Coordinate roof accessories, miscellaneous sheet metal accessory items, including piping vents and other devices with the roofing system work.
- I. Metal Edge
 - 1. Inspect the nailer to assure proper attachment and configuration.
 - 2. Run one ply over the edge. Assure coverage of all wood nailers. Fasten plies with ring shank nails at eight (8) inches o.c.
 - 3. Install continuous cleat and fasten at six (6) inches o.c.
 - 4. Install new metal edge hooked to continuous cleat and set in bed of roof cement. Fasten flange to wood nailer every three (3) inches o.c. staggered.
 - 5. Prime metal edge at a rate of 100 square feet per gallon and allow to dry.
 - 6. Strip in flange with base flashing ply covering entire flange in bitumen with six (6) inches on to the field of roof. Assure ply laps do not coincide with metal laps.
 - 7. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches on to the field of the roof.
- J. Coping Cap
 - 1. Minimum flashing height is eight (8) inches (203mm) above finished roof height. Maximum flashing height is 24 inches. Prime vertical wall at a rate of 100 square feet per gallon and allow to dry.
 - 2. Set cant in bitumen. Run all field plies over cant a minimum of two (2) inches (50mm).
 - 3. Attach tapered board to top of wall.

4. Install base flashing ply covering entire wall and wrapped over top of wall and down face with six (6) inches (152mm) on to field of roof and set in cold asphalt. Nail membrane at eight (8) inches (203mm) o.c.
5. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches (228mm) on to the field of the roof. Apply a three-course application of mastic and mesh at all seams and allow to cure and aluminize.
6. Install continuous cleat and fasten at six (6) inches (152mm) o.c. to outside wall.
7. Install new metal coping cap hooked to continuous cleat.
8. Fasten inside cap 24 inches (609mm) o.c. with approved fasteners and neoprene washers.

K. Reglet Mounted Counterflashing

1. Minimum flashing height is eight (8) inches (203mm) above finished roof height. Maximum flashing height is 24 inches. Prime vertical wall at a rate of 100 square feet per gallon and allow to dry.
2. Set cant in bitumen. Run all field plies over cant a minimum of two (2) inches (50mm).
3. Install base flashing ply covering wall set in bitumen with six (6) inches (152mm) on to field of the roof.
4. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches (228mm) on to the field of the roof. Apply a three-course application of mastic and mesh at all vertical seams and allow to cure and aluminize.
5. Apply butyl tape to wall behind flashing. Secure termination bar through flashing, butyl tape and into wall. Alternatively use caulk to replace the butyl tape.
6. Cut reglet in masonry one joint above flashing.
7. Secure reglet counterflashing with expansion fasteners and caulk reglet opening.

L. Through Wall Counterflashing

1. Minimum flashing height is 8". Prime vertical wall at a rate of 100 square feet per gallon and allow to dry.
2. Set cant in Flashing Mastic. Run all plies over cant a minimum of 2".
3. Install base flashing ply set in Flashing Mastic covering wall with 6" on to field of roof.
4. The second ply shall be a modified flashing ply installed in Flashing Mastic over the base flashing ply and 9" on to field of roof. All vertical seams will receive a three-course application of Flashing Mastic and mesh allowed to cure and aluminize.
5. Apply butyl tape to wall behind flashing. Secure termination bar through flashing, butyl tape and into wall 8" O.C.

M. Manufactured Wall Panel W/Modified Roof/Flashing (Slip Flashing)

1. Minimum flashing height is eight (8) inches (203mm) above finished roof height. Prime vertical wall at a rate of 100 square feet per gallon and allow to dry.
2. Set cant in bitumen. Run all plies over cant a minimum of two (2) inches (50mm).
3. Install base flashing ply covering wall with six (6) inches (152mm) on to field of the roof.

4. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches (228mm) on to the field of the roof. Apply a three-course application of mastic and mesh at all vertical seams and allow to cure and aluminize.
5. Install manufacturer's standard hat channel into the top of the modified membrane to act as a termination bar.
6. Install hat channels at 24" (609mm) o.c. vertically spaced up the wall.
7. Install the uppermost hat channel at the bottom edge of the coping cap. Insert rigid insulation between the hat channels. Place manufacturer's standard seam tape on top of all hat channels.
8. Fasten the first manufactured wall panel vertically plumb and fasten every six (6) inches (152mm)o.c.
9. Install adjoining panels by engaging the opposing interlocking seam and fastening as described above.
10. Complete inside and outside corners by installing pre-fabricated corners or job site braking a full width panel to accommodate the corner, so that the sides engage the lock of the panels to the corner areas.
11. Trim excess seam tape and seam raw edges with manufacturer's recommended sealant.
12. Fasten slip flashing to existing coping cap with a waterproof rivet every 24" (609mm) o.c. to act as a counterflashing over the manufactured wall panel.

N. Expansion Joint

1. Minimum curb height is eight (8) inches (203mm) above finished roof height. Chamfer top of curb. Prime vertical curb at a rate of 100 square feet per gallon and allow to dry.
2. Mechanically attach wood cant to expansion joint nailers. Run all field plies over cant a minimum of two (2) inches (50mm).
3. Install compressible insulation in neoprene cradle.
4. Install base flashing ply covering curb set in bitumen with six (6) inches (152mm) on to field of the roof.
5. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches (228mm) on to the field of the roof. Attach top of membrane to top of curb and nail at eight (8) inches (203mm) o.c. Apply a three-course application of mastic and mesh at all vertical seams and allow to cure and aluminize.
6. Install pre-manufactured expansion joint cover. Fasten sides at 12 inches (609mm) o.c. with fasteners and neoprene washers. Furnish all joint cover laps with butyl tape between metal covers.

O. Equipment Support

1. Minimum curb height is eight (8) inches. Prime vertical at a rate of 100 square feet per gallon and allow to dry.
2. Set cant in bitumen. Run all field plies over cant a minimum of two (2) inches.
3. Install base flashing ply covering curb set in bitumen with six (6) inches on to field of the roof.
4. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches on to the field of the roof. Attach top of membrane to top of curb and nail at eight (8) inches o.c. Apply a three-course application of mastic and mesh at all vertical seams and allow time to cure. Once cured aluminize.

5. Install pre-manufactured cover. Fasten sides at 24 inches o.c. with fasteners and neoprene washers. Furnish all joint cover laps with butyl tape between metal covers.
6. Set equipment on neoprene pad and fasten as required by equipment manufacturer.

P. Curb Detail/Air Handling Station

1. Minimum curb height is eight (8) inches (203mm) above finished roof height. Prime vertical at a rate of 100 square feet per gallon and allow to dry.
2. Set cant in bitumen. Run all field plies over cant a minimum of two (2) inches (50mm).
3. Install base flashing ply covering curb set in bitumen with six (6) inches (152mm) on to field of the roof.
4. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches (228mm) on to the field of the roof. Apply a three-course application of mastic and mesh at all vertical seams and allow to cure and aluminize.
5. Install pre-manufactured counterflashing with fasteners and neoprene washers or per manufacturer's recommendations.
6. Set equipment on neoprene pad and fasten as required by equipment manufacturer.

Q. Hatch

1. Minimum curb height is eight (8) inches (203mm) above finished roof height. Prime vertical at a rate of 100 square feet per gallon and allow to dry.
2. Set cant in bitumen. Run all field plies over cant a minimum of two (2) inches (50mm).
3. Install base flashing ply covering curb set in bitumen with six (6) inches (152mm) on to field of the roof.
4. Install a second ply of modified flashing ply in bitumen over the base flashing ply, nine (9) inches (228mm) on to the field of the roof. Attach top of membrane to top of wood nailer and apply a three-course application of mastic and mesh. Allow to cure and aluminize.

R. Roof Drain

1. Plug drain to prevent debris from entering plumbing.
2. Taper insulation to drain minimum of 8' from center of drain.
3. Run roof system plies over drain. Cut out plies inside drain bowl.
4. Set lead/copper flashing (30" square minimum) in 1/4" bed of mastic.
5. Run lead/copper into drain a minimum of 2". Prime lead/copper at a rate of 100 square feet per gallon and allow to dry.
6. Install base flashing ply (40" square minimum) in Flashing Mastic.
7. Install modified membrane (48" square minimum) in Flashing Mastic.
8. Install clamping ring and assure all plies are under the clamping ring.
9. Remove drain plug and install strainer.

S. Plumbing Stack

1. Minimum stack height is 12".

2. Run roof system over the roof. Seal the base of the stack with elastomeric sealant.
3. Prime flange of new sleeve. Install properly sized sleeves set in 1/4" bed of roof cement.
4. Install base flashing ply in Flashing Mastic.
5. Install modified membrane in Flashing Mastic.
6. Caulk the intersection of the membrane with elastomeric sealant.
7. Turn sleeve a minimum of 1" down inside of stack.

T. Pitch Pocket

1. Run all plies up to the penetration.
2. Place the pitch pocket over the penetration and prime all flanges.
3. Strip in flange of pitch pocket with one (1) ply of base flashing ply. Extend six (6) inches onto field of roof.
4. Install second layer of modified membrane extending nine (9) inches onto field of the roof.
5. Fill pitch pocket half full with non-shrink grout. Let this cure and top off with pourable sealant.
6. Caulk joint between roof system and pitch pocket with roof cement.

3.6 APPLICATION OF SURFACING

A. Roof Coating:

1. The existing roof surface must be sound and free of defects such as blisters, splits, fish mouths, etc., all defects must be repaired with a suitable patching material.
2. Coating should be spray, brush or roller applied at a rate of 1.5 gal./100 sq. ft. over mineral surfaced modified. Apply a two-coat application in a crosshatch manner.
3. White energy star rated coating will be installed first. Grey base coat will be installed second as a top coat.

3.7 FIELD QUALITY CONTROL

- A. The DB Entity shall engage and pay for an independent testing laboratory to perform field inspection and testing as required.
- B. Correct defects or irregularities discovered during field inspection.
- C. Require attendance of roofing and insulation materials manufacturers' representatives at site during installation of the roofing system.

3.8 CLEANING

- A. Remove bitumen adhesive drippings from all walls, windows, floors, ladders and finished surfaces.
- B. In areas where finished surfaces are soiled by asphalt or any other sources of soiling caused by work of this section, consult manufacturer of surfaces for cleaning instructions and conform to their instructions.
- C. Repair or replace defaced or disfigured finishes caused by work of this Section.

3.9 FINAL INSPECTION

- A. At completion of roofing installation and associated work, meet with the DB Entity, installer, installer of associated work, Owner, roofing system manufacturer representative's, and other representatives directly concerned with performance of roofing system.
- B. Walk roof surface areas of the building, inspect perimeter building edges as well as flashing of roof penetrations, walls, curbs and other equipment. List all items requiring correction or completion and furnish copy of list to each party in attendance.
- C. The roofing system manufacturer reserves the right to request a thermographic scan of the roof during final inspection to determine if any damp or wet materials have been installed. The thermographic scan shall be provided by the [Roofing] subcontractor.
- D. If core cuts verify the presence of damp or wet materials, the [Roofing] subcontractor shall be required to replace the damaged areas at his own expense.
- E. Repair or replace deteriorated or defective work found at time above inspection as required to produce an installation which is free of damage and deterioration at time of Contract Substantial Completion and according to warranty requirements.
- F. Notify the MBTA upon completion of corrections.
- G. Following the final inspection, provide written notice of acceptance of the installation from the roofing system manufacturer.

END OF SECTION

SECTION 07600

FLASHING AND SHEET METAL

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Edge strip and flashing.
 - 2. Fascia and trim.
 - 3. Counterflashings over bituminous base flashing.
 - 4. Counterflashings for roof accessories.
 - 5. Base flashing coverings.
 - 6. Fascia and edge metal.
 - 7. Lead flashing for bituminous membranes.
 - 8. Other components.
 - 9. Counterflashings at roof mounted equipment and vent stacks.
 - 10. Fully welded scupper and drainage assemblies.

- B. Related Work:
 - 1. Section 06100 – ROUGH CARPENTRY
 - 2. Section 07420 – METAL WALL PANEL SYSTEMS
 - 3. Section 07423 – RAIN SCREEN SYSTEMS
 - 4. Section 07550 – MODIFIED BITUMEN BUILT-UP ROOFING
 - 5. Section 07720 – ROOF ACCESSORIES

1.2 REFERENCES

ASTM A-446	Specification for steel sheet
ASTM B-209	Specification for aluminum sheet
ASTM B-221	Specification for aluminum extruded shape
ASTM A 370	Specification for 316L stainless steel sheet
FS QQ-L-201	Specification for Lead Sheet
ASTM A792	Steel Sheet, Aluminum-Zinc Alloy-Coated, by the Hot-Dip Process
ASTM B32	Solder Metal
ASTM B209	Aluminum and Alloy Sheet and Plate
ASTM B486	Paste Solder
ASTM D226	Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing
ASTM D486	Asphalt Roof Cement, Asbestos-free
FS O-F-506	Flux, Soldering, Paste and Liquid FM Loss Prevention Data Sheet
NRCA	National Roofing Contractors Association - Roofing
Manual SMACNA	Architectural Sheet Metal Manual
FM GLOBAL	Factory Mutual Global

1.3 SUBMITTALS

- A. Submit under provisions of Section 01300 - Submittals.
- B. Product Data: Provide manufacturer's specification data sheets for each product in accordance with Section 01300.
- C. Provide approval letters from metal manufacturer for use of their metal within this particular roofing system type.
- D. Submit two samples, 12 x 12 inch in size illustrating typical external corner, internal corner, valley, junction to vertical dissimilar surface, material and finish.
- E. Shop Drawings
 - 1. For manufactured and shop fabricated gravel stops, fascia, scuppers, and all other sheet metal fabrications.
 - 2. Shop drawings: Indicate material profile, jointing pattern, jointing details, fastening methods, flashing, terminations, and installation details.
 - 3. Indicate type, gauge and finish of metal. Indicate adjacent materials and substrates.
- F. Certification
 - 1. Submit roof manufacturer's certification where metal fasteners furnished are acceptable to roof manufacturer.
 - 2. Submit roof manufacturer's certification that metal furnished is acceptable to roofing manufacturer as a component of roofing system and is eligible for roof manufacturer's system warranty.
 - 3. Submit certification that metal and fastening system furnished is Tested and Approved by Factory Mutual for 1-90 Wind Up-Lift Requirements.
- G. Manufacturer's Product Data
 - 1. Metal material characteristics and installation recommendations.
 - 2. Submit color chart to Architect prior to material ordering and/or fabrication so that equivalent colors to those specified can be approved.

1.4 QUALITY CONTROL

- A. FM Approvals Listing: Provide roofing, base flashings, and component materials that comply with requirements in FM Approvals 4450 and FM Approvals 4470 as part of a membrane roofing system, and that are listed in FM Approvals' "RoofNav" for Class 1 or noncombustible construction, as applicable. Identify materials with FM Approvals markings. Obtain FM acceptance of system proposed for use prior to ordering materials.
 - 1. Flashing and Sheet Metal:

- a. Fire/Windstorm Classification: In accordance with FM recommendations.
- b. Roofing shall meet FM Global requirements for rating in the field of the roof, perimeter and corners.
- c. Provide additional securement as required in FMG Data Sheet 1-49. Wind ratings shall be calculated based on individual site conditions.
- d. Hail Resistance: MH and in accordance with FM recommendations.
- e. Provide "RoofNav" assembly number corresponding to an FM approved roof assembly. Refer to www.roofnav.com for information and Form 2688.

B. Reference Standards

1. Comply with details and recommendations of SMACNA Manual for workmanship, methods of joining, anchorage, provisions for expansion, etc.
2. Factory Mutual Loss Prevention Data Sheet 1-49 windstorm resistance 1-90.

C. Contractor's Warranty

1. Contractor shall provide the Authority with a notarized written warranty assuring that all sheet metal work including caulking and fasteners to be watertight and secure for a period of two years from the date of final acceptance of the building. Warranty shall include all materials and workmanship required to repair any leaks that develop, and make good any damage to other work or equipment caused by such leaks or the repairs thereof.

1.5 QUALIFICATIONS

- A. Fabricator and Installer: Company specializing in sheet metal flashing work with 5 years experience.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials in manufacturer's original, unopened containers or packages with labels intact and legible.
- B. Stack pre-formed and pre-finished material to prevent twisting, bending, or abrasion, and to provide ventilation. Slope metal sheets to ensure drainage.
- C. Prevent contact with materials which may cause discoloration or staining.

1.7 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 APPROVED EQUIVALENT

- A. Contractor must submit any product not specified a minimum ten days before the bid date to Architect in order for product to be considered for approval. The Architect will notify Contractor, in writing, of decision to accept or reject request. Submission shall include supporting information including material sample, installation instructions, product data, and specifications.

2.2 MATERIALS

- A. Miscellaneous Metals and Flashings:

- 1. All installed metal shall be of similar material to its associated base material. Refer to scope of work for but not limited to the list of base materials. Materials that cause interactions that impair performance, or cause degradation, including galvanic corrosion shall be prohibited. Lead coated copper flashing, except when prohibited due to corrosive or material reaction of adjacent or lower materials.

2.3 RELATED MATERIALS

- A. Metal Primer: Zinc chromate type.
- B. Plastic Cement: ASTM D 4586.
- C. Sealant: Specified in Section 07900 or on drawings.
- D. Lead: Meets Federal Specification QQ-L-201, Grade B, four pounds per square foot.
- E. Zinc: Matching color and thickness of adjacent zinc panels.
 - 1. Underlayment at Zinc shall be Enkamat or other approved separator. Rosin paper or roofing felt not allowed in zinc assemblies.
- F. Solder: ANSI/ASTM B32; 95/05 type.
- G. Flux: FS O-F-506.
- H. Underlayment: ASTM D2178, No15 asphalt saturated roofing felt.
- I. Slip Sheet: Rosin sized building paper.
- J. Fasteners:
 - 1. Corrosion resistant screw fastener as recommended by metal manufacturer. Finish exposed fasteners same as flashing metal.
 - 2. Fastening shall conform to Factory Mutual 1-90 requirements or as stated on section details, whichever is more stringent.

K. Termination Bars:

1. Shall be aluminum unless otherwise recommended by membrane manufacturers.
Material shall be .125" x 1" (minimum) aluminum conforming to ASTM B-221, mill finish.
2. Bar shall have caulk cup as required.

PART 3 - EXECUTION

3.1 PROTECTION

- A. Protect contact areas of dissimilar metals with heavy asphalt or other approved coating, specifically made to stop electrolytic action.
- B. All dissimilar materials shall be separated with non-reactive substrate to prevent galvanic interaction and corrosion.

3.2 GENERAL

- A. Install work watertight, without waves, warps, buckles, fastening stress, or distortion, allowing for expansion and contraction.
- B. Fastening of metal to walls and wood blocking shall comply with SMACNA Architectural Sheet Metal Manual, Factory Mutual I-90 wind uplift specifications and/or manufacturer's recommendations whichever is of the highest standard.
- C. All accessories or other items essential to the completeness of sheet metal installation, whether specifically indicated or not, shall be provided and of the same material as item to which applied.
- D. Metal fascia and copings shall be secured to wood nailers at the bottom edge with a continuous cleat. Cleats shall be at least one gauge heavier than the metal it secures.

3.3 INSPECTION

- A. Verify roof openings, curbs, pipes, sleeves, ducts, or vents through roof are solidly set, cant strips and reglets are in place, and nailing strips locations in conjunction with FM Global requirements.
- B. Verify membrane termination and base flashings are in place, sealed, and secure.
- C. Beginning of installation means acceptance of existing conditions.
- D. Field measure site conditions prior to fabricating work.

3.4 SHOP FABRICATED SHEET METAL

- A. Installing Contractor shall be responsible for determining if the sheet metal systems are in general conformance with roof manufacturer's recommendations.
- B. Metal work shall be shop fabricated to configurations and forms in accordance with recognized sheet metal practices.
- C. Hem exposed edges.

- D. Angle bottom edges of exposed vertical surfaces to form drip.
- E. All corners for sheet metal shall be lapped with adjoining pieces fastened and set in sealant.
- F. Joints for gravel stop fascia system, cap flashing, and surface-mount counterflashing shall be formed with a 1/4" opening between sections. The opening shall be covered by a cover plate or backed by an internal drainage plate formed to the profile of fascia piece. The cover plate shall be embedded in mastic, fastened through the opening between the sections and loose locked to the drip edges.
- G. Install sheet metal to comply with Architectural Sheet Metal manual, Sheet Metal and Air Conditioning Contractor's National Associations, Inc.
- H. Fully welded water tight scupper assemblies, with flanges, tail pipes, end caps and transitions, as shown and required. The scupper assemblies shall be tested for water tightness after fabrication is complete, and prior to incorporation into the finished construction.

3.5 FLASHING MEMBRANE INSTALLATION

A. METAL EDGE DETAIL

- 1. See details for scuppers. For manufactured edge metal, scuppers shall be factory fabricated.
- 2. Accessories: Joint covers, corners, supports, strip flashing at joining, fastenings and other accessories shall be included.
- 3. Install continuous cleat fasten 6" O.C. Fasten flange to wood nailer every 6" staggered.
- 4. Install new metal edge hooked to continuous cleat.
- 5. Metal shall match adjacent wall panels indicated on drawings, unless otherwise noted.
- 6. Prime metal edge at a rate of 100 square feet per gallon and allow to dry.

B. COPING CAP/ SURFACE MOUNTED COUNTERFLASHING

- 1. Copings shall be provided with factory fabricated welded watertight coping accessories such as miters, transitions, end caps, etc. and finished to match coping system.
- 2. Accessories: Joint covers, corners, supports, strip flashing at joinings, fastening, and other accessories shall be included.
- 3. Install continuous cleat fasten 6" O.C.
- 4. Install new coping cap hooked to continuous cleat.

C. HATCH

- 1. Counterflashing shall be provided with watertight accessories such as miters, transitions, end caps, etc. and finished to match.
- 2. Accessories: Joint covers, corners, fasteners, strip flashing at joinings, fastening, and other accessories shall be included.
- 3. Install pre-manufactured expansion joint cover. Fasten sides 8" O.C. with fasteners

and neoprene washers.

4. Set equipment on neoprene pad and fasten as required by equipment manufacturer.

D. ROOF DRAIN

1. Prime lead/copper at a rate of 100 square feet per gallon and allow to dry.
2. Set lead/copper flashing (30" square minimum) in a 1/4" bed of mastic.
3. Install clamping ring and strainer assure all plies are under the clamping ring.

E. PLUMBING STACK

1. Prime flange and sleeve at a rate of 100 square feet per gallon and allow to dry.
2. Install properly sized sleeves in a 1/4" bed of elastomeric sealant.
3. Turn sleeve a minimum of 1" down inside of stack.
4. Caulk intersection of the membrane and flange with elastomeric sealant.
5. Provide seamless Stainless steel vent pip as Washington Station, as indicated on drawings.

F. SCUPPER ASSEMBLIES

1. Scupper assemblies shall be configured as shown in drawings with the minimum joints possible, fully welded with waterproof, water tight joints.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07610

SHEET METAL ROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
1. Batten seam roofing.
 2. Flat seam roofing.
 3. High-temperature underlayment.
 4. Drainage mat.
 5. Snow guards.
 6. Gutters and downspouts adjacent to sheet metal roofing.
- B. Related Work:
1. Section 01800, SUSTAINABILITY REQUIREMENTS
 2. Section 06100, CARPENTRY; Roof sheathing.
 3. Section 07600, FLASHING AND SHEET METAL.

1.2 REFERENCES

- A. Comply with applicable requirements of the following standards. Where these standards conflict with other specified requirements, the most restrictive requirements shall govern.
1. American National Standards Institute(ANSI):
58.1 Design Loads for Buildings and Other Structures
 2. American Society for Testing and Materials (ASTM):
D 226 Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing
 3. Sheet Metal and Air Conditioning Contractors National Association
(SMACNA): Manual Architectural Sheet Metal Manual
 4. United Laboratories (UL):
580 Tests for Uplift Resistance of Roof Assemblies
 5. Rheinzink Application in Architecture, 2nd Updated Edition, January 2002

1.3 SUBMITTALS

- A. Product data including metal manufacturer's and fabricator's specifications, installation instructions, and general recommendations for roofing applications. Include certification or other data substantiating that materials comply with requirements.

- B. Shop Drawings: Show fabrication and installation layouts of sheet metal roofing, including plans, elevations, and keyed references to termination points. Distinguish between shop- and field- assembled work. Include the following:
1. Details for forming sheet metal roofing, including seams and dimensions.
 2. Details for joining and securing sheet metal roofing, including layout of fasteners, clips, and other attachments. Include pattern of seams.
 3. Details of termination points and assemblies, including fixed points.
 4. Details of expansion joints, including showing direction of expansion and contraction.
 5. Details of roof penetrations.
 6. Details of edge conditions, including eaves, ridges, valleys, rakes, crickets, and counterflashings.
 7. Details of special conditions.
 8. Details of connections to adjoining work.
 9. Details of the following accessory items, at a scale of not less than 1-1/2 inches per 12 inches:
 - a. Flashing and trim.
 - b. Roof curbs.
 - c. Snow guards.
- C. Verification Samples: Submit representative samples to architect for approval of each material that is to be exposed in the completed work. Show full color ranges and finish variations expected. Provide samples having minimum size of 144 sq. in.
- D. Delegated Design: Under the supervision of an engineer, licensed in the state of MA, provide sign and sealed calculations and certification of the performance of this work. Indicate how design requirements for resistance to wind loading and other performance criteria have been satisfied.
- E. Test Reports: Provide certified reports for all specified tests.
- F. Installer and Manufacturer: Installer shall be trained or certified by the manufacturer to perform work. Manufacturer shall certify installer as acceptable for terms of warranty.

1.4 PERFORMANCE REQUIREMENTS

- A. General: Provide complete sheet metal roofing system, including, but not limited to, custom-fabricated metal roof pans, cleats, clips, anchors and fasteners, sheet metal flashing and drainage components related to sheet metal roofing, fascia panels, trim, underlayment, and accessories as indicated and as required for a weathertight installation.
- B. Wind-Uplift Resistance: Provide custom-fabricated sheet metal roofing capable of resisting the following design negative uplift pressure. Provide clips, fasteners, and clip spacings of type indicated and with capability to sustain, without failure, a load equal to 3 times the design negative uplift pressure.

1. Design Negative Uplift Pressures:

<u>AREA</u>	<u>Positive</u>	<u>Negative</u>
Main Roof	35 psf	35 psf
Roof Edges	35 psf	45 psf
Roof Corners	35 psf	68 psf

C. Thermal Movements: Provide sheet metal roofing that allows for thermal movements resulting from the following maximum change (range) in ambient and surface temperatures by preventing buckling, opening of joints, hole elongation, overstressing of components, failure of joint sealants, failure of connections, and other detrimental effects. Provide clips that resist rotation and avoid shear stress as a result of sheet metal roofing thermal movements. Base engineering calculation on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.

1. Temperature Change (Range): 120 deg F, ambient; 180 deg F, material surfaces.

D. Water Infiltration: Provide sheet metal roofing that does not allow water infiltration to building interior, with metal flashing and connections of sheet metal roofing lapped to allow moisture to run over and off the material.

E. Metal Protection: Where dissimilar metals will contact each other, protect against galvanic action by painting contact surfaces with bituminous coating, by applying rubberized-asphalt underlayment to each contact surface, or by other permanent separation as recommended by manufacturers of dissimilar metals or by fabricator. Metal protection shall not be visible to public in final configuration.

1.5 QUALITY ASSURANCE

A. Custom-Fabricated Sheet Metal Roofing Fabricator Qualifications: Shop that employs skilled workers who custom-fabricate sheet metal roofing similar to that required for this Project and whose products have a record of successful in-service performance. Shop must have 5 years minimum experience doing work of similar scope and complexity.

B. FM Approvals Listing: Provide roofing, base flashings, and component materials that comply with requirements in FM Approvals 4450 and FM Approvals 4470 as part of a roofing system, and that are listed in FM Approvals' "RoofNav" for Class 1 or noncombustible construction, as applicable. Identify materials with FM Approvals markings. Obtain FM acceptance of system proposed for use prior to ordering materials.

1. Roofing System:

2. Fire/Windstorm Classification: In accordance with FM recommendations.

3. Roofing shall meet FM Global requirements for rating in the field of the roof, perimeter and corners.

4. Provide additional securement as required in FMG Data Sheet 1-52.

5. Hail Resistance: MH and in accordance with FM recommendations.

6. Provide "RoofNav" assembly number corresponding to an FM approved roof assembly. Refer to www.roofnav.com for information and Form 2688.

- C. Sheet Metal Roofing Standard: Comply with SMACNA's "Architectural Sheet Metal Manual." Conform to dimensions and profiles shown unless more stringent requirements are indicated.
- D. Pre-installation Roofing Conference: Before starting roof construction, conduct conference at Project site. Review methods and procedures related to roof construction and sheet metal roofing including, but not limited to, the following:
 - 1. Meet with Authority, Architect, Authority's insurer if applicable, sheet metal roofing Installer, and installers whose work interfaces with or affects sheet metal roofing including installers of roof substrates, accessories and roof-mounted equipment.
 - 2. Review and finalize construction schedule and verify availability of materials, Installer's personnel, equipment, and facilities needed to make progress and avoid delays.
 - 3. Review methods and procedures related to sheet metal roofing installation.
 - 4. Examine substrate conditions for compliance with requirements, including flatness and attachment to structural members.
 - 5. Review structural loading limitations of substrate during and after roofing.
 - 6. Review flashings, special roof details, roof drainage, roof penetrations, equipment curbs, and condition of other construction that will affect sheet metal roofing.
 - 7. Review governing regulations and requirements for insurance, certificates, and testing and inspecting if applicable.
 - 8. Review temporary protection requirements for sheet metal roofing during and after installation.
 - 9. Review roof observation and repair procedures after sheet metal roofing installation.
- E. Mockups: Build full scale mockups for each roofing type to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for fabrication and installation.
 - 1. Provide Sheet Metal Roofing work required to complete mock-up; including supports, attachments, and accessories. Provide each roof condition such as internal and external corners, fascia wrapping, parapet or ridge condition.
 - 2. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Engineer specifically approves such deviations in writing.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver sheet metal roofing, components, and other sheet metal roofing materials so as not to be damaged or deformed. Package sheet metal roofing materials for protection during transportation and handling.
- B. Unload, store, and erect sheet metal roofing materials in a manner to prevent bending, warping, twisting, and surface damage.
- C. Stack materials on platforms or pallets, covered with suitable weathertight and ventilated covering.
- D. Store sheet metal roofing materials to ensure dryness. Do not store sheet metal roofing materials in contact with other materials that might cause staining, denting, or other surface damage.

- E. Store metal away from uncured concrete and masonry.
- F. Protect strippable protective covering on sheet metal roofing from exposure to sunlight and high humidity, except to extent necessary for period of sheet metal roofing installation.

1.7 WARRANTY

- A. Submit 2-part, 5-year, written, signed and sealed warranty:
 - 1. By the roofing manufacturer for roof material defects
 - 2. By the manufacturers of other components of the wall assembly for their material defects.
 - 3. By the installer agreeing to repair or replace systems or components as a result of workmanship defects.
 - a. Structural failures.
 - b. Loose parts.
 - c. Wrinkling or buckling.
 - d. Failure to remain weathertight, including uncontrolled water leakage.
 - e. Deterioration of metals, metal finishes, and other materials beyond normal weathering, including nonuniformity of color or finish.
 - f. Galvanic action between sheet metal roofing and dissimilar materials.
 - 4. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 ROOFING MATERIALS

- A. Zinc Alloy Sheet/Coils: Zinc Alloy meeting ASTM B69-13 for ARCHITECTURAL rolled zinc whose base is electrolytic high grade fine zinc (DIN EN1179) with a 99.995 % Zn degree of purity and alloying additives of 1% copper and 1% titanium in accordance with DIN EN 988.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Rheinzink America Inc.; RHEINZINK.
 - b. Umicore Building Products USA, Inc.; VM ZINC series.
 - c. Jarden Zinc Products; Zinc meeting ASTM B69-13.
 - 2. Pre-Weathered: Pickling process (no phosphating)
 - 3. Minimum Panel Thickness: 0.7 mm
 - 4. Minimum Flashing Thickness: 0.7 mm
 - 5. Finish: Standard manufacturer's palette .
- B. Aluminum Sheet: ASTM B 209 (ASTM B 209M), alloy as standard with manufacturer for finish required, with temper as required to suit forming operations and performance required; with smooth, flat surface.
 - 1. Thickness: 0.040 inch (1.02 mm) unless otherwise indicated.

- a. Batten Caps: 0.050 inch (1.27 mm) thick.
 - b. Exterior Finish: Clear anodized.
- C. Flashing shall be the same material type, finish, color, and thickness as the roof panels, but the temper may be reduced to facilitate fabrication.
- D. Gutters and Downspouts shall be manufactured from 316L Stainless Steel, minimum thickness - 12 gauge.
 - 1. Gutter shape shall be as shown on drawings.
 - 2. Allowances for gutter expansion shall be determined per SMACNA Plate 6, and butt type expansion joints per SMACNA Plate 8 shall spaced a maximum 30 ft. -0 in. on centers.
 - 3. The minimum width for the gutter bottom is 12 in.
 - 4. The minimum downspout size is 3 in diameter.
 - 5. The gutter shall be fabricated as a fully welded trough with end plates and 6" tail pipes.
 - 6. Gutter sets in a supporting steel channel, provide separation pad between materials.
 - 7. Downspout strainers: Provide custom fabricated 3" diameter stainless steel strainers with 70% open perforations, including at the top cap. Strainers shall be 6" tall, with 3" exposed above the gutter bottom.
- E. Snow Guards: Prefabricated, noncorrosive units designed to be installed without penetrating sheet metal roofing, and complete with predrilled holes, clamps, or hooks for anchoring.
 - 1. Seam-Mounted, Bar-Type Snow Guards: Stainless-steel rods or bars held in place by stainless- steel clamps attached to vertical ribs of standing-seam sheet metal roofing.
 - a. Stainless-Steel Finish: Mill.
 - b. Provide one of the following or approved equal:
 - 1. Alpine Snow Guards, Div. of Vermont Slate & Copper Services, Inc.; Model No. 05-98.
 - 2. LMCurbs; S-5! SnoFence.
 - 3. Riddell & Company, Inc.; Snobar.
 - 4. Snow Management Systems, a division of Contek, Inc.; Vermont Snowguard.
- F. Pipe Flashing: Premolded, EPDM pipe collar with flexible aluminum ring bonded to base.

2.2 PRODUCT PERFORMANCE

- A. The standing seam roof system shall be designed to safely resist the positive and negative loads as required for the location and type of project designed. The panel system shall have a U.L. Class 90 rating.
- B. Structural-uniform uplift load capacity of the panel system shall be determined in accordance with the principles of ASTM E1592, "Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference" as follows:

- C. The Factor of Safety on the test results shall be 1.65 for the panel and clip/halter ultimate loads with no increase for wind.
 - 1. The Factor of Safety for fasteners shall be 3.0 for single fastener in each connection, 2.25 for 2 or more fasteners in each connection and 4.0 in masonry.
 - 2. Design uplift capacity for condition of gage, span or loading other than those tested may be determined by interpolation of test results.
 - 3. Deflection shall be I/180 for positive loading.
- D. Water penetration of the panel assembly at 20psf pressure for 15 minutes at 5 gal./hr./sf shall have "no uncontrollable leakage" when tested in accordance with ASTM E331 and ASTM E1646.
- E. Panels are to be fabricated full length with absolutely no end lap conditions allowed. The manufacturing equipment must be owned and operated by the manufacturer who must also be the installer and take complete responsibility for the entire workscope.
- F. Fasten the roofing panels to the structure through the use of concealed halters/clips which are designed to allow for all panel movement through a temperature differential of 180°F without impeding the performance of the panel.

2.3 UNDERLAYMENT MATERIALS

- A. Self-Adhering, High-Temperature Sheet: 30 to 40 mils thick minimum, consisting of slip-resisting polyethylene-film top surface laminated to layer of butyl or SBS-modified asphalt adhesive, with release-paper backing; cold applied. Provide primer when recommended by underlayment manufacturer.
 - 1. Thermal Stability: Stable after testing at 240 deg F; ASTM D 1970.
 - 2. Low Temperature Flexibility: Passes after testing at minus 20 deg F; ASTM D 1970.
 - 3. Available Products:
 - a. Carlisle Coatings & Waterproofing, Div. of Carlisle Companies Inc.; Dri-Start "HR" High Performance Roofing Underlayment.
 - b. Grace, W. R. & Co.; Vycor Ultra.
 - c. Henry Company; Perma-Seal PE.
 - d. Metal-Fab Manufacturing, LLC; MetShield.
 - e. TC MiraDRI; WIP 300HT.
- B. Roof Underlayment: Enkamat 7010 AirZ, or equal compatible with adjacent materials

2.4 MISCELLANEOUS MATERIALS

- A. General: Provide materials and types of fasteners, solder, welding rods, protective coatings, separators, sealants, and other miscellaneous items as required for a complete roofing system and as recommended by fabricator for sheet metal roofing.
- B. Solder for Zinc: ASTM B 32, 60 percent lead and 40 percent tin with low antimony, as recommended by manufacturer.

- C. Elastomeric Joint Sealant: ASTM C 920, of base polymer, type, grade, class, and use classifications required to produce joints in sheet metal roofing that will remain weathertight and as recommended by roll-formed sheet metal roofing manufacturer for installation indicated.
- D. Bituminous Coating: Cold-applied asphalt emulsion according to ASTM D 1187.

2.5 ACCESSORIES

- A. Sheet Metal Roofing Accessories: Provide components required for a complete sheet metal roofing assembly including trim, copings, fasciae, corner units, ridge closures, clips, flashings, sealants, gaskets, fillers, closure strips, and similar items. Match material and finish of sheet metal roofing, unless otherwise indicated.
 - 1. Cleats: Intermittent and continuous attachment devices for mechanically seaming into joints and formed from the following materials and thicknesses unless otherwise indicated:
 - a. Aluminum Roofing: 0.0250-inch thick stainless steel.
 - b. Zinc Roofing: Manufacturer's preformed stainless-steel cleats.
 - 2. Expansion-Type Cleats: Cleats of a design that allows longitudinal movement of roof panels without stressing panel seams; of same material as other cleats.
 - 3. Backing Plates: Plates at roofing splices, fabricated from material recommended by SMACNA.
 - 4. Closure Strips: Closed-cell, expanded, cellular, rubber or crosslinked, polyolefin foam or closed-cell laminated polyethylene; minimum 1-inch- (25-mm-) thick, flexible-closure strips; cut or premolded to match sheet metal roofing profile. Provide closure strips where necessary to ensure weathertight construction.
 - 5. Clips: Minimum 0.024-in. thick, stainless-steel panel clips designed to withstand negative-load requirements.

2.6 FABRICATION

- A. General: Custom fabricate sheet metal roofing to comply with details shown and recommendations in SMACNA's "Architectural Sheet Metal Manual" that apply to design, dimensions (panel width and seam height), geometry, metal thickness, and other characteristics of installation. Fabricate sheet metal roofing and accessories in shop to greatest extent possible.
 - 1. Flat-Seam Roofing: Form flat-seam panels from metal sheets 15 by 24 inches with 1/2-inch (13-mm) notched and folded edges.
 - 2. Batten-Seam Roofing: Form batten-seam panels with edges turned up 1.5 inches and with 1/2-inch (13-mm) flange turned toward center of pan.
 - 3. Zinc Double-Lock Standing Seam: Double-Lock Standing Seam 1.5 inch high seams. (maximum width 15.75" o.c.).
- B. Fabricate sheet metal roofing to allow for expansion in running work sufficient to prevent leakage, damage, and deterioration of the Work. Form exposed sheet metal work to fit substrates without excessive oil canning, buckling, and tool marks, true to line and levels indicated, and with exposed edges folded back to form hems.
 - 1. Form expansion joints of intermeshing hooked flanges, not less than 1 inch (25 mm) deep,

filled with butyl sealant concealed within joints.

2. Use lapped expansion joints only where indicated on Drawings.
- C. Sealant Joints: Where movable, nonexpansion-type joints are indicated or required to produce weathertight seams, form metal to provide for proper installation of elastomeric sealant, in compliance with SMACNA standards.
- D. Sheet Metal Accessories: Custom fabricate flashings and trim to comply with recommendations in SMACNA's "Architectural Sheet Metal Manual" that apply to design, dimensions, metal, and other characteristics of item indicated. Obtain field measurements for accurate fit before shop fabrication.
1. Form exposed sheet metal accessories without excessive oil canning, buckling, and tool marks; true to line, levels, and slopes; and with exposed edges folded back to form hems.
 2. Seams: Fabricate nonmoving seams with flat-lock seams. Tin edges to be seamed, form seams, and solder.
 3. Sealed Joints: Form nonexpansion, but movable, joints in metal to accommodate elastomeric sealant.
 4. Conceal fasteners and expansion provisions where possible. Do not use exposed fasteners on faces of accessories exposed to view.
 5. Fabricate cleats and attachment devices of sizes recommended by SMACNA's "Architectural Sheet Metal Manual" for application, but not less than thickness of metal being secured.
- E. Do not use graphite pencils to mark metal surfaces.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances, substrate, and other conditions affecting performance of the Work.
1. Examine solid roof sheathing to verify that sheathing joints are supported by framing or blocking, that tops of fasteners are flush with surface, and that installation is within flatness tolerances required for finished roofing installation.
 2. Verify that substrate is sound, dry, smooth, clean, sloped for drainage, and completely anchored, and that provision has been made for drainage, flashings, and penetrations through sheet metal roofing.
- B. Examine roughing-in for components and systems penetrating sheet metal roofing to verify actual locations of penetrations relative to seam locations of sheet metal roofing before installation.

3.2 PREPARATION

- A. Coordinate metal roofing with rain drainage work, flashing, trim and construction of decks, parapets, walls, and other adjoining work to provide a permanently leakproof, secure, and noncorrosive installation.

3.3 INSTALLATION, GENERAL

- A. Manufacturer's Recommendations: Except as otherwise shown or specified, comply with recommendations and instructions of manufacturer of sheet metal being fabricated and installed.
- B. Separate dissimilar metals by painting each metal surface in area of contact with a bituminous coating, by applying rubberized asphalt underlayment to each metal surface, or by other permanent separation as recommended by manufacturers of dissimilar metals.
- C. Install flashings to cover underlayment according to requirements in Section 076200 "Sheet Metal Flashing and Trim."
- D. Form and fabricate sheets, seams, strips, cleats, valleys, ridges, edge treatments, integral flashings, and other components of metal roofing to profiles, patterns, and drainage arrangements shown and as required for permanently leakproof construction. Provide for thermal expansion and contraction of the work. Seal joints as shown and as required for leakproof construction. Shop-fabricate materials to greatest extent possible.
- E. Fabricate and install work with lines and corners of exposed units true and accurate. Form exposed faces flat and free of buckles, excessive waves, and avoidable tool marks considering temper and reflectivity of metal. Provide uniform, neat seams with minimum exposure of solder, welds, and sealant. Except as otherwise shown, fold back sheet metal to form a hem on concealed side of exposed edges.
- F. Conceal fasteners and expansion provisions where possible in exposed work, and locate so as to minimize possibility of leakage. Cover and seal fasteners and anchors as required for a tight installation.
- G. Soldered Joints: Clean surfaces to be soldered, removing oils and foreign matter. Pre-tin edges of sheets with solder to a width of 1-1/2 inches (38 mm); however, reduce pre-tinning where pre-tinned surface would show in completed Work.
 - 1. Do not solder aluminum sheet.

3.4 INSTALLATION

- A. The manufacturer must certify the installer in order to provide a complete single source weather-tight package.
- B. All attachments shall allow for thermal expansion and contraction of the roofing materials.
- C. Flat-Seam Roofing: Attach flat-seam metal panels to substrate with cleats, starting at eave and working upward toward ridge. After panels are in place, mallet seams tight and solder.
 - 1. Attach roofing panels with cleats spaced not more than 24 inches (600 mm) o.c. Lock and solder panels to base flashing.
 - 2. Attach edge flashing to face of roof edge with continuous cleat fastened to roof substrate at 12-inch (300-mm) o.c. spacing. Lock panels to edge flashing and solder.
- D. Batten-Seam Roofing: Attach batten-seam metal panels to substrate with cleats, starting at eave and working upward toward ridge. Hold cleats in place with battens and fold edges of cleats over to hold panels. After panels are in place and before batten cap is installed, apply continuous bead of sealant to top of upturned flanges of each panel. Install batten cap covering batten and panel

edges, and fold batten cap and panel together so batten cap and panel edges are completely engaged in seams.

- E. Standing-Seam Zinc Roofing: Attach standing-seam metal panels to substrate with cleats, starting at canopy edge and working upward toward gutter. After panels are in place, mallet seams tight and solder.
 - 1. Attach roofing panels with cleats spaced as required to meet FM Global standards. Lock and solder panels to base flashing.
 - 2. Attach edge flashing to face of canopy edge, as shown on drawings. Use continuous cleat fastened to roof substrate at as required to meet FM Global Standards. Lock panels to edge flashing and solder.

3.5 CLEANING AND PROTECTION

- A. Remove protective film (if any) from exposed surfaces of metal roofing promptly upon installation. Strip with care to avoid damage to finishes.
- B. Clean and neutralize flux materials. Clean off excess solder.
- C. Provide final protection in a manner acceptable to installer that ensures that metal roofing is without damage or deterioration at time of Substantial Completion.
- D. Replace sheet metal roofing components that have been damaged or have deteriorated beyond successful repair by finish touchup or similar minor repair procedures.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07720

ROOF ACCESSORIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies roof hatches and roof tie-offs.
- B. Related Work:
 - 1. Section 05500 - MISCELLANEOUS METALS: Metal vertical ladders
 - 2. Section 06100 - ROUGH CARPENTRY: Wood cants and wood nailers
 - 3. Section 07620 - SHEET METAL FLASHING AND TRIM: Shop- and field-fabricated metal flashing and counterflashing, roof expansion-joint covers, and miscellaneous sheet metal trim and accessories.
 - 4. Division 15 - HEATING, VENTILATING, AND AIR CONDITIONING: Roof-mounted ventilators.
 - 5. Division 16 - ELECTRICAL: Power supply and final connections for automatically operated heat and smoke vents.

1.2 SUBMITTALS

- A. Product Data: For each type of roof accessory indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
- B. Shop Drawings: Show fabrication and installation details for roof accessories. Show layouts of roof accessories including plans and elevations. Indicate dimensions, weights, loadings, required clearances, method of field assembly, and components. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Roof Tie-Offs: Include provide plans, elevations, and details of anchorages, connections and accessory items. Provide installation templates for work installed by others. Show the general arrangement of all components, clearances and principal dimensions, assemblies of window washing equipment. Include weights of components and maximum loads and spacings. Include the seal of a qualified professional engineer who is legally qualified to practice in the Commonwealth of Massachusetts. As part of shop drawings, include a safety inspection log book for yearly inspections. Submit two copies of as-built shop drawings showing anchor locations and details. This drawing shall be posted near exits onto the roof.

1.3 QUALITY ASSURANCE

- A. Sheet Metal Standard: Comply with SMACNA's "Architectural Sheet Metal Manual" details for fabrication of units, including flanges and cap flashing to coordinate with type of roofing indicated.
- B. FM Approvals Listing: Provide roof accessories and component materials that comply with requirements in FM Approvals 4450 and FM Approvals 4470 as part of a membrane roofing system, and that are listed in FM Approvals' "RoofNav" for Class 1 or noncombustible construction,

as applicable. Identify materials with FM Approvals markings. Obtain FM acceptance of system proposed for use prior to ordering materials.

1. Roofing System:

- a. Fire/Windstorm Classification: In accordance with FM recommendations.
- b. Roofing shall meet FM Global requirements for rating in the field of the roof, perimeter and corners.
- c. Provide additional securement as required in FMG Data Sheet 1-29.
- d. Hail Resistance: MH and in accordance with FM recommendations.
- e. Provide "RoofNav" assembly number corresponding to an FM approved roof assembly. Refer to www.roofnav.com for information and Form 2688.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Pack, handle, and ship roof accessories properly labeled in heavy-duty packaging to prevent damage.

1.5 PROJECT CONDITIONS

- A. Field Measurements: Verify required openings for each type of roof accessory by field measurements before fabrication and indicate measurements on Shop Drawings.

1.6 COORDINATION

- A. Coordinate layout and installation of roof accessories with roofing membrane and base flashing and interfacing and adjoining construction to provide a leakproof, weathertight, secure, and noncorrosive installation.

PART 2 -PRODUCTS

2.1 ROOF HATCHES

- A. Roof Hatches: Fabricate roof hatches with insulated double-wall lids and insulated double-wall curb frame with integral deck mounting flange and lid frame counterflashing. Fabricate with welded or mechanically fastened and sealed corner joints. Provide continuous weathertight perimeter gasketing and equip with corrosion-resistant or hot-dip galvanized hardware.

1. Available Manufacturers:

- a. Babcock-Davis; a Cierra Products Inc. Company.
- b. Bilco Company (The).
- c. Nystrom, Inc.
- d. O'Keeffe's Inc.
- e. Wasco Products, Inc.

2. Loads: Fabricate roof hatches to withstand 40-lbf/sq. ft. external and 20-lbf/sq. ft. internal loads.

3. Type and Size: Lid type and size as indicated on the Drawings.

4. Curb and Lid Material: Galvanized steel sheet, 0.079 inch thick.
5. Insulation: Manufacturer's standard board insulation.
6. Interior Lid Liner: Manufacturer's standard metal liner of same material and finish as outer metal lid.
7. Exterior Curb Liner: Manufacturer's standard metal liner of same material and finish as metal curb.
8. Fabricate units to minimum height of 12 inches unless otherwise indicated.
9. Hardware: Galvanized steel spring latch with turn handles, butt- or pintle-type hinge system, and padlock hasps inside and outside.
10. Ladder Safety Post: Manufacturer's standard ladder safety post. Post to lock in place on full extension. Provide release mechanism to return post to closed position.

2.2 ROOF TIE-OFFS

- A. Roof Tie-Offs (Safety Tie-Back Anchors): Model SM-4 by Summit Anchor Company, or equal by ProBel, Boston Anchor or equal.
 1. Configuration: Forged pad eye quenched and tempered, welded to high-strength steel tube and welded to base plate and set flush with substrate.
 2. Material: Hot-dip galvanized steel with stainless steel bolts.

2.3 MISCELLANEOUS MATERIALS

- A. Wood Nailers: Softwood lumber, pressure treated with waterborne preservatives for aboveground use, complying with AWPA C2; not less than 1-1/2 inches thick.
- B. Bituminous Coating: Cold-applied asphalt mastic, SSPC-Paint 12, compounded for 15-mil dry film thickness per coat. Provide inert-type noncorrosive compound free of asbestos fibers, sulfur components, and other deleterious impurities.
- C. Fasteners: Same metal as metals being fastened, or nonmagnetic stainless steel or other noncorrosive metal as recommended by roof accessory manufacturer. Match finish of exposed fasteners with finish of material being fastened. Provide nonremovable fastener heads to exterior exposed fasteners.
- D. Gaskets: Manufacturer's standard tubular or fingered design of neoprene, EPDM, or PVC; or flat design of foam rubber, sponge neoprene, or cork.
- E. Elastomeric Sealant: ASTM C 920, polyurethane sealant; of type, grade, class, and use classifications required to seal joints in sheet metal flashing and trim and remain watertight.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, to verify actual locations, dimensions, and other conditions affecting performance of work.

1. Verify that substrate is sound, dry, smooth, clean, sloped for drainage, and securely anchored and is ready to receive roof accessories.
2. Verify dimensions of roof openings for roof accessories.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. General: Install roof accessories according to manufacturer's written instructions. Anchor roof accessories securely in place and capable of resisting forces specified. Use fasteners, separators, sealants, and other miscellaneous items as required for completing roof accessory installation. Install roof accessories to resist exposure to weather without failing, rattling, leaking, and fastener disengagement.
- B. Install roof accessories to fit substrates and to result in watertight performance.
- C. Metal Protection: Where dissimilar metals will contact each other or corrosive substrates, protect against galvanic action by painting contact surfaces with bituminous coating or by other permanent separation as recommended by manufacturer.
 1. Coat concealed side of uncoated aluminum roof accessories with bituminous coating where in contact with wood, ferrous metal, or cementitious construction.
 2. Underlayment: Where installing exposed-to-view components of roof accessories directly on cementitious or wood substrates, install a course of felt underlayment and cover with a slip sheet, or install a course of polyethylene underlayment.
 3. Bed flanges in thick coat of asphalt roofing cement where required by roof accessory manufacturers for waterproof performance.
- D. Install roof accessories level, plumb, true to line and elevation, and without warping, jogs in alignment, excessive oil canning, buckling, or tool marks.
- E. Roof Hatch Installation:
 1. Check roof hatch for proper operation. Adjust operating mechanism as required. Clean and lubricate joints and hardware.
 2. Attach safety railing system to roof hatch curb.
 3. Attach ladder safety post according to manufacturer's written instructions.
- F. Roof Tie-Off Installation: Erect and install tieback and lifeline anchor systems complete in accordance with the approved shop drawings and all applicable codes, and in accordance with manufacturer's recommendations.
- G. Seal joints with elastomeric sealant as required by manufacturer of roof accessories.

3.3 TOUCH UP

- A. Touch up factory-primed surfaces with compatible primer ready for field painting in accordance with Division 9 painting Sections.
- B. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair

galvanizing to comply with ASTM A 780.

3.4 CLEANING

- A. Clean exposed surfaces according to manufacturer's written instructions.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07811

SPRAYED FIRE-RESISTIVE MATERIALS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies exposed and concealed sprayed fire-resistive materials.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03300 - CAST-IN-PLACE CONCRETE: Concrete protecting structural steel.
 - 3. Section 04800 - MASONRY: Masonry protecting structural steel.
 - 4. Section 05120 - STRUCTURAL STEEL FOR STATIONS AND BUILDINGS: Surface conditions required for structural steel receiving sprayed fire-resistive materials.
 - 5. Section 07840 - FIRESTOPPING: Firestopping and firesafing insulation.
 - 6. Section 09260 - GYPSUM BOARD ASSEMBLIES: Fire-resistance-rated assemblies.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: Structural framing plans indicating the following:
 - 1. Locations and types of surface preparations required before applying sprayed fire-resistive material.
 - 2. Extent of sprayed fire-resistive material for each construction and fire-resistance rating, including the following:
 - a. Applicable fire-resistance design designations of a qualified testing and inspecting agency acceptable to authorities having jurisdiction.
 - b. Minimum thicknesses needed to achieve required fire-resistance ratings of structural components and assemblies.
 - 3. Treatment of sprayed fire-resistive material after application.
- C. Samples for Verification: For each type of colored, exposed sprayed fire-resistive material, two Samples, each 4 inches square, of each color, texture, and material formulation to be applied. Where finishes involve normal color and texture variations, include Sample sets showing the full range of variations expected.
- D. Qualification Data: For Installer, manufacturer, and testing agency.
- E. Compatibility and Adhesion Test Reports: From sprayed fire-resistive material manufacturer indicating the following:

1. Materials have been tested for bond with substrates.
 2. Materials have been verified by sprayed fire-resistive material manufacturer to be compatible with substrate primers and coatings.
 3. Interpretation of test results and written recommendations for primers and substrate preparation needed for adhesion.
- F. Product Test Reports: Based on evaluation of comprehensive tests performed by a qualified testing agency, for proposed sprayed fire-resistive materials.

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: A firm or individual certified, licensed, or otherwise qualified by sprayed fire-resistive material manufacturer as experienced and with sufficient trained staff to install manufacturer's products according to specified requirements. A manufacturer's willingness to sell its sprayed fire-resistive materials to Contractor or to an installer engaged by Contractor does not in itself confer qualification on the buyer.
1. Installer's responsibilities include providing professional engineering services needed to assume engineering responsibility for designation of restrained and unrestrained conditions.
- B. Testing Agency Qualifications: An independent third party testing agency, acceptable to authorities having jurisdiction, with the experience and capability to conduct the testing indicated, as documented according to ASTM E 548.
- C. Source Limitations: Obtain sprayed fire-resistive materials through one source from a single manufacturer.
- D. Sprayed Fire-Resistive Materials Testing: By a qualified third party testing and inspecting agency engaged by Contractor or manufacturer to test for compliance with specified requirements for performance and test methods.
1. Sprayed fire-resistive materials are randomly selected for testing from bags bearing the applicable classification marking of UL or another testing and inspecting agency acceptable to authorities having jurisdiction.
 2. Testing is performed on specimens of sprayed fire-resistive materials that comply with laboratory testing requirements specified in Part 2 and are otherwise identical to installed fire-resistive materials, including application of accelerant, sealers, topcoats, tamping, troweling, rolling, and water overspray, if any of these are used in final application.
 3. Testing is performed on specimens whose application the independent testing and inspecting agency witnessed during preparation and conditioning. Include in test reports a full description of preparation and conditioning of laboratory test specimens.
- E. Compatibility and Adhesion Testing: Engage a qualified testing and inspecting agency to test for compliance with requirements for specified performance and test methods.
1. Test for bond per ASTM E 736 and requirements in UL's "Fire Resistance Directory" for coating materials. Provide bond strength indicated in referenced fire-resistance design, but not less than minimum specified in Part 2.
 2. Verify that manufacturer, through its own laboratory testing or field experience, has not

found primers or coatings to be incompatible with sprayed fire-resistive material.

- F. Fire-Test-Response Characteristics: Provide sprayed fire-resistive materials with the fire-test-response characteristics indicated, as determined by testing identical products per test method indicated below by UL or another testing and inspecting agency acceptable to authorities having jurisdiction. Identify bags containing sprayed fire-resistive materials with appropriate markings of applicable testing and inspecting agency.
 - 1. Fire-Resistance Ratings: Indicated by design designations from UL's "Fire Resistance Directory" or from the listings of another testing and inspecting agency acceptable to authorities having jurisdiction, for sprayed fire-resistive material serving as direct-applied protection tested per ASTM E 119.
 - 2. Surface-Burning Characteristics: ASTM E 84.
- G. Provide products containing no detectable asbestos as determined according to the method specified in 40 CFR 763, Subpart E, Appendix E, Section 1, "Polarized Light Microscopy".
- H. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1. Review methods and procedures related to sprayed fire-resistive materials including, but not limited to, the following:
 - 1. Review and finalize construction schedule and verify sequencing and coordination requirements.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver products to Project site in original, unopened packages with intact and legible manufacturers' labels identifying product and manufacturer, date of manufacture, shelf life if applicable, and fire- resistance ratings applicable to Project.
- B. Use materials with limited shelf life within period indicated. Remove from Project site and discard materials whose shelf life has expired.
- C. Store materials inside, under cover, aboveground, and kept dry until ready for use. Remove from Project site and discard wet or deteriorated materials.

1.5 PROJECT CONDITIONS

- A. Environmental Limitations: Do not apply sprayed fire-resistive material when ambient or substrate temperature is 40 deg F or lower unless temporary protection and heat is provided to maintain temperature at or above this level for 24 hours before, during, and for 24 hours after product application.
- B. Ventilation: Ventilate building spaces during and after application of sprayed fire-resistive material.
- C. Use natural means or, if they are inadequate, forced-air circulation until fire-resistive material dries thoroughly.

1.6 COORDINATION

- A. Sequence and coordinate application of sprayed fire-resistive materials with other related work specified in other Sections to comply with the following requirements:
1. Provide temporary enclosure as required to confine spraying operations and protect the environment.
 2. Provide temporary enclosures for applications to prevent deterioration of fire-resistive material due to exposure to weather and to unfavorable ambient conditions for humidity, temperature, and ventilation.
 3. Avoid unnecessary exposure of fire-resistive material to abrasion and other damage likely to occur during construction operations subsequent to its application.
 4. Do not apply fire-resistive material to metal roof deck substrates until concrete topping, if any, has been completed. For metal roof decks without concrete topping, do not apply fire-resistive material to metal roof deck substrates until roofing has been completed; prohibit roof traffic during application and drying of fire-resistive material.
 5. Do not apply fire-resistive material to metal floor deck substrates until concrete topping has been completed.
 6. Except for thin-film intumescent fireproofing, do not begin applying fire-resistive material until clips, hangers, supports, sleeves, and other items penetrating fire protection are in place.
 7. Defer installing ducts, piping, and other items that would interfere with applying fire-resistive material until application of fire protection is completed.
 8. Do not install enclosing or concealing construction until after fire-resistive material has been applied, inspected, and tested and corrections have been made to defective applications.

1.7 WARRANTY

- A. Special Warranty: Manufacturer's standard form, signed by Contractor and by Installer, in which manufacturer agrees to repair or replace sprayed fire-resistive materials that fail in materials or workmanship within specified warranty period. Failures include, but are not limited to, the following:
1. Cracking, flaking, spalling, or eroding in excess of specified requirements; peeling; or delaminating of sprayed fire-resistive materials from substrates.
 2. Not covered under the warranty are failures due to damage by occupants and maintenance personnel, exposure to environmental conditions other than those investigated and approved during fire-response testing, and other causes not reasonably foreseeable under conditions of normal use.
- B. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 CONCEALED SPRAYED FIRE-RESISTIVE MATERIALS

- A. General: For concealed applications of sprayed fire-resistive materials, provide manufacturer's standard products complying with requirements indicated for material composition and physical properties representative of installed products.

- B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. Cementitious Sprayed Fire-Resistive Material:
 - a. Carboline Co., Fireproofing Products Div.; Pyrolite 15 High Yield.
 - b. Grace, W. R. & Co.--Conn., Construction Products Div.; Monokote Type MK-6/HY.
 - c. Isolatek International Corp., Cafco Products; Cafco 300.
 - d. Southwest Vermiculite Co., Inc.; 5EF.
- C. Material Composition: Cementitious sprayed fire-resistive material consisting of factory-mixed, dry formulation of gypsum or Portland cement binders and lightweight mineral or synthetic aggregates mixed with water at Project site to form a slurry or mortar for conveyance and application.
- D. Physical Properties: Minimum values, unless otherwise indicated, or higher values required to attain designated fire-resistance ratings, measured per standard test methods referenced with each property as follows:
1. Dry Density: 15 lb/cu. ft. for average and individual densities regardless of density indicated in referenced fire-resistance design, or greater if required to attain fire-resistance ratings indicated, per ASTM E 605 or AWCI Technical Manual 12-A, Section 5.4.5, "Displacement Method".
 2. Thickness: Provide minimum average thickness required for fire-resistance design indicated according to the following criteria, but not less than 0.375 inch, per ASTM E 605:
 - a. Where the referenced fire-resistance design lists a thickness of 1 inch or greater, the minimum allowable individual thickness of sprayed fire-resistive material is the design thickness minus 0.25 inch.
 - b. Where the referenced fire-resistance design lists a thickness of less than 1 inch but more than 0.375 inch, the minimum allowable individual thickness of sprayed fire-resistive material is the greater of 0.375 inch or 75 percent of the design thickness.
 - c. No reduction in average thickness is permitted for those fire-resistance designs whose fire-resistance ratings were established at densities of less than 15 lb/cu. ft.
 3. Bond Strength: 150 lbf/sq. ft. minimum per ASTM E 736 under the following conditions:
 - a. Field test sprayed fire-resistive material that is applied to flanges of wide-flange, structural steel members on surfaces matching those that will exist for remainder of steel receiving fire-resistive material.
 - b. If surfaces of structural steel receiving sprayed fire-resistive material are primed or otherwise painted for coating materials, perform series of bond tests specified in UL's "Fire Resistance Directory". Provide bond strength indicated in referenced UL fire-resistance criteria, but not less than 150 lbf/sq. ft. minimum per ASTM E 736.
 - c. Minimum thickness of sprayed fire-resistive material tested in laboratory shall be 0.75 inch.

4. Compressive Strength: 5.21 lbf/sq. in. as determined in the laboratory per ASTM E 761. Minimum thickness of sprayed fire-resistive material tested shall be 0.75 inch and minimum dry density shall be as specified, but not less than 15 lb/cu. ft.
5. Corrosion Resistance: No evidence of corrosion per ASTM E 937.
6. Deflection: No cracking, spalling, or delamination per ASTM E 759.
7. Effect of Impact on Bonding: No cracking, spalling, or delamination per ASTM E 760.
8. Air Erosion: Maximum weight loss of 0.025 g/sq. ft. in 24 hours per ASTM E 859. For laboratory tests, minimum thickness of sprayed fire-resistive material is 0.75 inch maximum dry density is 15 lb/cu. ft. test specimens are not prepurged by mechanically induced air velocities, and tests are terminated after 24 hours.
9. Fungal Resistance: No observed growth on specimens per ASTM G 21.

2.2 EXPOSED CEMENTITIOUS SPRAYED FIRE-RESISTIVE MATERIALS

- A. General: For exposed applications of sprayed fire-resistive materials, provide manufacturer's standard products complying with manufacturer's published performance for material composition and for minimum physical properties of each product listed, measured by standard test methods referenced with each property.
- B. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. Exposed Cementitious Sprayed Fire-Resistive Material:
 - a. Carbolite Co., Fireproofing Products Div.; Pyrocrete 239.
 - b. Grace, W. R. & Co.--Conn., Construction Products Div.; Monokote Type Z106.
 - c. Isolatek International Corp., Cafco Products; Cafco 400.
 - d. York, Inc.; -MD.
 - e. Southwest Vermiculite Co., Inc.; FW7.

2.3 AUXILIARY FIRE-RESISTIVE MATERIALS

- A. General: Provide auxiliary fire-resistive materials that are compatible with sprayed fire-resistive materials and substrates and are approved by UL or another testing and inspecting agency acceptable to authorities having jurisdiction for use in fire-resistance designs indicated.
- B. Substrate Primers: For use on each substrate and with each sprayed fire-resistive product, provide primer that complies with one or more of the following requirements:
 1. Primer's bond strength complies with requirements specified in UL's "Fire Resistance Directory", for coating materials based on a series of bond tests per ASTM E 736.
 2. Primer is identical to those used in assemblies tested for fire-test-response characteristics of sprayed fire-resistive material per ASTM E 119 by UL or another testing and inspecting agency acceptable to authorities having jurisdiction.
- C. Adhesive for Bonding Fire-Resistive Material: Product approved by manufacturer of sprayed fire-resistive material.

- D. Metal Lath: Expanded metal lath fabricated from material of weight, configuration, and finish required to comply with fire-resistance designs indicated and fire-resistive material manufacturer's written recommendations. Include clips, lathing accessories, corner beads, and other anchorage devices required to attach lath to substrates and to receive sprayed fire-resistive material.
- E. Reinforcing Fabric: Glass-fiber fabric of type, weight, and form required to comply with fire-resistance designs indicated, approved by manufacturer of intumescent mastic coating fire-resistive material.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for substrates and other conditions affecting performance of work. A substrate is in satisfactory condition if it complies with the following:
 - 1. Substrates comply with requirements in the Section where the substrate and related materials and construction are specified.
 - 2. Substrates are free of oil, grease, rolling compounds, incompatible primers, loose mill scale, dirt, or other foreign substances capable of impairing bond of fire-resistive materials with substrates under conditions of normal use or fire exposure.
 - 3. Objects penetrating fire-resistive material, including clips, hangers, support sleeves, and similar items, are securely attached to substrates.
 - 4. Substrates are not obstructed by ducts, piping, equipment, and other suspended construction that will interfere with applying fire-resistive material.
- B. Conduct tests according to fire-resistive material manufacturer's written recommendations to verify that substrates are free of oil, rolling compounds, and other substances capable of interfering with bond.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Cover other work subject to damage from fallout or overspray of fire-resistive materials during application.
- B. Clean substrates of substances that could impair bond of fire-resistive material, including dirt, oil, grease, release agents, rolling compounds, loose mill scale, and incompatible primers, paints, and encapsulants.
- C. For exposed applications, repair substrates to remove any surface imperfections that could affect uniformity of texture and thickness in finished surface of sprayed fire-resistive material. Remove minor projections and fill voids that would telegraph through fire-resistive products after application.

3.3 INSTALLATION, GENERAL

- A. Comply with fire-resistive material manufacturer's written instructions for mixing materials, application procedures, and types of equipment used to mix, convey, and spray on fire-resistive material, as applicable to particular conditions of installation and as required to achieve fire-resistance ratings indicated.
- B. Apply sprayed fire-resistive material that is identical to products tested as specified in Part 1 "Quality Assurance" Article and substantiated by test reports, with respect to rate of application, accelerator use, sealers, topcoats, tamping, troweling, water overspray, or other materials and procedures affecting test results.
- C. Install metal lath, as required, to comply with fire-resistance ratings and fire-resistive material manufacturer's written recommendations for conditions of exposure and intended use. Securely attach lath to substrate in position required for support and reinforcement of fire-resistive material. Use anchorage devices of type recommended in writing by sprayed fire-resistive material manufacturer. Attach lathing accessories where indicated or required for secure attachment to substrate.
- D. Coat substrates with adhesive before applying fire-resistive material where required to achieve fire-resistance rating or as recommended in writing by sprayed fire-resistive material manufacturer for material and application indicated.
- E. Extend fire-resistive material in full thickness over entire area of each substrate to be protected.
- F. Unless otherwise recommended in writing by sprayed fire-resistive material manufacturer, install body of fire-resistive covering in a single course.
- G. Spray apply fire-resistive materials to maximum extent possible. Following the spraying operation in each area, complete the coverage by trowel application or other placement method recommended in writing by sprayed fire-resistive material manufacturer.
- H. Where sealers are used, apply products that are tinted to differentiate them from sprayed fire-resistive material over which they are applied.

3.4 INSTALLATION, CONCEALED SPRAYED FIRE-RESISTIVE MATERIALS

- A. Apply concealed sprayed fire-resistive material in thicknesses and densities not less than those required to achieve fire-resistance ratings designated for each condition, but apply in greater thicknesses and densities if specified in Part 2 "Concealed Sprayed Fire-Resistive Materials" Article.

3.5 INSTALLATION, EXPOSED SPRAYED FIRE-RESISTIVE MATERIALS

- A. Apply exposed sprayed fire-resistive material in thicknesses and densities not less than those required to achieve fire-resistance ratings designated for each condition, but apply in greater thicknesses and densities if indicated.
- B. Provide a uniform finish complying with description indicated for each type of material and matching Engineer's sample or, if none, finish approved for field-erected mockup.

- C. Apply exposed cementitious sprayed fire-resistive material to produce the following finish:
 - 1. Spray-textured finish with no further treatment.
- D. Cure exposed cementitious sprayed fire-resistive material according to product manufacturer's written recommendations to prevent premature drying.

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified independent testing and inspecting agency to perform field tests and inspections and to prepare test reports.
 - 1. Testing and inspecting agency will interpret tests and state in each report whether tested work complies with or deviates from requirements.
- B. Remove and replace applications of sprayed fire-resistive material where test results indicate that it does not comply with specified requirements for cohesion and adhesion, for density, or for both.
- C. Apply additional sprayed fire-resistive material per manufacturer's written instructions where test results indicate that thickness does not comply with specified requirements.
- D. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.

3.7 CLEANING, PROTECTING, AND REPAIR

- A. Cleaning: Immediately after completing spraying operations in each containable area of Project, remove material overspray and fallout from surfaces of other construction and clean exposed surfaces to remove evidence of soiling.
- B. Protect sprayed fire-resistive material, according to advice of product manufacturer and Installer, from damage resulting from construction operations or other causes so fire protection will be without damage or deterioration at time of Substantial Completion.
- C. Coordinate application of sprayed fire-resistive material with other construction to minimize need to cut or remove fire protection. As installation of other construction proceeds, inspect sprayed fire-resistive material and patch any damaged or removed areas.
- D. Repair or replace work that has not been successfully protected.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07812

INTUMESCENT FIREPROOFING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies spray applied intumescent fireproofing.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 09900 – PAINTING; Finish top coats on top of intumescent fireproofing

1.2 REFERENCES

- A. Comply with applicable requirements of the following standards. Where these standards conflict with other specified requirements, the most restrictive requirement shall govern.
 - 1. American Society for Testing and Materials (ASTM):
 - E 84 Test for Surface Burning Characteristics of Building Materials
 - E 119 Fire Tests of Building Construction and Materials
 - 2. Steel Structures Painting Council (SSPC):
 - SP 1 Solvent Cleaning
 - SP 2 Hand Tool Cleaning
 - SP 3 Power Tool Cleaning
 - 3. Underwriters Laboratories, Inc. (UL):
 - UL Directory Fire Resistance Directory

1.3 SUBMITTALS

- A. Samples: Submit duplicate sample panels of sprayed-on intumescent fireproofing on sheet steel, at least 12 in. by 12 in., with proposed thickness, color, and surface finish.
- B. Product Data: Submit manufacturer's printed product data, specifications, standard details, installation instructions, use limitations and recommendations for each material used. Provide certifications that materials and systems comply with specified requirements.
- C. Test Reports: Provide certified reports for all specified tests indicating the following:
 - 1. Bond Strength of Fireproofing: ASTM D 4541, tested to provide minimum bond strength twenty times weight of fireproofing materials.
 - 2. Fire test reports of fireproofing application to substrate materials similar to project conditions.

3. U.L. Design Listings from U.L., Inc.

- D. Certification: Submit applicator's current certification, by product manufacturer, as a factory trained and manufacturer approved installer of this product.

1.4 QUALITY ASSURANCE

- A. Source: For each material type required for the work of this section, provide primary materials which are the product of one manufacturer. Provide secondary or accessory materials which are acceptable to the manufacturers of the primary materials.
- B. Installer: A firm with a minimum of three years experience in type of work required by this section and which is acceptable to the manufacturers of the primary materials.
- C. Mock-Ups: Prior to commencing the primary work of this section, provide 20 square foot mock-up at locations acceptable to Engineer. Obtain Engineer's acceptance of visual qualities. Protect and maintain accepted mock-ups throughout the remainder of the work of this section to serve as criteria for acceptance of the work. Approved mock-ups may be incorporated into the finished work.

1.5 ENVIRONMENTAL REQUIREMENTS

- A. When air and substrate temperature is less than 45 deg. F., follow manufacturer's field instructions for cold weather installation. Do not apply when surface temperature is less than 5 deg. F. above the dew point.
- B. Provide ventilation in areas to receive fireproofing during and 72 hours minimum after application, to dry materials and dissipate solvent odors.
- C. Maintain non-toxic, unpolluted working area. Provide temporary enclosures to prevent spray from contaminating air.

1.6 TESTS

- A. Fire Resistance Ratings: Where fire resistant ratings are indicated or required by Authorities having jurisdiction, provide materials and construction which are identical to assemblies whose fire resistance ratings have been tested in compliance with ASTM E 119 by independent agencies acceptable to the Engineer and authorities having jurisdiction.
- B. Burning Characteristics: Provide materials whose surface burning characteristics, when tested in compliance with ASTM E 84 are Class A.

1.7 DELIVERY, STORAGE AND HANDLING

- A. Manufactured materials shall be mill-mixed and shall be delivered in original, unopened packages bearing the name of the product, manufacturer's name, and the Underwriters' Laboratories, Inc. label.
- B. Materials shall be kept dry until ready for use, and shall be kept off the ground, under cover and away from sweating walls and other damp surfaces with minimum temperature of 55°F.

1.8 WARRANTY

- A. Provide certificate stating that sprayed fireproofing has been completed in full accordance with requirements to provide necessary fire resistance ratings.
- B. Provide warranty stating applied fireproofing will remain free from cracks, checking, dusting, flaking, separation, and blistering for one year from date of Substantial Completion, and that failure to provide such performance will constitute reinstallation or repair to satisfaction of Authority at no additional cost.

PART 2 - PRODUCTS

2.1 INTUMESCENT FIREPROOFING

- A. Provide CAFCO Sprayfilm WB5, thin film intumescent fireproof coating system for interior fire protection of structural steel, manufactured by Isolatek International, Stanhope, NJ 07874; or equal as manufactured by Carbolite or Albi.
 - 1. Provide materials that have been fire tested and classified by Underwriter's Laboratories in accordance with ASTM E 84 and E 119.
 - 2. Assume full responsibility for the proper performance of all materials used, for appropriateness of method of application with respect to materials used, for appropriateness of method of application with respect to materials used and substrates encountered, and for the compatibility of any materials applied with shop coats and other coats previously applied, including primers. Follow manufacturer's instructions for compatibility check.
 - 3. Durometer Hardness: 69, Shore D as per ASTM D 2240.
 - 4. Bond Strength: 340 psi minimum as per ASTM D 4541.
 - 5. Abrasion Resistance: 0.2600 g/1000 cycles loss as per ASTM D 4060.
 - 6. Impact Resistance: minimum 40 inch- lbs. intrusions, as per ASTM D 2794.
- B. Primer: Surface preparation of structural steel and primer is specified as work of Section 05100, STRUCTURAL STEEL. Coordinate with structural steel fabricator to ensure that compatible primers are used.
- C. Top Coat: Colored top coats are specified as work of Section 09900, PAINTING. Coordinate with the painting trades to ensure that compatible top coats are applied in the field.

2.2 PERFORMANCE CRITERIA

- A. Materials, procedures for application, dry densities, and thickness necessary to provide the required protection shall be approved by UL for the uses and fire ratings indicated on the Drawings. Submit certification by an independent Testing Laboratory that materials, dry densities, thickness, and application procedures satisfy the requirements of the governing laws and building code, and UL requirements, with respect to the minimum protection requirements below when tested in accordance with ASTM E 119.
- B. Fireproofing Performance: Structural steel members throughout the Project to receive intumescent fireproofing shall be protected under this Section with adequate fireproofing thickness

to provide the fire resistance ratings indicated on the Drawings.

- C. Fire ratings interpolated or extrapolated from actual test data will not be acceptable. Provide evidence prior to application that proposed materials, and installation methods and materials have been approved by all authorities that have jurisdiction.

PART 3 - EXECUTION

3.1 PRIOR WORK OF OTHER SECTIONS

- A. Ducts, piping, conduit, and other suspended equipment which would interfere with the uniform application of the intumescent fireproofing material shall be positioned after application of fireproofing.
- B. Patching and repairing of intumescent fireproofing resulting from cutting or damage by other trades shall be performed under this Section.
- C. Finish Painting: Paint top coats will be applied in the field by the Painting Trade under Section 09900 PAINTING.

3.2 SURFACE PREPARATION

- A. Examine surfaces to which intumescent fireproofing is to be applied, and notify Engineer in writing of conditions detrimental to the proper and expeditious application of fireproofing which cannot be corrected by normal cleaning of surfaces. Starting of work within an area shall be construed as acceptance of the conditions of that area.
 - 1. Where shop painted steel is to be fireproofed with intumescent fireproofing, paint surface shall be checked for compatibility with intumescent coating prior to fireproofing application.
 - 2. Where compatibility is a problem, steel shall be sandblasted and reprimed with fireproofing manufacturer's recommended primer material.
- B. Application of fireproofing shall constitute acceptance of the suitability of the surface to receive this work by the fireproofing applicator.

3.3 SAMPLE AREA

- A. Install 20 sq. ft. minimum sample area of fireproofing comprising a typical column installation for joint approval by representative of fireproofing manufacturer and Engineer and local authority (if required). Fireproofing in other areas shall not proceed until sample installation is approved. Approved sample installation shall remain in place and open to observation as a standard for fireproofing work.

3.4 MIXING AND APPLICATION

- A. Mixing and installation shall conform to manufacturer's published instructions.
- B. Materials and equipment shall be as approved by materials manufacturer. Application shall be by manufacturer's licensed applicators. Provide supervisory services of qualified manufacturer's representative for initial application.

- C. Work shall comply with applicable UL standards in addition to requirements imposed by applicable laws and codes, for indicated ratings.
- D. Apply intumescent fireproofing exactly as described in certificates submitted to prove compliance with specified protection requirements. Control application to maintain uniform quality and thickness.
 - 1. Apply in number of coats required in accordance with UL Directory. Final wet film thickness application shall meet or exceed that required for specified rating.
 - 2. Prior to drying of surface film, all surfaces shall be rolled to remove unsightly drippings or surface irregularities.

3.5 CLEAN-UP

- A. Upon completion of each day's work, sweep area clean, place waste material in suitable bags or containers, and remove from site.
- B. Upon completion of fireproofing work, clean walls, floors, and surrounding surfaces of overspray, drippings, etc.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07840

FIRESTOPPING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Through-penetration firestop systems for penetrations through fire-resistance-rated constructions, including both empty openings and openings containing penetrating items.
 - 2. Fire-resistive joint systems for floor, wall, and head-of-wall joints.

- B. Related Work:
 - 1. Section 07842 - FIRE-RESISTIVE JOINT SYSTEMS: Fire-resistive joint sealers.
 - 2. Section 07920 - JOINT SEALANTS: Standard joint sealers.
 - 3. Section 15400 – PLUMBING FIXTURES: Piping penetrations.
 - 4. Section 15500 - FIRE PROTECTION: Fire-suppression piping penetrations.
 - 5. Section 15600 – HEATING, VENTILATING, AND AIR CONDITIONING: Duct and piping penetrations.
 - 6. Division 16 – ELECTRICAL: Cable and conduit penetrations.

1.2 PERFORMANCE REQUIREMENTS

- A. General: For penetrations through fire-resistance-rated constructions, including both empty openings and openings containing penetrating items, provide through-penetration firestop systems that are produced and installed to resist spread of fire according to requirements indicated, resist passage of smoke and other gases, and maintain original fire-resistance rating of construction penetrated.

- B. F-Rated Systems: Provide through-penetration firestop systems with F-ratings indicated, but not less than that equaling or exceeding fire-resistance rating of constructions penetrated, as determined per ASTM E 814.

- C. For through-penetration firestop systems exposed to view, traffic, moisture, and physical damage, provide products that, after curing, do not deteriorate when exposed to these conditions both during and after construction.
 - 1. For piping penetrations for plumbing and wet-pipe sprinkler systems, provide moisture-resistant through-penetration firestop systems.
 - 2. For floor penetrations with annular spaces exceeding 4 inches in width and exposed to possible loading and traffic, provide firestop systems capable of supporting floor loads involved, either by installing floor plates or by other means.
 - 3. For penetrations involving insulated piping, provide through-penetration firestop systems not requiring removal of insulation.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For each through-penetration firestop system, show each type of construction condition penetrated, relationships to adjoining construction, and type of penetrating item. Include firestop design designation of qualified testing and inspecting agency that evidences compliance with requirements for each condition indicated. Submit documentation, including illustrations, from a qualified testing and inspecting agency that is applicable to each through-penetration firestop system configuration for construction and penetrating items.
- C. Through-Penetration Firestop System Schedule: Indicate locations of each through-penetration firestop system, along with the following information:
 - 1. Types of penetrating items.
 - 2. Types of constructions penetrated, including fire-resistance ratings and, where applicable, thicknesses of construction penetrated.
 - 3. Through-penetration firestop systems for each location identified by firestop design designation of qualified testing and inspecting agency.
- D. Qualification Data: For Installer and Inspection and Testing Agency.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Either a firm that has been approved by FM Global according to FMG 4991, "Approval of Firestop Contractors" or a firm experienced in installing through-penetration firestop systems similar in material, design, and extent to that indicated for this Project, whose work has resulted in construction of a minimum of five projects with a record of successful performance. Qualifications include having the necessary experience, staff, and training to install manufacturer's products per specified requirements.
- B. Source Limitations: Obtain through-penetration firestop systems, for each kind of penetration and construction condition indicated, through one source from a single manufacturer.
- C. Fire-Test-Response Characteristics: Provide through-penetration firestop systems that comply with the following requirements and those specified in Part 1 "Performance Requirements" Article:
 - 1. Firestop tests are performed by a qualified testing and inspecting agency.
 - 2. Through-penetration firestop systems are identical to those tested per testing standard referenced in Part 1 "Performance Requirements" Article. Provide rated systems complying with the following requirements:
 - a. Through-penetration firestop system products bear classification marking of qualified testing and inspecting agency.
 - b. Through-penetration firestop systems correspond to those indicated by reference to through-penetration firestop system designations listed in the UL "Fire Resistance Directory".

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver through-penetration firestop system products to Project site in original, unopened containers or packages with intact and legible manufacturers' labels identifying product and manufacturer, date of manufacture, lot number, shelf life if applicable, qualified testing and inspecting agency's classification marking applicable to Project, curing time, and mixing instructions for multicomponent materials.
- B. Store and handle materials for through-penetration firestop systems to prevent their deterioration or damage due to moisture, temperature changes, contaminants, or other causes.

1.6 PROJECT CONDITIONS

- A. Environmental Limitations: Do not install through-penetration firestop systems when ambient or substrate temperatures are outside limits permitted by through-penetration firestop system manufacturers or when substrates are wet due to rain, frost, condensation, or other causes.
- B. Ventilate through-penetration firestop systems per manufacturer's written instructions by natural means or, where this is inadequate, forced-air circulation.

1.7 COORDINATION

- A. Coordinate construction of openings and penetrating items to ensure that through-penetration firestop systems are installed according to specified requirements.
- B. Coordinate sizing of sleeves, openings, core-drilled holes, or cut openings to accommodate through-penetration firestop systems.
- C. Do not cover up through-penetration firestop system installations that will become concealed behind other construction until each installation has been inspected by the building inspector, if required by authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Products: Subject to compliance with requirements, through-penetration firestop systems that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Hilti, Inc.
 - 2. BioFireshield; RectorSeal Corporation.
 - 3. 3M; Fire Protection Products Division.
 - 4. Or approved equal.

2.2 FIRESTOPPING MATERIALS

- A. Compatibility: Provide through-penetration firestop systems that are compatible with one another; with the substrates forming openings; and with the items, if any, penetrating through-penetration firestop systems, under conditions of service and application, as demonstrated by through-penetration firestop system manufacturer based on testing and field experience.

- B. **Materials:** Provide through-penetration firestop systems containing primary materials and fill materials which are part of the tested assemblies indicated in the Through-Penetration Firestop System Schedule at the end of Part 3. Fill materials are those referred to in directories of referenced testing and inspecting agencies as "fill", "void" or "cavity" materials.
- C. **Accessories:** Provide components for each through-penetration firestop system that are needed to install fill materials and to comply with requirements in this Section. Use only components specified by through-penetration firestop system manufacturer and approved by qualified testing and inspecting agency for firestop systems indicated

2.3 MIXING

- A. For those products requiring mixing before application, comply with through-penetration firestop system manufacturer's written instructions for accurate proportioning of materials, water (if required), type of mixing equipment, selection of mixer speeds, mixing containers, mixing time, and other items or procedures needed to produce products of uniform quality with optimum performance characteristics for application indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for opening configurations, penetrating items, substrates, and other conditions affecting performance of work. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. **Surface Cleaning:** Clean out openings immediately before installing through-penetration firestop systems to comply with firestop system manufacturer's written instructions and with the following requirements:
 - 1. Remove from surfaces of opening substrates and from penetrating items foreign materials that could interfere with adhesion of through-penetration firestop systems.
 - 2. Clean opening substrates and penetrating items to produce clean, sound surfaces capable of developing optimum bond with through-penetration firestop systems. Remove loose particles remaining from cleaning operation.
 - 3. Remove laitance and form-release agents from concrete.
- B. **Priming:** Prime substrates where recommended in writing by through-penetration firestop system manufacturer using that manufacturer's recommended products and methods. Confine primers to areas of bond; do not allow spillage and migration onto exposed surfaces.
- C. **Masking Tape:** Use masking tape to prevent through-penetration firestop systems from contacting adjoining surfaces that will remain exposed on completion of Work and that would otherwise be permanently stained or damaged by such contact or by cleaning methods used to remove smears from firestop system materials. Remove tape as soon as possible without disturbing firestop system's seal with substrates.

3.3 THROUGH-PENETRATION FIRESTOP SYSTEM INSTALLATION

- A. General: Install through-penetration firestop systems to comply with requirements in this Section and with firestop system manufacturer's written installation instructions and published drawings for products and applications indicated.
- B. Install forming/damming/backing materials and other accessories of types required to support fill materials during their application and in the position needed to produce cross-sectional shapes and depths required to achieve fire ratings indicated.
- C. Install fill materials for firestop systems by proven techniques to produce the following results:
 - 1. Fill voids and cavities formed by openings, forming materials, accessories, and penetrating items as required to achieve fire-resistance ratings indicated.
 - 2. Apply materials so they contact and adhere to substrates formed by openings and penetrating items.
 - 3. For fill materials that will remain exposed after completing Work, finish to produce smooth, uniform surfaces that are flush with adjoining finishes.

3.4 FIELD QUALITY CONTROL

- A. Inspecting Agency: Engage a qualified, independent inspecting agency to inspect through-penetration firestops. Independent inspecting agency shall comply with ASTM E 2174 requirements including those related to qualifications, conducting inspections, and preparing test reports.
- B. Where deficiencies are found, repair or replace through-penetration firestop systems so they comply with requirements.
- C. Proceed with enclosing through-penetration firestop systems with other construction only after inspection reports are issued and firestop installations comply with requirements.

3.5 CLEANING AND PROTECTING

- A. Clean off excess fill materials adjacent to openings as Work progresses by methods and with cleaning materials that are approved in writing by through-penetration firestop system manufacturers and that do not damage materials in which openings occur.
- B. Provide final protection and maintain conditions during and after installation that ensure that through- penetration firestop systems are without damage or deterioration at time of Substantial Completion. If, despite such protection, damage or deterioration occurs, cut out and remove damaged or deteriorated through-penetration firestop systems immediately and install new materials to produce systems complying with specified requirements.

3.6 THROUGH-PENETRATION FIRESTOP SYSTEM SCHEDULE

CONCRETE FLOORS		UL-CLASSIFIED SYSTEMS			CONCRETE OR BLOCK WALLS		UL-CLASSIFIED SYSTEMS		
TYPE OF PENETRANT	F-RATING HR	HILTI	3M	BIO-FIRE	TYPE OF PENETRANT	F-RATING	HILTI	3M	BIO-FIRE
CIRCULAR BLANK OPENINGS	1	FA 0006, CAJ 0070	CAJ 0009	CAJ 0056	CIRCULAR BLANK OPENINGS	1	CAJ 0055, CAJ 0070	CAJ 0009	CAJ 0056
	2	FA 0006, CAJ 0070	CAJ 0009	CAJ 0056		2	CAJ 0055, CAJ 0070	CAJ 0009	CAJ 0056
	3	CAJ 0055	CAJ 0009	CAJ 0056		3	CAJ 0055	CAJ 0009	CAJ 0056
SINGLE METAL PIPES OR CONDUIT	1	CAJ 1226, CAJ 1278, FA 1017	CAJ 1058	CAJ 1264	SINGLE METAL PIPES OR CONDUIT	1	CAJ 1226, CAJ 1278,	CAJ 1058	CAJ 1264
	2	CAJ 1226, CAJ 1278, FA 1017	CAJ 1058	CAJ 1264		2	CAJ 1226, CAJ 1278,	CAJ 1058	CAJ 1264
	3	CAJ 1226, CAJ 1278, FA 1017	CAJ 1058	CAJ 1264		3	CAJ 1226, CAJ 1278,	CAJ 1058	CAJ 1264
	4	CAJ 8095, CBJ 1034	CAJ 1044	N/A		4	CAJ 8095, CBJ 1034, WJ 1042	CAJ 1044	WJ 1064
SINGLE NON-METALLIC PIPE OR CONDUIT (I.E. PVC, CPVC, ABS, ENT)	1	CAJ 2109, CAJ 2168, FA 2054, FA 2067	CAJ 2189, CAJ 2117, CAJ 2027	CAJ 2131	SINGLE NON-METALLIC PIPE OR CONDUIT (I.E. PVC, CPVC, ABS, ENT)	1	CAJ 2109, WJ 2108, WJ 2121	CAJ 2189, CAJ 2117, CAJ 2027	CAJ 2131
	2	CAJ 2109, CAJ 2168, FA 2054, FA 2067	CAJ 2189, CAJ 2117	CAJ 2131		2	CAJ 2109, WJ 2108, WJ 2121	CAJ 2189, CAJ 2117, CAJ 2027	CAJ 2131
	3	CAJ 2109, CAJ 2168, FA 2054,	CAJ 2005, CAJ	CAJ 2152		3	CAJ 2109, CAJ	CAJ 2005, CAJ	CAJ2152
			2117			2168, WJ 2091	2117, CAJ 2027		
	4	N/A*	N/A*	N/A	4	WJ 2091	N/A*	N/A	

SINGLE OR BUNDLED CABLES	1	FA 3007, CAJ 3095,	CAJ 3021	CAJ 3103	SINGLE OR BUNDLED CABLES	1	CAJ 3095, WJ 3060 WJ 3074	CAJ 3021	WJ 3071
	2	FA 3007, CAJ 3095,	CAJ 3021	CAJ 3103		2	CAJ 3095, WJ 3060 WJ 3074	CAJ 3021	WJ 3071
	3	FA 3007, CAJ 3095,	CAJ 3030	CAJ 3103		3	CAJ 3095, WJ 3050	CAJ 3030	CAJ 3103
	4	N/A*	N/A*	N/A		4	WJ 3050	N/A*	N/A
CABLE TRAY	1	CAJ 4034, CAJ 4054, CAJ 4017	CAJ 4003	CAJ 4048	CABLE TRAY	1	CAJ 4034, CAJ 4054, WJ 4016,	CAJ 4003	CAJ 4048
	2	CAJ 4034, CAJ 4054, CAJ 4017	CAJ 4003	CAJ 4048		2	CAJ 4034, CAJ 4054, WJ 4016,	CAJ 4003	CAJ 4048
	3	CAJ 4034, CAJ 4017	CAJ 4003	CAJ 4048		3	CAJ 4034, WJ 8007	CAJ 4003	CAJ 4048
	4	N/A*	N/A*	N/A		4	WJ 8007	N/A*	N/A
SINGLE INSULATED PIPES	1	FA 5016, FA 5017, CAJ 5090, CAJ 5091,	CAJ 5080, CAJ 5024, CAJ 5017	CAJ 5082	SINGLE INSULATED PIPES	1	CAJ 5090, CAJ 5091, WJ 5042	CAJ 5080, CAJ 5024, CAJ 5017	CAJ 5082
	2	FA 5016, FA 5017, CAJ 5090, CAJ 5091,	CAJ 5080, CAJ 5024, CAJ 5017	CAJ 5082		2	CAJ 5090, CAJ 5091, WJ 5042	CAJ 5080, CAJ 5024, CAJ 5017	CAJ 5082
	3	FA5016, CAJ 5061, CAJ 5090,	CAJ 5024, CAJ 5017	CAJ 5006		3	CAJ 5090, CAJ 5091,	CAJ 5024, CAJ 5017	CAJ 5006
	4	CBJ 5006	N/A*	N/A		4	WJ 5028, CBJ 5006	N/A*	N/A
ELECTRICAL BUSWAY	1	CAJ 6006, CAJ 6017	CAJ 6001, CAJ 6002	CAJ 6026	ELECTRICAL BUSWAY	1	CAJ 6006, CAJ 6017	CAJ 6001, CAJ 6002	CAJ 6026
	2	CAJ 6006, CAJ 6017	CAJ 6001, CAJ 6002	CAJ 6026		2	CAJ 6006, CAJ 6017	CAJ 6001, CAJ 6002	CAJ 6026
	3	CAJ 6006, CAJ 6017	CAJ 6001,	N/A		3	CAJ 6006,	CAJ 6001,	N/A
			CAJ 6002			CAJ 6017	CAJ 6002		

NON-INSULATED MECHANICAL DUCTWORK WITHOUT DAMPERS	1	CAJ 7046 CAJ 7051	CAJ 7003, CAJ 7021	CAJ 7036	NON-INSULATED MECHANICAL DUCTWORK WITHOUT DAMPERS	1	CAJ 7046, WJ 7029, WJ 7022	CAJ 7003, CAJ 7021	CAJ 7036
	2	CAJ 7046 CAJ 7051	CAJ 7003, CAJ 7021	N/A		2	CAJ 7046, WJ 7029, WJ 7022	CAJ 7003, CAJ 7021	CAJ 7036
	3	CAJ 7046 CAJ 7051	CAJ 7003, CAJ 7021	N/A		3	CAJ 7046 CAJ 7051	CAJ 7003, CAJ 7021	N/A
MIXED PENETRANTS	1	CAJ 8056, CAJ 8095, CAJ 8099	CAJ 8001, CAJ 8013	CAJ 8051	MIXED PENETRANTS	1	CAJ 8096, CAJ 8099 WJ 8007	CAJ 8001, CAJ 8013	CAJ 8051
	2	CAJ 8056, CAJ 8095, CAJ 8099	CAJ 8001, CAJ 8013	CAJ 8051		2	CAJ 8096, CAJ 8099 WJ 8007	CAJ 8001, CAJ 8013	CAJ 8051
	3	CAJ 8056, CAJ 8095, CAJ 8099	CAJ 8001, CAJ 8013	CAJ 8051		3	CAJ 8099 WJ 8007	CAJ 8001, CAJ 8013	CAJ 8051
	4	CAJ 8095	N/A*	N/A		4	WJ 8007	N/A*	N/A

WOOD FLOORS		UL-CLASSIFIED SYSTEMS			GYPSUM WALLBOARD ASSEMBLIES		UL-CLASSIFIED SYSTEMS		
TYPE OF PENETRANT	F-RATING	HILTI	3M	BIO-FIRE	TYPE OF PENETRANT	F-RATING	HILTI	3M	BIO-FIRE
METAL PIPES OR CONDUIT	1	FC 1009, FC 1059	FC 1002	FC 1031	METAL PIPES OR CONDUIT	1	WL 1054, WL 1164	WL 1146	WL 1115
	2	FC 1009, FC 1059	FC 1002	FC 1031		2	WL 1054, WL 1164	WL 1010, WL 1146	WL 1115
NON-METALLIC PIPE OR CONDUIT	1	FC 2025, FC 2126	FC 2024	FC 2059	NON-METALLIC PIPE OR CONDUIT	1	WL 2078, WL 2075, WL 2128	WL 2088, WL 2002	WL 2133
	2	FC 2025, FC 2126	FC 2024	FC 2059		2	WL 2078, WL 2075, WL 2128	WL 2088, WL 2002	WL 2133
	4	FC 2025, FC 2126	FC 2024	FC 2059		4	WL 2184, WL 2245	N/A*	

SINGLE OR BUNDLED CABLES	1	FC 3012, FC 3044	FC 3017	FC 3050	SINGLE OR BUNDLED CABLES	1	WL 3065	WL 3032, WL 3030	WL 3153
						2	WL 3065	WL 3032, WL 3030	WL 3153
	2	FC 3012	FC 3017	N/A		4	WL 3139	N/A*	
					CABLE TRAY	1	WL 4011, WL 4019	WL 4004	WL 4032
						2	WL 4011, WL 4019	WL 4004	WL 4032
						4	WL 8014	N/A*	
INSULATED PIPES	1	FC 5004, FC 5036, FC 5037	FC 5014	FC 5025	INSULATED PIPES	1	WL 5029, WL 5096	WL 5040, WL 5001, WL 5032	WL 5062
						2	WL 5029, WL 5096	WL 5040, WL 5001, WL 5032	WL 5062
	2	FC 5004	N/A*	FC 5025	4	WL 5073	N/A*		
					4	WL 5073			

NON-INSULATED MECHANICAL DUCTWORK WITHOUT DAMPERS	1	FC 7013	FC 7001		NON-INSULATED MECHANICAL DUCTWORK WITHOUT DAMPERS	1	WL 7040, WL 7042	WL 7008	WL 7037
						2	WL 7040, WL 7042	WL 7008, WL 7013, WL 7016	WL 7037
MIXED PENETRANTS	1	FC 8014, FC 8026	FC 8013	N/A	MIXED PENETRANTS	1	WL 8004, WL 8013	WL 8010	WL 8017
						2	WL 8004, WL 8013	WL 8010, WL 8002	WL 8017
	2	N/A*	N/A*	N/A		4	WL 8014	N/A*	
					4	WL 8014			

* No UL-Classified system is available as of August 2003. Engineer Judgement Drawing Required

NOTES:

1. Jobsite conditions of each through-penetration firestop system must meet all details of the UL-Classified System selected.
2. If jobsite conditions do not match any UL-classified systems in the schedules above, contact firestop manufacturer for alternative systems or Engineer Judgement Drawings.
3. Coordinate work with other trades to assure that penetration opening sizes are appropriate for penetrant locations, and vice versa.
4. For 3-hour rated gypsum walls, contact the firestop manufacturer for a UL-classified system or engineer judgement drawing.
5. The Contractor shall verify that the schedule is current at the time of construction, and that each referenced system is suitable for the intended application.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07842

FIRE-RESISTIVE JOINT SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies fire-resistive joint systems at the following locations.
1. Floor-to-floor joints.
 2. Floor-to-wall joints.
 3. Head-of-wall joints.
 4. Wall-to-wall joints.
 5. Perimeter fire-resistive joint systems consisting of floor-to-wall joints between perimeter edge of fire-resistance-rated floor assemblies and exterior curtain walls.
- B. Related Work:
1. Section 07840 - FIRESTOPPING: Firestopping for firestopping.
 2. Section 07920 - JOINT SEALANTS: Standard joint sealers.
 3. Section 15400 – PLUMBING FIXTURES: Piping penetrations.
 4. Section 15500 - FIRE PROTECTION: Fire-suppression piping penetrations.
 5. Section 15600 – HEATING, VENTILATING, AND AIR CONDITIONING: Duct and piping penetrations.
 6. Division 16 – ELECTRICAL: Cable and conduit penetrations.

1.2 PERFORMANCE REQUIREMENTS

- A. General: Provide fire-resistive joint systems that are produced and installed to resist spread of fire according to requirements indicated, resist passage of smoke and other gases, and maintain original fire-resistance rating of assembly in which fire-resistive joint systems are installed.
- B. For fire-resistive systems exposed to view, provide products with flame-spread and smoke-developed indexes of less than 25 and 450, respectively, as determined per ASTM E 84.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For each fire-resistive joint system, show each kind of construction condition in which joints are installed; also show relationships to adjoining construction. Include fire-resistive joint system design designation of testing and inspecting agency acceptable to authorities having jurisdiction that demonstrates compliance with requirements for each condition indicated. Submit documentation, including illustrations, from a qualified testing and inspecting agency that is applicable to each fire-resistive joint system configuration for construction

and penetrating items.

- C. Product Certificates: For each type of fire-resistive joint system, signed by product manufacturer.
- D. Qualification Data: For Installer and Inspection and Testing Agency.
- E. Field quality-control test reports.
- F. Research/Evaluation Reports: For each type of fire-resistive joint system.

1.4 QUALITY ASSURANCE

- A. Installation Responsibility: Assign installation of through-penetration firestop systems and fire-resistive joint systems in Project to a single qualified installer.
- B. Source Limitations: Obtain fire-resistive joint systems, for each kind of joint and construction condition indicated, through one source from a single manufacturer.
- C. Fire-Test-Response Characteristics: Provide fire-resistive joint systems that comply with the following requirements and those specified in this Section:
 - 1. A qualified testing and inspecting agency shall perform fire-resistance tests.
 - 2. Fire-resistive joint systems are identical to those tested per methods indicated in Article 1.2 "Performance Requirements" and comply with the following:
 - a. Fire-resistive joint system products bear classification marking of qualified testing and inspecting agency.
 - b. Fire-resistive joint systems correspond to those indicated by referencing system designations of the qualified testing and inspecting agency.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver fire-resistive joint system products to Project site in original, unopened containers or packages with qualified testing and inspecting agency's classification marking applicable to Project and with intact and legible manufacturers' labels identifying product and manufacturer, date of manufacture, lot number, shelf life, curing time, and mixing instructions for multi-component materials.
- B. Store and handle materials for fire-resistive joint systems to prevent their deterioration or damage due to moisture, temperature changes, contaminants, or other causes.

1.6 PROJECT CONDITIONS

- A. Environmental Limitations: Do not install fire-resistive joint systems when ambient or substrate temperatures are outside limits permitted by fire-resistive joint system manufacturers or when substrates are wet due to rain, frost, condensation, or other causes.
- B. Ventilate fire-resistive joint systems per manufacturer's written instructions by natural means or, if this is inadequate, forced-air circulation.

1.7 COORDINATION

- A. Coordinate construction of joints to ensure that fire-resistive joint systems are installed according to specified requirements.
- B. Coordinate sizing of joints to accommodate fire-resistive joint systems.
- C. Do not cover up fire-resistive joint system installations that will become concealed behind other construction until Contractor's inspecting agency and building inspector of authorities having jurisdiction have examined each installation. Warrantee: 2 years from substantial completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Products: Subject to compliance with requirements, fire-resistive joint systems that may be incorporated into the Work include, but are not limited to, those systems indicated in the Fire- Resistive Joint System Schedule at the end of Part 3.
 - 1. Hilti, Inc.
 - 2. BioFireshield; RectorSeal Corporation.
 - 3. 3M; Fire Protection Products Division.
 - 4. Or approved equal.

2.2 FIRE-RESISTIVE JOINT SYSTEMS

- A. Compatibility: Provide fire-resistive joint systems that are compatible with joint substrates, under conditions of service and application, as demonstrated by fire-resistive joint system manufacturer based on testing and field experience.
- B. Accessories: Provide components of fire-resistive joint systems, including primers and forming materials that are needed to install fill materials and to comply with Part 1 "Performance Requirements" Article. Use only components specified by fire-resistive joint system manufacturer and approved by the qualified testing and inspecting agency for systems indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions, with Installer present, for compliance with requirements for joint configurations, substrates, and other conditions affecting performance of work.
 - 1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Cleaning: Clean joints immediately before installing fire-resistive joint systems to comply with fire-resistive joint system manufacturer's written instructions and the following

requirements:

1. Remove from surfaces of joint substrates foreign materials that could interfere with adhesion of fill materials.
 2. Clean joint substrates to produce clean, sound surfaces capable of developing optimum bond with fill materials. Remove loose particles remaining from cleaning operation.
 3. Remove laitance and form-release agents from concrete.
- B. Priming: Prime substrates where recommended in writing by fire-resistive joint system manufacturer using that manufacturer's recommended products and methods. Confine primers to areas of bond; do not allow spillage and migration onto exposed surfaces.
- C. Masking Tape: Use masking tape to prevent fill materials of fire-resistive joint system from contacting adjoining surfaces that will remain exposed on completion of Work and that would otherwise be permanently stained or damaged by such contact or by cleaning methods used to remove smears from fire-resistive joint system materials. Remove tape as soon as possible without disturbing fire-resistive joint system's seal with substrates or damaging adjoining surfaces.

3.3 INSTALLATION

- A. General: Install fire-resistive joint systems to comply with Part 1 "Performance Requirements" Article and fire-resistive joint system manufacturer's written installation instructions for products and applications indicated.
- B. Install forming/packing/backing materials and other accessories of types required to support fill materials during their application and in position needed to produce cross-sectional shapes and depths required to achieve fire ratings indicated.
- C. Install fill materials for fire-resistive joint systems by proven techniques to produce the following results:
1. Fill voids and cavities formed by openings and forming/packing/backing materials as required to achieve fire-resistance ratings indicated.
 2. Apply fill materials so they contact and adhere to substrates formed by joints.
 3. For fill materials that will remain exposed after completing Work, finish to produce smooth, uniform surfaces that are flush with adjoining finishes.

3.4 FIELD QUALITY CONTROL

- A. Inspecting Agency: Engage a qualified independent inspecting agency to inspect fire-resistive joint systems and prepare inspection reports.
- B. Testing Services: Inspecting of completed installations of fire-resistive joint systems shall take place in successive stages as installation of fire-resistive joint systems proceeds. Do not proceed with installation of joint systems for the next area until inspecting agency determines completed work shows compliance with requirements.
1. Inspecting agency shall state in each report whether inspected fire-resistive joint systems comply with or deviate from requirements.

- C. Remove and replace fire-resistive joint systems where inspections indicate that they do not comply with specified requirements.
- D. Additional inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.
- E. Proceed with enclosing fire-resistive joint systems with other construction only after inspection reports are issued and fire-resistive joint systems comply with requirements.

3.5 CLEANING AND PROTECTING

- A. Clean off excess fill materials adjacent to joints as Work progresses by methods and with cleaning materials that are approved in writing by fire-resistive joint system manufacturers and that do not damage materials in which openings occur.
- B. Provide final protection and maintain conditions during and after installation that ensure fire-resistive joint systems are without damage or deterioration at time of Substantial Completion. If damage or deterioration occurs despite such protection, cut out and remove damaged or deteriorated fire-resistive joint systems immediately and install new materials to produce fire-resistive joint systems complying with specified requirements.

3.6 TESTED (DYNAMIC) JOINT FIRESTOP SYSTEM SCHEDULE

JOINT TYPE	F-RATING	UL-CLASSIFIED SYSTEM NUMBER					
		JOINT WIDTH LESS THAN OR EQUAL TO 2"			JOINT WIDTH LESS THAN OR EQUAL TO 6"		
		HILTI	3M	BIO-FIRESHIELD	HILTI	3M	BIO-FIRESHIELD
CONCRETE FLOOR-TO-FLOOR	1	see note 2	FF-D-0002	N/A**	FF-D-1026, FF-D-1039	FF-D-1002, FF-D-1003, FF-D-1004	N/A**
	2	see note 2	FF-D-0002	N/A**	FF-D-1026, FF-D-1039	FF-D-1002, FF-D-1003, FF-D-1004	N/A**
	3	see note 2	N/A**	N/A**	FF-D-1026, FF-D-1039	N/A**	N/A**
EDGE OF CONCRETE FLOOR SLAB-TO-WALL (also see CURTAIN WALLS & note 1))	1	see note 2	-	N/A**	FW-D-1011, FW-D-1012, FW-D-1013, FW-D-1021	FW-D-1002, FW-D-1003, FW-D-1009	FW-D-1023
	2	see note 2	-	N/A**	FW-D-1011, FW-D-1012, FW-D-1013, FW-D-1021	FW-D-1002, FW-D-1003, FW-D-1009	FW-D-1023
	3	see note 2	-	N/A**	FW-D-1011, FW-D-1021	FW-D-1002, FW-D-1009	N/A**
CONCRETE OR BLOCK WALL TO FLAT CONCRETE SLAB FLOOR (TOP-OF-WALL)	1	HW-D-0097	HW-D-0023, HW-D-0029	HW-D-0114	HW-D-1008, HW-D-1009	HW-D-1003	HW-D-1023
	2	HW-D-0097	HW-D-0023, HW-D-0029	HW-D-0114	HW-D-1008, HW-D-1009	HW-D-1003	HW-D-1023

	3	see note 2	-	HW-D-0114	HW-D-1008	HW-D-1002, HW-D-1007	N/A**
CONCRETE OR BLOCK WALL TO CONCRETE OVER FLUTED METAL DECK (TOP-OF- WALL)	1	HW-D-0080, HW-D-0081, HW-D-0098, HW-D 0181	HW-D-0022, HW-D-0030, HW-D- 0040HW-D- 0013	HW-D-0200	HW-D- 1037	HW-D 1041	N/A**
	2	HW-D-0080, HW-D-0081, HW-D-0098, HW-D 0181	HW-D-0022, HW-D-0030, HW-D- 0040HW-D- 0013	HW-D-0200	HW-D- 1037	HW-D 1041	N/A**
	3	N/A**	N/A**	N/A**	N/A**		N/A**
GYPSUM WALL TO FLAT CONCRETE SLAB FLOOR (TOP- OF-WALL)	1	HW-D-0082, HW-D-0083, HW-D-0097	HW-D-0012, HW-D-0021	HW-D-0180	N/A**		
	2	HW-D-0082, HW-D-0083, HW-D-0097	HW-D-0012, HW-D-0021	HW-D-0180	N/A**		
	3	N/A**	N/A**	N/A**	N/A**		
GYPSUM WALL TO CONCRETE OVER FLUTED METAL DECK (TOP-OF- WALL)	1	HW-D-0042, HW-D-0049, HW-D-0076, HW-D-0264	HW-D-0011, HW-D-0020, HW-D-0031	HW-D-0033	N/A**		
	2	HW-D-0042, HW-D-0049, HW-D-0076, HW-D-0264	HW-D-0011, HW-D-0020, HW-D-0031	HW-D-0033	N/A**		
	3	HW-D-292	N/A**	N/A**	N/A**		
CONCRETE WALL- TO-WALL	1	WW-D-0017, WW-D-0032	-	WW-D-0009	WW-D-1011, WW-D-1012	WW-D-1003, WW-D-1004, WW-D-1010	N/A**
	2	WW-D-0017, WW-D-0032	-	WW-D-0009	WW-D-1011, WW-D-1012	WW-D-1003, WW-D-1004, WW-D-1010	N/A**
	3	-	-	WW-D-0010	WW-D-1011	WW-D-1003, WW-D-1010	N/A**
<i>CURTAIN WALLS (see note 1)</i>		JOINT WIDTH LESS THAN OR EQUAL TO 6"			JOINT WIDTH LESS THAN OR EQUAL TO 8"		
EDGE OF FLOOR TO NON-RATED ALUMINUM & GLASS CURTAIN WALL	2 hr In- tegrity Rating				CW-D-2026, CW-D-2027		CW-D-2019, CW-D-2015
EDGE OF FLOOR TO NON-RATED CONCRETE/STONE SPANDREL	2 hr In- tegrity Rating	CW-D-1001			CW-D-2025		CW-D-2017

** CONTACT MANUFACTURER FOR CURRENT UL-CLASSIFIED SYSTEM OR ENGINEER JUDGEMENT DRAWING

NOTES:

1. EDGE OF SLAB, CURTAIN WALL SYSTEMS ARE ALSO TESTED BY OMEGA POINT LABS. CONTACT MANUFACTURER FOR ADDITIONAL LISTINGS.
2. CLASSIFIED SYSTEMS FOR 2" - 6" WIDE JOINTS MAY BE USED FOR JOINTS 2" WIDE AND

LESS.

3. CONFIRM THAT MOVEMENT CAPABILITIES OF THE SELECTED UL SYSTEM MEETS OR EXCEEDS THE SPECIFIED MOVEMENT RANGE OF THE PARTICULAR JOINT.
4. SYSTEM PERFORMANCE MAY BE AFFECTED BY FACTORS SUCH AS METAL STUD WIDTH, JOINT WIDTH OR THE PRESENCE OF FIREPROOFING MATERIALS WITHIN THE JOINT. CONSULT INDIVIDUAL DETAILS FOR SPECIFICATIONS & LIMITATIONS.
5. HEAD-OF-WALL SYSTEMS SPECIFIED ONLY FOR 2- OR 3-HR SYSTEMS MAY NOT BE SUITABLE FOR MASONRY WALLS OR GYPSUM WALL ASSEMBLIES WITH LOWER HOURLY RATINGS.
6. CONTACT THE FIRESTOP MANUFACTURER FOR CLARIFICATION

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 07911

EXPANSION JOINT ASSEMBLIES

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies work involving the following items:
1. The furnishing and installation of expansion joints for Roadway Bridges.
 2. The furnishing and installation of expansion joints for the Washington Street Railroad Bridge.
 3. The furnishing and installation of expansion joints for Emergency Egress Viaduct Structures. For expansion joint systems for the Green Line Viaduct, see specification Section 07162 – Spray-On Waterproofing.
- B. Related Work:
1. Section 05810 – EXPANSION JOINT COVER ASSEMBLIES.
 2. Section 07162 – SPRAY-ON WATERPROOFING.
- C. For all Roadway Bridge Strip Seal Bridge Joint System requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 972.
1. For Roadway Bridge expansion joint submittal requirements, including, but not limited to shop drawings, working drawings, Requests For Information, and Non Conformance and testing reports, refer to Section 01300 – SUBMITTALS of the Contract Specifications.
 2. Per Division 1 of the Contract Specifications, the Contractor is responsible for all sampling and testing as outlined in their approved Quality Management Plan and Testing Plan. The Contractor is also responsible for all costs related to the sampling, testing, and related work.
 3. For all expansion joint requirements regarding Measurement and Payment, see Part 4 below.
- D. For the Washington Street Railroad Bridge and Emergency Egress Viaduct, the Contractor shall install a Strip Seal Bridge Joint System in conformance with the contract drawings and details. The details as indicated on the contract drawings are intended as a general guide for a typical glandular type strip seal joint system. Shop drawings which include details of the gland shape, steel extrusion shape, welding procedure specifications, anchor arrangement, temperature correction requirements, and temporary support details shall be submitted for approval of the Engineer. For requirements regarding General Information, Products, and Execution, refer to MassDOT Standard Specifications (with Supplemental Specifications) Section 972.
1. For all Washington Street Railroad Bridge and Emergency Egress Viaduct expansion joint requirements regarding Measurement and Payment, see Part 4 below.

PART 2 – PRODUCTS

2.1 EXPANSION JOINTS FOR WASHINGTON STREET RAILROAD BRIDGE

- A. Not used.

2.2 EXPANSION JOINTS FOR VIADUCT STRUCTURES

- A. Not used.

2.3 ACCEPTANCE SAMPLING AND DOCUMENTATION REQUIREMENTS FOR MASSDOT ROADWAY BRIDGES

- A. The following samples must be submitted to the Program Manager per MassDOT Research and Materials assurance requirements:
 - 1. For Neoprene Strip Seals
 - a. Sampling Frequency: A minimum of one per joint.

PART 3 – EXECUTION

3.1 TESTING, INSTALLATION, AND INSPECTION OF EXPANSION JOINTS FOR WASHINGTON STREET RAILROAD BRIDGE

- A. Not used.

3.2 TESTING, INSTALLATION, AND INSPECTION OF EXPANSION JOINTS FOR VIADUCT STRUCTURES

- A. Not used.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 07920

JOINT SEALANTS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies joint sealants and fillers for interior and exterior applications.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 - 2. Section 04800 - MASONRY: Masonry control and expansion joint fillers and gaskets.
 - 3. Section 08801 - GLASS AND GLAZING: Glazing sealants.
 - 4. Section 09260 - GYPSUM BOARD ASSEMBLIES: Sealing perimeter joints of gypsum board partitions to reduce sound transmission.
 - 5. Section 09360 – MODULAR TACTILE SURFACES.
 - 6. Section 09510 - ACOUSTICAL CEILINGS: Sealing edge moldings at perimeters of acoustical ceilings.

1.2 PERFORMANCE REQUIREMENTS

- A. Provide elastomeric joint sealants that establish and maintain watertight and airtight continuous joint seals without staining or deteriorating joint substrates.
- B. Provide joint sealants for interior applications that establish and maintain airtight and water-resistant continuous joint seals without staining or deteriorating joint substrates.

1.3 SUBMITTALS

- A. Product Data: For each joint-sealant product indicated.
- B. Samples for Verification: For each type and color of joint sealant required, provide Samples with joint sealants in 1/2-inch wide joints formed between two 6-inch long strips of material matching the appearance of exposed surfaces adjacent to joint sealants.
- C. Qualification Data: For Installer.
- D. Preconstruction Field Test Reports: Indicate which sealants and joint preparation methods resulted in optimum adhesion to joint substrates based on preconstruction testing specified in Part 1 "Quality Assurance" Article.
- E. Compatibility and Adhesion Test Reports: From sealant manufacturer, indicating the following:
 - 1. Materials forming joint substrates and joint-sealant backings have been tested for compatibility and adhesion with joint sealants.
 - 2. Interpretation of test results and written recommendations for primers and substrate preparation needed for adhesion.

- F. Field Test Report Log: For each elastomeric sealant application.
- G. Product Test Reports: Based on comprehensive testing of product formulations performed by a qualified testing agency, indicating that sealants comply with requirements.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized Installer who is approved or licensed for installation of elastomeric sealants required for this Project.
- B. Source Limitations: Obtain each type of joint sealant through one source from a single manufacturer.
- C. Preconstruction Compatibility and Adhesion Testing: Submit to joint-sealant manufacturers, for testing indicated below, samples of materials that will contact or affect joint sealants.
 - 1. Use manufacturer's standard test method to determine whether priming and other specific joint preparation techniques are required to obtain rapid, optimum adhesion of joint sealants to joint substrates.
 - 2. Schedule sufficient time for testing and analyzing results to prevent delaying the Work.
 - 3. For materials failing tests, obtain joint-sealant manufacturer's written instructions for corrective measures including use of specially formulated primers.
 - 4. Testing will not be required if joint-sealant manufacturers submit joint preparation data that are based on previous testing of current sealant products for adhesion to, and compatibility with, joint substrates and other materials matching those submitted.
- D. Preconstruction Field-Adhesion Testing: Before installing elastomeric sealants, field test their adhesion to Project joint substrates as follows:
 - 1. Locate test joints where indicated on Project or, if not indicated, as directed by Engineer.
 - 2. Conduct field tests for each application indicated below:
 - a. Each type of elastomeric sealant and joint substrate indicated.
 - b. Each type of nonelastomeric sealant and joint substrate indicated.
 - 3. Notify Engineer seven days in advance of dates and times when test joints will be erected.
 - a. Test Method: Test joint sealants according to Method A, Field-Applied Sealant Joint Hand Pull Tab, in Appendix X1 in ASTM C 1193.
 - 1. For joints with dissimilar substrates, verify adhesion to each substrate separately; extend cut along one side, verifying adhesion to opposite side. Repeat procedure for opposite side.
 - 4. Report whether sealant in joint connected to pulled-out portion failed to adhere to joint substrates or tore cohesively. Include data on pull distance used to test each type of product and joint substrate. For sealants that fail adhesively, retest until satisfactory adhesion is obtained.
 - 5. Evaluation of Preconstruction Field-Adhesion-Test Results: Sealants not evidencing adhesive failure from testing, in absence of other indications of noncompliance with requirements, will be considered satisfactory. Do not use sealants that fail to adhere to joint substrates during testing.

- E. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1.

1.5 PROJECT CONDITIONS

- A. Do not proceed with installation of joint sealants under the following conditions:
 - 1. When ambient and substrate temperature conditions are outside limits permitted by joint-sealant manufacturer or are below 40 deg F.
 - 2. When joint substrates are wet.
 - 3. Where joint widths are less than or greater than those allowed by joint-sealant manufacturer for applications indicated.
 - 4. Contaminants capable of interfering with adhesion have not yet been removed from joint substrates.
 - 5. When substrates have not cured sufficiently.

1.6 WARRANTY

- A. Special Installer's Warranty: Installer's standard form in which Installer agrees to repair or replace elastomeric joint sealants that do not comply with performance and other requirements specified in this Section within specified warranty period.
 - 1. Warranty Period: Two years from date of Substantial Completion.
- B. Special Manufacturer's Warranty: Manufacturer's standard form in which elastomeric sealant manufacturer agrees to furnish elastomeric joint sealants to repair or replace those that do not comply with performance and other requirements specified in this Section within specified warranty period.
 - 1. Warranty Period: Five years from date of Substantial Completion.
- C. Special warranties specified in this Article exclude deterioration or failure of elastomeric joint sealants from the following:
 - 1. Movement of the structure resulting in stresses on the sealant exceeding sealant manufacturer's written specifications for sealant elongation and compression caused by structural settlement or errors attributable to design or construction.
 - 2. Disintegration of joint substrates from natural causes exceeding design specifications.
 - 3. Mechanical damage caused by individuals, tools, or other outside agents.
 - 4. Changes in sealant appearance caused by accumulation of dirt or other atmospheric contaminants.

1.7 PRE-CONSTRUCTION MEETING

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 MATERIALS, GENERAL

- A. Compatibility: Provide joint sealants, backings, and other related materials that are compatible with one another and with joint substrates under conditions of service and application, as demonstrated by sealant manufacturer, based on testing and field experience.
- B. VOC Content of Interior Sealants: Provide interior sealants and sealant primers that comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24):
 - 1. Sealants: 250 g/L.
 - 2. Sealant Primers for Nonporous Substrates: 250 g/L.
 - 3. Sealant Primers for Porous Substrates: 775 g/L.
- C. Colors of Exposed Joint Sealants: As indicated by manufacturer's designations.
- D. All joints between panels shall be sealed with sealant matching adjacent panels or substrates. Any areas that are unclear shall be brought to the attention of the Engineer/Architect to determine the appropriate action.

2.2 JOINT SEALANTS

- A. Elastomeric Sealants: Comply with ASTM C 920 and other requirements indicated for each liquid-applied chemically curing sealant specified, including those referencing ASTM C 920 classifications for type, grade, class, and uses related to exposure and joint substrates.
- B. Stain-Test-Response Characteristics: Elastomeric sealants shall be nonstaining to porous substrates. Provide products that have undergone testing according to ASTM C 1248 and have not stained porous joint substrates indicated for Project.
- C. Suitability for Contact with Food: Where elastomeric sealants are indicated for joints that will come in repeated contact with food, provide products that comply with 21 CFR 177.2600.
- D. Single-Component Neutral-Curing Silicone Sealant:
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Dow Corning Corporation; 790.
 - b. GE Silicones; SilPruf LM SCS2700.
 - c. Tremco; Spectrem 1.
 - d. Pecora Corporation; 864.
 - 2. Extent of Use: Joints in exterior vertical surfaces and soffit surfaces.
- E. Multicomponent Pourable Urethane Sealant:
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:

- a. Bostik Findley; Chem-Calk 550.
 - b. Meadows, W. R., Inc.; POURTHANE.
 - c. Pecora Corporation; Urexpan NR-200.
 - d. Tremco; THC-901.
2. Extent of Use: Joints in exterior horizontal surfaces; heel proof.
- F. Single-Component Mildew-Resistant Acid-Curing Silicone Sealant:
- 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Dow Corning Corporation; 786 Mildew Resistant.
 - b. GE Silicones; Sanitary SCS1700.
 - c. Tremco; Tremsil 200.
 - 2. Extent of Use: Sanitary joints at toilet rooms.
- G. Latex Sealant: Comply with ASTM C 834, Type P, Grade NF.
- 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Bostik Findley; Chem-Calk 600.
 - b. Pecora Corporation; AC-20+.
 - c. Sonneborn, Division of ChemRex Inc.; Sonolac.
 - d. Tremco; Tremflex 834.
 - 2. Extent of Use: Joints in interior vertical and horizontal surfaces. Coordinate with spec section 03331 – Architectural Concrete Finish for joint fillers on horizontal surfaces at polished concrete floor areas.

2.3 JOINT-SEALANT BACKING

- A. General: Provide sealant backings of material and type that are nonstaining; are compatible with joint substrates, sealants, primers, and other joint fillers; and are approved for applications indicated by sealant manufacturer based on field experience and laboratory testing.
- B. Cylindrical Sealant Backings: ASTM C 1330, Type C (closed-cell material with a surface skin). O (open-cell material). B (bicellular material with a surface skin) or any of the preceding types, as approved in writing by joint-sealant manufacturer for joint application indicated, and of size and density to control sealant depth and otherwise contribute to producing optimum sealant performance:
- C. Elastomeric Tubing Sealant Backings: Neoprene, butyl, EPDM, or silicone tubing complying with ASTM D 1056, nonabsorbent to water and gas, and capable of remaining resilient at temperatures down to minus 26 deg F. Provide products with low compression set and of size and shape to provide a secondary seal, to control sealant depth, and to otherwise contribute to optimum sealant performance.

- D. Bond-Breaker Tape: Polyethylene tape or other plastic tape recommended by sealant manufacturer for preventing sealant from adhering to rigid, inflexible joint-filler materials or joint surfaces at back of joint where such adhesion would result in sealant failure. Provide self-adhesive tape where applicable.

2.4 MISCELLANEOUS MATERIALS

- A. Primer: Material recommended by joint-sealant manufacturer where required for adhesion of sealant to joint substrates indicated, as determined from preconstruction joint-sealant-substrate tests and field tests.
- B. Compressible Filler: Premolded filler strips complying with ASTM D 1056, Grade 2A1; compressible up to 35 percent; of width and thickness indicated; formulated from neoprene.
- C. Cleaners for Nonporous Surfaces: Chemical cleaners acceptable to manufacturers of sealants and sealant backing materials, free of oily residues or other substances capable of staining or harming joint substrates and adjacent nonporous surfaces in any way, and formulated to promote optimum adhesion of sealants to joint substrates.
- D. Masking Tape: Nonstaining, nonabsorbent material compatible with joint sealants and surfaces adjacent to joints.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine joints indicated to receive joint sealants, with Installer present, for compliance with requirements for joint configuration, installation tolerances, and other conditions affecting joint-sealant performance.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Cleaning of Joints: Clean out joints immediately before installing joint sealants to comply with joint-sealant manufacturer's written instructions and the following requirements:
 - 1. Remove all foreign material from joint substrates that could interfere with adhesion of joint sealant, including dust, paints (except for permanent, protective coatings tested and approved for sealant adhesion and compatibility by sealant manufacturer), old joint sealants, oil, grease, waterproofing, water repellents, water, surface dirt, and frost.
 - 2. Clean porous joint substrate surfaces by brushing, grinding, blast cleaning, mechanical abrading, or a combination of these methods to produce a clean, sound substrate capable of developing optimum bond with joint sealants. Remove loose particles remaining after cleaning operations above by vacuuming or blowing out joints with oil-free compressed air. Porous joint substrates include concrete, masonry and unglazed surfaces of ceramic tile.
 - 3. Remove laitance and form-release agents from concrete.
 - 4. Clean nonporous surfaces with chemical cleaners or other means that do not stain, harm substrates, or leave residues capable of interfering with adhesion of joint sealants. Nonporous joint substrates include the following metal, glass, porcelain enamel and glazed surfaces of ceramic tile.

- B. Joint Priming: Prime joint substrates, where recommended in writing by joint-sealant manufacturer, based on preconstruction joint-sealant-substrate tests or prior experience. Apply primer to comply with joint-sealant manufacturer's written instructions. Confine primers to areas of joint-sealant bond; do not allow spillage or migration onto adjoining surfaces.
- C. Masking Tape: Use masking tape where required to prevent contact of sealant with adjoining surfaces that otherwise would be permanently stained or damaged by such contact or by cleaning methods required to remove sealant smears. Remove tape immediately after tooling without disturbing joint seal.

3.3 INSTALLATION OF JOINT SEALANTS

- A. General: Comply with joint-sealant manufacturer's written installation instructions for products and applications indicated, unless more stringent requirements apply.
- B. Sealant Installation Standard: Comply with recommendations in ASTM C 1193 for use of joint sealants as applicable to materials, applications, and conditions indicated.
- C. Install sealant backings of type indicated to support sealants during application and at position required to produce cross-sectional shapes and depths of installed sealants relative to joint widths that allow optimum sealant movement capability.
 - 1. Do not leave gaps between ends of sealant backings.
 - 2. Do not stretch, twist, puncture, or tear sealant backings.
 - 3. Remove excess material.
 - 4. Remove absorbent sealant backings that have become wet before sealant application and replace them with dry materials.
- D. Install bond-breaker tape behind sealants where sealant backings are not used between sealants and backs of joints.
- E. Install sealants using proven techniques that comply with the following and at the same time backings are installed:
 - 1. Place sealants so they directly contact and fully wet joint substrates.
 - 2. Completely fill recesses in each joint configuration.
 - 3. Produce uniform, cross-sectional shapes and depths relative to joint widths that allow optimum sealant movement capability.
 - 4. Install in uniform continuous ribbons without gaps or air pockets.
- F. Tooling of Nonsag Sealants: Immediately after sealant application and before skinning or curing begins, tool sealants according to requirements specified below to form smooth, uniform beads of configuration indicated; to eliminate air pockets; and to ensure contact and adhesion of sealant with sides of joint.
 - 1. Remove excess sealant from surfaces adjacent to joints.
 - 2. Use tooling agents that are approved in writing by sealant manufacturer and that do not discolor sealants or adjacent surfaces.

3. Provide concave joint configuration per Figure 5A in ASTM C 1193, unless otherwise indicated.

3.4 REPAIR AND CLEANING

- A. Remove damaged or deteriorated joint sealants immediately so installations with repaired areas are indistinguishable from original work.
- B. Clean off excess sealant or sealant smears adjacent to joints as the Work progresses by methods and with cleaning materials approved in writing by manufacturers of joint sealants and of products in which joints occur.

3.5 PROTECTION

- A. Protect joint sealants during and after curing period from contact with contaminating substances and from damage resulting from construction operations or other causes so sealants are without deterioration or damage at time of Substantial Completion. If, despite such protection, damage or deterioration occurs, cut out and remove damaged or deteriorated joint sealants immediately so installations with repaired areas are indistinguishable from original work.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 08111

STEEL DOORS AND FRAMES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies hollow-metal doors and frames.
- B. Items To Be Installed Only: Install lock cylinders and cores as furnished by Section 08711 – DOOR HARDWARE.
- C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 04800 – MASONRY; building anchors into and grouting steel frames in masonry construction.
 - 3. Section 08711 – DOOR HARDWARE; door hardware for steel doors.
 - 4. Section 08801 – GLASS AND GLAZING; glazed lites.
 - 5. Section 09900 – PAINTING; field painting steel doors and frames.

1.2 SUBMITTALS

- A. Product Data: Include construction details, material descriptions, core descriptions, label compliance, fire-resistance rating, and finishes for each type of steel door and frame specified.
- B. Shop Drawings: In addition to requirements below, provide a schedule of standard steel doors and frames using same reference numbers for details and openings as those on Drawings:
 - 1. Elevations of each door design.
 - 2. Details of doors, including vertical and horizontal edge details.
 - 3. Frame details for each frame type, including dimensioned profiles.
 - 4. Details and locations of reinforcement and preparations for hardware.
 - 5. Details of each different wall opening condition.
 - 6. Details of anchorages, accessories, joints, and connections.
 - 7. Details of glazing frames and stops showing glazing.
 - 8. Details of conduit and preparations for electrified door hardware and controls.
- C. Qualification Data: For Installer.
- D. Product Test Reports: Based on evaluation of comprehensive fire tests performed by a qualified testing agency, for each type of standard steel door and frame.

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: An employer of workers trained and approved by manufacturer.
- B. Source Limitations: Obtain standard steel doors and frames through one source from a single

manufacturer.

- C. Fire-Rated Door, Sidelight and Transom Frame Assemblies: Assemblies complying with NFPA 80 that are listed and labeled by a testing and inspecting agency acceptable to authorities having jurisdiction, for fire-protection ratings indicated.
- D. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver doors and frames palletized, wrapped, or crated to provide protection during transit and Project-site storage. Do not use nonvented plastic. Provide additional protection to prevent damage to finish of factory-finished doors and frames.
- B. Deliver welded frames with two removable spreader bars across bottom of frames, tack welded to jambs and mullions.
- C. Store doors and frames under cover at Project site. Place units in a vertical position with heads up, spaced by blocking, on minimum 4-inch-high wood blocking. Avoid using nonvented plastic or canvas shelters that could create a humidity chamber. If wrappers on doors become wet, remove cartons immediately. Provide minimum 1/4-inch space between each stacked door to permit air circulation.

1.5 PROJECT CONDITIONS

- A. Field Measurements: Verify openings by field measurements before fabrication and indicate measurements on Shop Drawings.
 - 1. Established Dimensions: Where field measurements cannot be made without delaying the Work, establish opening dimensions and proceed with fabricating standard steel frames without field measurements. Coordinate wall construction to ensure that actual opening dimensions correspond to established dimensions.

1.6 COORDINATION

- A. Coordinate installation of anchorages for standard steel frames. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to Project site in time for installation.

1.7 PRE-CONSTRUCTION MEETINGS

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. Ceco Door Products; an ASSA ABLOY Group Company.
 2. CURRIES Company; an ASSA ABLOY Group Company.
 3. Mesker Door Inc.
 4. Pioneer Industries, Inc.
 5. Republic Builders Products Company.
 6. Steelcraft Doors.

2.2 MATERIALS

- A. Cold-Rolled Steel Sheet: ASTM A 1008/A 1008M, Commercial Steel (CS), Type B; suitable for exposed applications.
- B. Hot-Rolled Steel Sheet: ASTM A 1011/A 1011M, Commercial Steel (CS), Type B; free of scale, pitting, or surface defects; pickled and oiled.
- C. Metallic-Coated Steel Sheet: ASTM A 653/A 653M, Commercial Steel (CS), Type B; with minimum A40 zinc-iron-alloy (galvannealed) coating designation.
- D. Supports and Anchors: After fabricating, galvanize units to be built into exterior walls according to ASTM A 153/A 153M, Class B.
- E. Inserts, Bolts, and Fasteners: Provide items to be built into exterior walls, hot-dip galvanized according to ASTM A 153/A 153M.
- F. Powder-Actuated Fasteners in Concrete: Fastener system of type suitable for application indicated, fabricated from corrosion-resistant materials, with clips or other accessory devices for attaching standard steel door frames of type indicated.
- G. Grout: Comply with ASTM C 476, 3,000 psi with a slump of 4 inches for standard steel door frames built into concrete or masonry, as measured according to ASTM C 143/C 143M.
- H. Glazing: Comply with requirements in Section 08801 – GLASS AND GLAZING.
- I. Bituminous Coating: Cold-applied asphalt mastic, SSPC-Paint 12, compounded for 15-mil dry film thickness per coat. Provide inert-type noncorrosive compound free of asbestos fibers, sulfur components, and other deleterious impurities.

2.3 STANDARD STEEL DOORS

- A. General: Provide doors of design indicated, not less than thickness indicated; fabricated with smooth surfaces, without visible joints or seams on exposed faces, unless otherwise indicated. Comply with ANSI A250.8.
 1. Design: Flush panel.
 2. Core Construction: Manufacturer's standard kraft-paper honeycomb, polystyrene, polyurethane, mineral-board, or vertical steel-stiffener core that produces doors complying with ANSI A250.8.

- a. Fire Door Core: As required to provide fire-protection and temperature-rise ratings indicated.
 - b. Thermal-Rated (Insulated) Exterior Doors: Where indicated, provide doors fabricated with thermal-resistance value (R-value) of not less than 4.0 deg F x h x sq. ft./Btu when tested according to ASTM C 1363.
 - 3. Top and Bottom Edges: Closed with flush 0.042-inch-thick end closures or channels of same material as face sheets.
 - 4. Tolerances: Comply with Steel Door Institute, SDI 117, "Manufacturing Tolerances for Standard Steel Doors and Frames."
- B. Exterior Doors: Face sheets fabricated from metallic-coated steel sheet. Provide doors complying with requirements indicated below by referencing ANSI A250.8 for level and model and ANSI A250.4 for physical-endurance level:
- 1. Level 3 and Physical Performance Level A (Extra Heavy Duty), Model 2 (Seamless), 1-3/4 inches thick.
- C. Interior Doors: Face sheets fabricated from cold-rolled steel sheet, unless otherwise indicated to comply with exterior door requirements. Provide doors complying with requirements indicated below by referencing ANSI A250.8 for level and model and ANSI A250.4 for physical-endurance level:
- 1. Level 2 and Physical Performance Level B (Heavy Duty), Model 2 (Seamless), 1-3/4 inches thick.
- D. Hardware Reinforcement: Fabricate reinforcement plates from same material as door face sheets to comply with the following minimum sizes:
- 1. Hinges: Minimum 0.123 inch thick by 1-1/2 inches wide by 6 inches longer than hinge, secured by not less than 6 spot welds.
 - 2. Pivots: Minimum 0.167 inch thick by 1-1/2 inches wide by 6 inches longer than hinge, secured by not less than 6 spot welds.
 - 3. Lock Face, Closers, and Concealed Holders: Minimum 0.067 inch thick.
 - 4. All Other Surface-Mounted Hardware: Minimum 0.067 inch thick.
- E. Fabricate concealed stiffeners and hardware reinforcement from either cold- or hot-rolled steel sheet.

2.4 STANDARD STEEL FRAMES

- A. General: Comply with ANSI A250.8 and with details indicated for type and profile.
- B. Exterior Frames: Fabricated from metallic-coated steel sheet.
 - 1. Fabricate frames with mitered or coped and welded face corners and seamless face joints.
 - 2. Frames for Level 3 Steel Doors: 0.067-inch-thick steel sheet.
- C. Interior Frames: Fabricated from cold-rolled steel sheet, unless otherwise indicated to comply with exterior frame requirements.
 - 1. Fabricate frames with mitered or coped and welded face corners and seamless face joints.
 - 2. Frames for Level 2 Steel Doors: 0.053-inch-thick steel sheet.
- D. Hardware Reinforcement: Fabricate reinforcement plates from same material as frames to comply

with the following minimum sizes:

1. Hinges: Minimum 0.123 inch thick by 1-1/2 inches wide by 6 inches longer than hinge, secured by not less than 6 spot welds.
 2. Pivots: Minimum 0.167 inch thick by 1-1/2 inches wide by 6 inches longer than hinge, secured by not less than 6 spot welds.
 3. Lock Face, Flush Bolts, Closers, and Concealed Holders: Minimum 0.067 inch thick.
 4. All Other Surface-Mounted Hardware: Minimum 0.067 inch thick.
- E. Supports and Anchors: Fabricated from electrolytic zinc-coated or metallic-coated steel sheet.
- F. Jamb Anchors:
1. Masonry Type: Adjustable strap-and-stirrup or T-shaped anchors to suit frame size, not less than 0.042 inch thick, with corrugated or perforated straps not less than 2 inches wide by 10 inches long; or wire anchors not less than 0.177 inch thick.
 2. Stud-Wall Type: Designed to engage stud, welded to back of frames; not less than 0.042 inch thick.
 3. Postinstalled Expansion Type for In-Place Concrete or Masonry: Minimum 3/8-inch-diameter bolts with expansion shields or inserts. Provide pipe spacer from frame to wall, with throat reinforcement plate, welded to frame at each anchor location.
- G. Floor Anchors: Formed from same material as frames, not less than 0.042 inch thick, and as follows:
1. Monolithic Concrete Slabs: Clip-type anchors, with two holes to receive fasteners.
 2. Separate Topping Concrete Slabs: Adjustable-type anchors with extension clips, allowing not less than 2-inch height adjustment. Terminate bottom of frames at finish floor surface.
- H. Fabricate concealed stiffeners and hardware reinforcement from either cold- or hot-rolled steel sheet.

2.5 STOPS AND MOLDINGS

- A. Moldings for Glazed Lites in Doors: Minimum 0.032 inch thick, fabricated from same material as door face sheet in which they are installed.
- B. Fixed Frame Moldings: Formed integral with standard steel frames, minimum 5/8 inch high, unless otherwise indicated.
- C. Loose Stops for Glazed Lites in Frames: Minimum 0.032 inch thick, fabricated from same material as frames in which they are installed.

2.6 FABRICATION

- A. General: Fabricate standard steel doors and frames to be rigid and free of defects, warp, or buckle. Accurately form metal to required sizes and profiles, with minimum radius for thickness of metal. Where practical, fit and assemble units in manufacturer's plant. To ensure proper assembly at Project site, clearly identify work that cannot be permanently factory assembled before shipment.
- B. Standard Steel Doors:
1. Exterior Doors: Provide weep-hole openings in bottom of exterior doors to permit moisture to escape. Seal joints in top edges of doors against water penetration.
 2. Glazed Lites: Factory cut openings in doors.

- C. Standard Steel Frames: Where frames are fabricated in sections due to shipping or handling limitations, provide alignment plates or angles at each joint, fabricated of same thickness metal as frames.
1. Welded Frames: Weld flush face joints continuously; grind, fill, dress, and make smooth, flush, and invisible.
 2. Sidelight and Transom Bar Frames: Provide closed tubular members with no visible face seams or joints; fabricated from same material as door frame. Fasten members at crossings and to jambs by butt welding.
 3. Provide countersunk, flat- or oval-head exposed screws and bolts for exposed fasteners, unless otherwise indicated.
 4. Plaster Guards: Weld guards to frame at back of hardware mortises in frames installed in concrete or masonry.
 5. Where installed in masonry, leave vertical mullions in frames open at top for grouting.
 6. Floor Anchors: Weld anchors to bottom of jambs and mullions with at least four spot welds per anchor.
 7. Jamb Anchors: Provide number and spacing of anchors as follows:
 - a. Masonry Type: Locate anchors not more than 18 inches from top and bottom of frame. Space anchors not more than 32 inches o.c. and as follows:
 - 1) Two anchors per jamb up to 60 inches in height.
 - 2) Three anchors per jamb from 60 to 90 inches in height.
 - 3) Four anchors per jamb from 90 to 120 inches in height.
 - 4) Four anchors per jamb plus 1 additional anchor per jamb for each 24 inches or fraction thereof more than 120 inches in height.
 - b. Stud-Wall Type: Locate anchors not more than 18 inches from top and bottom of frame. Space anchors not more than 32 inches o.c. and as follows:
 - 1) Three anchors per jamb up to 60 inches in height.
 - 2) Four anchors per jamb from 60 to 90 inches in height.
 - 3) Five anchors per jamb from 90 to 96 inches in height.
 - 4) Five anchors per jamb plus 1 additional anchor per jamb for each 24 inches or fraction thereof more than 96 inches in height.
 - 5) Two anchors per head for frames more than 42 inches wide and mounted in metal- stud partitions.
 - c. Compression Type: Not less than two anchors in each jamb.
 - d. Postinstalled Expansion Type: Locate anchors not more than 6 inches from top and bottom of frame. Space anchors not more than 26 inches o.c.
 8. Door Silencers: Except on weather-stripped doors, drill stops to receive door silencers as follows. Provide plastic plugs to keep holes clear during construction.
 - a. Single-Door Frames: Drill stop in strike jamb to receive three door silencers.
 - b. Double-Door Frames: Drill stop in head jamb to receive two door silencers.
- D. Hardware Preparation: Factory prepare standard steel doors and frames to receive templated mortised hardware; include cutouts, reinforcement, mortising, drilling, and tapping, according to the Door Hardware Schedule and templates furnished as specified in Section 08711 - DOOR HARDWARE.

1. Reinforce doors and frames to receive nontemplated mortised and surface-mounted door hardware.
 2. Comply with applicable requirements in ANSI A250.6 and ANSI/DHI A115 Series specifications for door and frame preparation for hardware. Locate hardware as indicated on Shop Drawings or, if not indicated, according to ANSI A250.8.
- E. Stops and Moldings: Provide stops and moldings around glazed lites where indicated. Form corners of stops and moldings with butted or mitered hairline joints.
1. Single Glazed Lites: Provide fixed stops and moldings welded on secure side of door or frame.
 2. Multiple Glazed Lites: Provide fixed and removable stops and moldings such that each glazed lite is capable of being removed independently.
 3. Provide fixed frame moldings on outside of exterior and on secure side of interior doors and frames.
 4. Provide loose stops and moldings on inside of doors and frames.
 5. Coordinate rabbet width between fixed and removable stops with type of glazing and type of installation indicated.

2.7 STEEL FINISHES

- A. General: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes. Finish standard steel door and frames after assembly.
- B. Metallic-Coated Steel Surface Preparation: Clean surfaces with nonpetroleum solvent so surfaces are free of oil and other contaminants. After cleaning, apply a conversion coating suited to the organic coating to be applied over it. Clean welds, mechanical connections, and abraded areas, and apply galvanizing repair paint specified below to comply with ASTM A 780.
1. Galvanizing Repair Paint: High-zinc-dust-content paint for regalvanizing welds in steel, complying with SSPC-Paint 20.
- C. Steel Surface Preparation: Clean surfaces to comply with SSPC-SP 1, "Solvent Cleaning"; remove dirt, oil, grease, or other contaminants that could impair paint bond. Remove mill scale and rust, if present, from uncoated steel; comply with SSPC-SP 3, "Power Tool Cleaning," or SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning."
- D. Factory Priming for Field-Painted Finish: Apply shop primer specified below immediately after surface preparation and pretreatment. Apply a smooth coat of even consistency to provide a uniform dry film thickness of not less than 0.7 mils.
1. Shop Primer: Manufacturer's standard, fast-curing, lead- and chromate-free primer complying with ANSI A250.10 acceptance criteria; recommended by primer manufacturer for substrate; compatible with substrate and field-applied finish paint system indicated; and providing a sound foundation for field-applied topcoats despite prolonged exposure.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements

for installation tolerances and other conditions affecting performance of standard steel doors and frames.

1. Examine roughing-in for embedded and built-in anchors to verify actual locations of standard steel frame connections before frame installation.
2. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Remove welded-in shipping spreaders installed at factory.
- B. Prior to installation and with installation spreaders in place, adjust and securely brace standard steel door frames for squareness, alignment, twist, and plumb to the following tolerances:
 1. Squareness: Plus or minus 1/16 inch, measured at door rabbet on a line 90 degrees from jamb perpendicular to frame head.
 2. Alignment: Plus or minus 1/16 inch, measured at jambs on a horizontal line parallel to plane of wall.
 3. Twist: Plus or minus 1/16 inch, measured at opposite face corners of jambs on parallel lines, and perpendicular to plane of wall.
 4. Plumbness: Plus or minus 1/16 inch, measured at jambs on a perpendicular line from head to floor.
- C. Drill and tap doors and frames to receive nontemplated mortised and surface-mounted door hardware.

3.3 INSTALLATION

- A. General: Provide doors and frames of sizes, thicknesses, and designs indicated. Install standard steel doors and frames plumb, rigid, properly aligned, and securely fastened in place; comply with Drawings and manufacturer's written instructions.
- B. Standard Steel Frames: Install standard steel frames for doors, sidelights, transoms, borrowed lights and other openings, of size and profile indicated. Comply with SDI 105.
 1. Set frames accurately in position; plumbed, aligned, and braced securely until permanent anchors are set. After wall construction is complete, remove temporary braces, leaving surfaces smooth and undamaged.
 - a. At fire-protection-rated openings, install frames according to NFPA 80.
 - b. Where frames are fabricated in sections due to shipping or handling limitations, field splice at approved locations by welding face joint continuously; grind, fill, dress, and make splice smooth, flush, and invisible on exposed faces.
 - c. Install frames with removable glazing stops located on secure side of opening.
 - d. Install door silencers in frames before grouting.
 - e. Remove temporary braces necessary for installation only after frames have been properly set and secured.
 - f. Check plumb, squareness, and twist of frames as walls are constructed. Shim as necessary to comply with installation tolerances.
 - g. Apply bituminous coating to backs of frames that are filled with mortar, and grout.
 2. Floor Anchors: Provide floor anchors for each jamb and mullion that extends to floor and secure with postinstalled expansion anchors.

- a. Floor anchors may be set with powder-actuated fasteners instead of postinstalled expansion anchors if so indicated and approved on Shop Drawings.
3. Metal-Stud Partitions: Solidly pack mineral-fiber insulation behind frames.
 4. Masonry Walls: Coordinate installation of frames to allow for solidly filling space between frames and masonry with mortar as specified in Section 04800 - MASONRY,
 5. Concrete Walls: Solidly fill space between frames and concrete with grout. Install grout in lifts and take precautions, including bracing frames, to ensure that frames are not deformed or damaged by grout forces.
 6. In-Place Concrete or Masonry Construction: Secure frames in place with postinstalled expansion anchors. Countersink anchors, and fill and make smooth, flush, and invisible on exposed faces.
 7. In-Place Gypsum Board Partitions: Secure frames in place with postinstalled expansion anchors through floor anchors at each jamb. Countersink anchors, and fill and make smooth, flush, and invisible on exposed faces.
 8. Ceiling Struts: Extend struts vertically from top of frame at each jamb to supporting construction above, unless frame is anchored to masonry or to other structural support at each jamb. Bend top of struts to provide flush contact for securing to supporting construction above.
Provide adjustable wedged or bolted anchorage to frame jamb members.
 9. Installation Tolerances: Adjust standard steel door frames for squareness, alignment, twist, and plumb to the following tolerances:
 - a. Squareness: Plus or minus 1/16 inch, measured at door rabbet on a line 90 degrees from jamb perpendicular to frame head.
 - b. Alignment: Plus or minus 1/16 inch, measured at jambs on a horizontal line parallel to plane of wall.
 - c. Twist: Plus or minus 1/16 inch, measured at opposite face corners of jambs on parallel lines, and perpendicular to plane of wall.
 - d. Plumbness: Plus or minus 1/16 inch, measured at jambs at floor.
- C. Standard Steel Doors: Fit hollow-metal doors accurately in frames, within clearances specified below.
Shim as necessary.
1. Non-Fire-Rated Standard Steel Doors:
 - a. Jambs and Head: 1/8 inch plus or minus 1/16 inch.
 - b. Between Edges of Pairs of Doors: 1/8 inch plus or minus 1/16 inch.
 - c. Between Bottom of Door and Top of Threshold: Maximum 3/8 inch.
 - d. Between Bottom of Door and Top of Finish Floor (No Threshold): Maximum 3/4 inch.
 2. Fire-Rated Doors: Install doors with clearances according to NFPA 80.
 3. Smoke-Control Doors: Install doors according to NFPA 105.
- D. Glazing: Comply with installation requirements in Section 08801 – GLASS AND GLAZING and with standard steel door and frame manufacturer's written instructions. Secure stops with countersunk flat- or oval-head machine screws spaced uniformly not more than 9 inches o.c., and not more than 2 inches o.c. from each corner.

3.4 ADJUSTING AND CLEANING

- A. Final Adjustments: Check and readjust operating hardware items immediately before final

inspection. Leave work in complete and proper operating condition. Remove and replace defective work, including standard steel doors or frames that are warped, bowed, or otherwise unacceptable to the Engineer.

- B. Clean grout and other bonding material off standard steel doors and frames immediately after installation.
- C. Prime-Coat Touchup: Immediately after erection, sand smooth rusted or damaged areas of prime coat and apply touchup of compatible air-drying primer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 08139

ACCESS DOORS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Factory fabricated heavy duty access doors (hatches).
 - 2. Access doors to pipe spaces, if required.
 - 3. Access doors to equipment not otherwise accessible.
- B. Items To Be Installed Only: Install lock cylinders and cores as furnished by Section 08711 – DOOR HARDWARE.
- C. Related Work:
 - 1. Section 03450 – ARCHITECTURAL PRECAST CONCRETE.
 - 2. Section 03331 – ARCHITECTURAL CONCRETE FINISH.
 - 3. Section 08711 – DOOR HARDWARE.
 - 4. Section 16720 – ELECTRONIC ACCESS CONTROL SYSTEMS.

1.2 SUBMITTALS

- A. Product Data: Provide manufacturer's product data for all materials and assembly in this specification. Provide evidence that each manufacturer providing access doors has been manufacturing that type of access door or hatch for a minimum of five years.
- B. Shop Drawings showing plans, sections and details. Shop Drawings shall show dimensions locating assembly in the building and relation to supporting structural elements
- C. Engineering and structural analysis, as well as any necessary calculations shall be prepared under the supervision of, and signed and sealed by, a qualified professional engineer licensed in the Commonwealth of Massachusetts. Engineer shall have minimum 5 years experience performing work of similar scope and complexity. These calculations shall include gravity, wind and seismic loading. The internal structure, dimensions and specifications for all items shall be indicated in the Contractor's shop drawings.
- D. Installer: Installer shall be trained or certified by the manufacturer to perform work. Manufacturer shall certify installer as acceptable for terms of warranty.

1.3 QUALITY ASSURANCE

- A. For actual installation of the work of this Section, use only personnel who are thoroughly familiar with the manufacturer's recommended methods of installation and who are completely trained in the skills required.

- B. The manufacturers of the access doors or hatches shall have a minimum of five years experience in the manufacture of access doors of the type they are providing. Each type of access door shall be provided by a single manufacturer.
- C. Fire-Resistance:
 - 1. Provide bituminous coating and all available methods to increase fire resistance of assembly of floor access door.
 - 2. Whenever a fire-resistance classification is shown, or for construction where access doors are installed, provide access required door assembly with panel door, frame, hinge, and latch from manufacturers listed in UL Classified Building Materials index for the rating shown.
 - 3. Provide UL label on each access panel for which a fire rating is required. Do not paint over label. All labels shall be clear and visible for inspection
- D. Coordinate with structural design.

1.4 CITED STANDARDS

- A. Underwriters Laboratories (UL)
 - 1. Classified Building Material Index

1.5 WARRANTY

- A. Materials and workmanship shall be free of defects for period of 25 years from date of installation. Should a part fail to function in normal use within this period, manufacturer shall furnish a new part at and replace it in the assembly at no charge.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. General Performance: Comply with performance requirements specified, as determined by testing of stainless steel-framed entrances representing those indicated for this Project without failure due to defective manufacture, fabrication, installation, or other defects in construction.
- B. Structural Loads:
 - 1. Wind Loads: As indicated on Drawings.

2.2 MANUFACTURERS - HATCHES

- A. Design of hatches is based on BILCO Company products. Provide fire-rated and non-rated heavy-duty access hatch doors as manufactured by BILCO Company, or approved equal.
 - 1. Performance Characteristics
 - a. Non-rated door shall be designed to support either a minimum live load of 300-psf or match the design load of the surrounding floor, whichever is more, and support a concentrated load of 1,000-pounds.

- b. Rated door shall be designed to support a minimum live load of 150-psf, or shall match the design load of the surrounding floor, whichever is more, and support a concentrated load of 1,000-pounds.
 - c. Operation of the cover shall be smooth and easy with controlled operation throughout the entire arc of opening and closing.
 - d. Double door (non-rated) shall be designed w/ reinforced cover to accommodate H-20 psf live load. Basis of design: Bilco model JD-AL H20 Channel Frame Door or approved equal.
2. Entire door, including all hardware components, shall be highly corrosion resistant.
3. Covers:
- a. Fire Rated: 1/4" aluminum 2hr rated floor hatch. Basis of Design: Bilco FR-Fire Rated Floor Door or approved equal.
 - b. Unrated: 1/4" Aluminum metal plate with slip-resistant coating equal to SlipNOT by W.S. Molnar Company or equal, , thickness to meet load requirements
4. Frame: Channel frame shall be extruded aluminum with bend down anchor tabs around the perimeter. A continuous EPDM gasket shall be mechanically attached to the aluminum frame to create a barrier around the entire perimeter of the cover and significantly reduce the amount of dirt and debris that may enter the channel frame.
5. Provide drainage connection to sanitary system from floor hatches in public areas, platforms, and mezzanines.
6. Hinges: Shall be specifically designed for horizontal installation and shall be through bolted to the cover with tamperproof Type 316 stainless steel lock bolts and shall be through bolted to the frame with Type 316 stainless steel bolts and locknuts.
7. Lifting mechanisms: Manufacturer shall provide the required number and size of compression spring operators enclosed in telescopic tubes to provide, smooth, easy, and controlled cover operation throughout the entire arc of opening and to act as a check in retarding downward motion of the cover when closing. The upper tube shall be the outer tube to prevent accumulation of moisture, grit, and debris inside the lower tube assembly. The lower tube shall interlock with a flanged support shoe fastened to a formed 1/4-inch gusset support plate.
8. A removable exterior turn/lift handle with a spring loaded ball detent shall be provided to open the covers and the latch release shall be protected by a flush, gasketed, removable screw plug.
9. Hardware:
- a. Hinges: Heavy forged aluminum hinges, each having a minimum 1/4-inch diameter Type 316 stainless steel pin, shall be provided and shall pivot so the cover does not protrude into the channel frame.
 - b. Covers shall be equipped with a hold open arm that automatically locks the covers in the open position.
 - c. Covers shall be fitted with the required number and size of compression spring operators. Springs shall have an electro-coated acrylic finish. Spring tubes

shall be constructed of a reinforced nylon 6/6-based engineered composite material.

- d. A Type 316 stainless steel snap lock with fixed handle shall be mounted on the underside of the cover.
 - e. Hardware: Anti-corrosion throughout. For installation in highly corrosive environments or when prolonged exposure to hot water or steam is anticipated, specify Type 316 stainless steel hardware. Platforms, mezzanines and pump rooms are highly corrosive environments in this context.
10. Finishes: Factory finish shall be mill finish aluminum with bituminous coating applied to the exterior of the frame.
11. Personnel Hatches: Where required by the Hatch Schedule, hatches shall have integral security roll up shutter with protection on exposed three sides of open hatch. Shutter shall not impede hatch clearances and access.

2.3 MANUFACTURERS - FLOOR ACCESS DOORS

- A. Floor Access Door: Type JD-H20 by BILCO or equal by Milcor or Nystrom.
- B. Performance characteristics:
 - 1. Covers: Shall be a bar grate type with 73% open and reinforced to support AASHTO H-20 wheel load with a maximum deflection of 1/150th of the span. Manufacturer to provide structural calculations stamped by a registered professional engineer upon request. (Note: For installation in an off-street location where not subject to high density, fast moving traffic.)
 - 2. Operation of the covers shall be smooth and easy with controlled operation throughout the entire arc of opening and closing.
 - 3. Operation of the covers shall not be affected by temperature.
- C. Covers: Shall be 1/4" steel diamond pattern.
- D. Frame: Channel frame shall be 1/4" steel with full anchor flange around the perimeter.
- E. Hinges: Shall be specifically designed for horizontal installation and shall be through bolted to the covers with tamperproof Type 316 stainless steel lock bolts and shall be through bolted to the frame with Type 316 stainless steel bolts and locknuts.
- F. Drain Coupling: Provide a 1-1/2" drain coupling located in the right front corner of the channel frame (note: can be placed at a different location if specified).
- G. Lifting mechanisms: Manufacturer shall provide the required number and size of compression spring operators enclosed in telescopic tubes to provide, smooth, easy, and controlled cover operation throughout the entire arc of opening and to act as a check in retarding downward motion of the covers when closing. The upper tube shall be the outer tube to prevent accumulation of moisture, grit, and debris inside the lower tube assembly. The lower tube shall interlock with a flanged support shoe fastened to a formed 1/4" gusset support plate.
- H. A removable exterior turn/lift handle with a spring loaded ball detent shall be provided to open the covers and the latch release shall be protected by a flush, gasketed, removable screw plug.

I. Hardware

1. Hinges: Heavy forged brass hinges, each having a minimum 3/8" (9.5mm) diameter Type 316 stainless steel pin, shall be provided and shall pivot so the cover does not protrude into the channel frame.
2. Covers shall be equipped with a hold open arm that automatically locks the cover in the open position.
3. Covers shall be fitted with the required number and size of compression spring operators.
4. A Type 316 stainless steel snap lock with fixed handle shall be mounted on the underside of the cover.
5. Hardware: Compression spring tubes shall be an anti-corrosive composite, all fasteners shall be Type 316 stainless steel material, and all other hardware shall be zinc plated and chromate sealed. [For installation in highly corrosive environments or when prolonged exposure to hot water or steam is anticipated, specify Type 316 stainless steel hardware].

J. Finishes: Factory finish shall be red oxide primed steel.

2.4 MANUFACTURERS - ACCESS DOORS

- A. Provide access door assembly manufactured by BAR-CO; DUR-RED; Bilco; Milcor Inc.; Nystrom Inc.; Karp Associates, Inc.; or approved equal. Assembly shall be an integral unit complete with all parts and ready for installation.
- B. Provide fire-rated units as required by fire rating of penetrated assembly. Design is based on BAR-CC Model FB-1.
- C. Frames for Concrete, Masonry, and Tile Wall Only (Flush Panel Units): Fabricate frame from 10-gauge steel. Provide frame with exposed flange not less than 1-inch wide around perimeter of frame for exposed masonry and tile finish.
- D. Frameless Units for Drywall Surfaces (Recessed Panel Units): Provide access doors without exposed frames for drywall adhered to recessed panel.
- E. Panels: Fabricate from 14-gauge steel with concealed spring hinges set to open to 175-degrees. Provide removable pin type hinges of the quantity required to support the access panel sizes used in the Work.
- F. Provide fire-rated insulation on door of fire-rated assemblies.
- G. Locking Devices
 1. For non-rated access doors, provide flush, screwdriver operated cam locks of number required to hold door in flush, smooth plane when closed.
 2. For fire-rated doors, provide flush, key operated cylinder locks.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Ensure substrates are in suitable condition to receive the Work.

- B. Verify that other trades with related work are completed before installing hatch door.

3.2 INSTALLATION

- A. Check as-built conditions and verify the manufacturer's access hatch door details for accuracy to fit the application prior to fabrication. Comply with the vault access door manufacturer's installation instructions.
- B. Furnish manufacturer's recommended attachment system for installing door and anchoring it to the supporting structure.

3.3 FIELD QUALITY CONTROL

- A. Examine the areas and conditions where access doors are to be installed and correct any conditions detrimental to the proper and timely completion of the work. Do not proceed with the work until unsatisfactory conditions are corrected to permit proper installation of the Work. For floor hatches, ensure that the drainage pipes are properly located.

3.4 COORDINATION

- A. Coordinate all work with the mechanical trades to insure proper locations and in a timely manner to permit orderly progress of the total work.
- B. Set frames accurately in position and securely attach to supports with face panels plumb or level in relation to adjacent finish surfaces.
- C. Adjust hardware and panels after installation for proper operation.
- D. Remove and replace panels or frames that are warped, bowed, or otherwise damaged.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 08334

OVERHEAD COILING GRILLES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies manually operated and electric-motor operated overhead coiling grilles.
- B. Items To Be Installed Only: Install lock cylinders and cores as furnished by Section 08711 – DOOR HARDWARE.
- C. Related Work:
 - 1. Section 05500 - MISCELLANEOUS METALS; miscellaneous steel supports.
 - 2. Section 07920 - JOINT SEALANTS; weatherproof joints at hoods.
 - 3. Section 08711 - DOOR HARDWARE; lock cylinders and keying.
 - 4. Section 09900 - PAINTING; field-applied paint finish.
 - 5. Division 16 - ELECTRICAL; electrical service and connections for powered operators, and accessories.

1.2 PERFORMANCE REQUIREMENTS

- A. Operation-Cycle Requirements: Provide overhead coiling grille components and operators capable of operating for not less than 20,000 cycles and for 10 cycles per day.

1.3 SUBMITTALS

- A. Product Data: For each type and size of overhead coiling grille and accessory.
 - 1. Summary of forces and loads on walls and jambs.
- B. Shop Drawings: For special components and installations not dimensioned or detailed in manufacturer's product data.
- C. Qualification Data: For Installer.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for both installation and maintenance of units required for this Project.
- B. Source Limitations: Obtain overhead coiling grilles through one source from a single manufacturer.
 - 1. Obtain operators and controls from overhead coiling grille manufacturer.

- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Overhead Door Corp.
 - 2. Raynor.
 - 3. Wayne-Dalton Corp.

2.2 GRILLE CURTAIN MATERIALS AND CONSTRUCTION

- A. General: Fabricate overhead coiling grille curtain consisting of a network of 1/4-inch-minimum diameter horizontal rods, or rods covered with tube spacers, spaced as indicated. Interconnect rods by vertical links approximately 5/8 inch wide, spaced as indicated and rotating on rods.
 - 1. Space rods at approximately 1-1/2 inches o.c.
 - 2. Space links approximately 6 inches apart in a straight in-line pattern.
 - 3. Aluminum Grille Curtain: ASTM B 221 alloy and temper recommended by aluminum producer and finisher for type of use and finish indicated.
- B. Endlocks: Continuous end links, chains, or other devices at ends of rods; locking and retaining grille curtain in guides against excessive pressures, maintaining grille curtain alignment, and preventing lateral movement.
- C. Bottom Bar: Manufacturer's standard continuous channel, tubular shape, or two angles, finished to match grille.
 - 1. Astragal: Provide a replaceable, adjustable, continuous, compressible gasket of flexible vinyl, rubber, or neoprene; for placement between angles or fitted to shape, as a cushion bumper for grille.
 - 2. Provide motor-operated grilles with combination bottom astragal and sensor edge.
- D. Grille Curtain Jamb Guides: Manufacturer's standard extruded-aluminum shape having curtain groove with return lips or bars to retain curtain. Provide continuous integral wear strips to prevent metal-to-metal contact and to minimize operational noise; with removable stops on guides to prevent overtravel of curtain.

2.3 HOODS AND ACCESSORIES

- A. Hood: Form to entirely enclose coiled curtain and operating mechanism at opening head. Contour to fit end brackets to which hood is attached. Roll and reinforce top and bottom edges for stiffness. Provide closed ends for surface-mounted hoods, and provide fascia for any portion of between-jamb mounting projecting beyond wall face. Provide intermediate support brackets as required to prevent sagging.

1. Fabricate hoods for aluminum grilles of minimum 0.032-inch-thick aluminum, alloy and temper recommended by aluminum producer and finisher for type of use and finish indicated, complying with ASTM B 209.
 2. Provide removable metal soffit of same material and finish as curtain if hood is mounted above ceiling, unless otherwise indicated.
- B. Push/Pull Handles: For push-up-operated or emergency-operated grilles, provide manufacturer's standard lifting handles on each side of grille.
- C. Fabricate locking device assembly with lock, spring-loaded dead bolt, operating handle, cam plate, and adjustable locking bar to engage through slots in tracks. Lock cylinder is specified in Section 08711 - DOOR HARDWARE.
- D. If grille curtain is power operated, provide safety interlock switch to disengage power supply when grille is locked.

2.4 COUNTERBALANCING MECHANISM

- A. General: Counterbalance grille curtain by means of adjustable-tension, steel helical torsion spring mounted around a steel shaft and contained in a spring barrel connected to grille curtain with barrel rings. Use grease-sealed bearings or self-lubricating graphite bearings for rotating members.
- B. Counterbalance Barrel: Fabricate spring barrel of hot-formed, structural-quality, welded or seamless carbon-steel pipe, of sufficient diameter and wall thickness to support rolled-up grille curtain without distortion of curtain and to limit barrel deflection to not more than 0.03 in./ft. of span under full load.
- C. Provide spring balance of one or more oil-tempered, heat-treated steel helical torsion springs. Size springs to counterbalance weight of grille curtain, with uniform adjustment accessible from outside barrel. Provide cast-steel barrel plugs to secure ends of springs to barrel and shaft.
- D. Fabricate torsion rod for counterbalance shaft of cold-rolled steel, sized to hold fixed spring ends and carry torsional load.
- E. Brackets: Provide mounting brackets of manufacturer's standard design, either cast iron or cold-rolled steel plate.

2.5 MANUAL GRILLE OPERATORS

- A. Push-up Operation: Design counterbalance mechanism so required lift or pull for grille operation does not exceed 25 lbf.

2.6 ELECTRIC GRILLE OPERATORS

- A. General: Provide electric grille operator assembly of size and capacity recommended and provided by grille manufacturer for grilles specified, with electric motor and factory-prewired motor controls, starter, gear-reduction unit, solenoid-operated brake, clutch, remote-control stations, control devices, integral gearing for locking grille, and accessories required for proper operation.
- B. Comply with NFPA 70.

- C. Disconnect Device: Provide hand-operated disconnect or mechanism for automatically engaging chain and sprocket operator and releasing brake for emergency manual operation while disconnecting motor, without affecting timing of limit switch. Mount disconnect and operator so they are accessible from floor level. Include interlock device to automatically prevent motor from operating when emergency operator is engaged.
- D. Design operator so motor may be removed without disturbing limit-switch adjustment and without affecting emergency auxiliary operator.
- E. Provide control equipment complying with NEMA ICS 1, NEMA ICS 2, and NEMA ICS 6, with NFPA 70 Class 2 control circuit, maximum 24-V, ac or dc.
- F. Grille-Operator Type: Provide wall-, hood-, or bracket-mounted, jackshaft, gear-head-type grille operator unit consisting of electric motor, enclosed worm-gear running-in-oil primary drive, and chain and sprocket secondary drive; with quick disconnect-release for manual operation.
- G. Electric Motors: Provide high-starting torque, reversible, continuous-duty, Class A insulated, electric motors complying with NEMA MG 1; with overload protection; sized to start, accelerate, and operate grille in either direction from any position, at not less than 2/3 fps and not more than 1 fps, without exceeding nameplate ratings or service factor.
 - 1. Type: Polyphase, medium-induction type.
 - 2. Service Factor: According to NEMA MG 1, unless otherwise indicated.
 - 3. Coordinate wiring requirements and electric characteristics of motors with building electrical system.
- H. Remote-Control Station: Provide momentary-contact, three-button control station with push-button controls labeled "Open," "Close," and "Stop."
 - 1. Provide interior units, full-guarded, surface-mounted, heavy-duty type, with general-purpose NEMA ICS 6, Type 1 enclosure.
- I. Obstruction Detection Device: Provide each motorized grille with indicated external automatic safety sensor capable of protecting full width of grille opening. Activation of sensor immediately stops and reverses downward grille travel.
- J. Limit Switches: Provide adjustable switches, interlocked with motor controls and set to automatically stop grille at fully opened and fully closed positions.
- K. Provide electric operators with ADA-compliant audible alarm and visual indicator lights.

2.7 FINISHES, GENERAL

- A. General: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
- B. Appearance of Finished Work: Variations in appearance of abutting or adjacent pieces are acceptable if they are within one-half of the range of approved Samples. Noticeable variations in the same piece are not acceptable. Variations in appearance of other components are acceptable if they are within the range of approved Samples and are assembled or installed to minimize contrast.

2.8 ALUMINUM FINISHES

- A. Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.
- B. Class II, Clear Anodic Finish: AA-M12C22A31 (Mechanical Finish: nonspecular as fabricated; Chemical Finish: etched, medium matte; Anodic Coating: Architectural Class II, clear coating 0.010 mm or thicker) complying with AAMA 611.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. General: Install grilles and operating equipment, complete with necessary hardware, according to Shop Drawings, manufacturer's written instructions, and as specified.

3.2 ADJUSTING

- A. Lubricate bearings and sliding parts; adjust grilles to operate easily, free of warp, twist, or distortion and with tight fit around entire perimeter.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Section 01015-SCHEDULE OF PRICES.

END OF SECTION

SECTION 08520

ALUMINUM WINDOWS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies fixed and casement aluminum windows (AW Class) with factory-installed glass and glazing.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 07600 – FLASHING AND SHEET METAL
 - 3. Section 07920 – JOINT SEALANTS
 - 4. Section 08801 – GLASS AND GLAZING

1.2 INTENT

- A. A major intent of the work of this section is to provide architectural aluminum windows meeting specified performance criteria.
- B. Drawings and details are intended to show basic design, profiles, sightlines, dimensions, sizes, alignment, pattern, and similar visual information. The Contractor shall design, engineer, and detail the entire aluminum window system and shall meet specified performance requirements while strictly maintaining the visual design concept indicated.

1.3 QUALITY ASSURANCE

- A. Source: For each type of window required for the work of this section, provide products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.
- B. Reference Standards: Comply with applicable requirements of the following standards. Where these standards are in conflict with specification requirements, the most restrictive requirement shall govern.
 - 1. AAMA GS-001, Voluntary Guide Specification for Aluminum Architectural Windows.
 - 2. ANSI/AAMA 101, Voluntary Specifications for Aluminum Prime Windows & Sliding Glass Doors.
 - 3. AAMA Curtain Wall Manual #10, Care and Handling of Architectural Aluminum from Shop to Site.
 - 4. AAMA 605.2, Voluntary Specifications for High Performance Organic Coatings on Architectural Extrusions and Panels.
 - 5. SMACNA, Architectural Sheet Metal Manual; details for fabrication and installation of flashings and counter flashings.
- C. Subdivision of Work: To limit responsibility, assign the complete aluminum window system, including installation of glass and perimeter sealants to one installer.

1.4 TESTS PROCEDURES AND PERFORMANCE REQUIREMENTS

- A. General: Provide aluminum windows capable of complying with performance requirements indicated, based on testing manufacturer's windows that are representative of those specified and that are of test size indicated below:
1. Minimum size required by AAMA/NWWDA/CSA 101/I.S.2/A440.
- B. AAMA/NWWDA Performance Requirements: Provide aluminum windows of the performance class and grade indicated that comply with AAMA/NWWDA/CSA 101/I.S.2/A440.
1. Performance Class: Architectural Grade AW.
 2. Performance Grade: Minimum for performance class indicated.
 3. Exception to AAMA/NWWDA/CSA 101/I.S.2/A440: In addition to requirements for performance class and performance grade, design glass framing system to limit lateral deflections of glass edges to less than 1/175 of glass-edge length or 3/4 inch whichever is less, at design pressure based on the following:
- C. Structural Performance: Provide aluminum windows capable of withstanding the following, including wind loads based on passing AAMA/NWWDA/CSA 101/I.S.2/A440, Uniform Load Structural Test, at basic wind speed indicated and as required by Code:
1. Deflection: Design glass framing system to limit lateral deflections of glass edges to less than 1/175 of glass-edge length or 3/4 inch, whichever is less, at design pressure based on structural computations.
 2. Wind and Seismic Loads: As indicated on the Structural Drawings, but not less than that required by Code.
 3. Movements of supporting structure including, but not limited to, story drift and deflection from uniformly distributed and concentrated live loads will require special considerations including but not limited to head receptors.
- D. Air Infiltration: Maximum rate not more than indicated when tested according to AAMA/NWWDA/CSA 101/I.S.2/A440, Air Infiltration Test.
1. Maximum Rate: As required by Code.
- E. Water Resistance: No water leakage as defined in AAMA/NWWDA/CSA referenced test methods at a water test pressure equaling that indicated, when tested according to AAMA/NWWDA/CSA 101/I.S.2/A440, Water Resistance Test.
1. Test Pressure: 15 percent of positive design pressure, but not less than 2.86 lbf/sq. ft. or more than 12 lbf/sq. ft.
- F. Condensation-Resistance Factor: Provide aluminum windows tested for thermal performance according to AAMA 1503, showing a CRF of 52 where windows are indicated to be "thermally improved."
- G. Thermal Transmittance: Provide aluminum windows with a whole-window U-value maximum indicated at 15-mph exterior wind velocity and winter condition temperatures when tested according to AAMA 1503.
1. U-Value: As required by Code. Submit proof of compliance with submittals as specified.
- H. Solar Heat-Gain Coefficient: Provide aluminum windows with a whole-window SHGC maximum as required by Code, determined according to NFRC 200 procedures. Submit proof of compliance with submittals as specified.

- I. Thermal Movements: Provide aluminum windows, including anchorage, that accommodate thermal movements of units resulting from the following maximum change (range) in ambient and surface temperatures without buckling, distortion, opening of joints, failure of joint sealants, damaging loads and stresses on glazing and connections, and other detrimental effects. Base engineering calculation on actual surface temperatures of materials due to solar heat gain and nighttime-sky heat loss.
 - 1. Temperature Change (Range): 120 deg F, ambient; 180 deg F material surfaces.
- J. Field Leakage Tests: The Contractor shall engage and pay for an independent testing agency to make in-place field tests for water leakage. Cooperate and complete window mock-up and surrounding wall construction as early as possible so that problems, if any, can be identified before majority of windows are installed. Test will generally include a prolonged water spray test. Any uncontrolled leakage will be considered a failure. Contractor shall pay for all remedial work and all retesting required because of failures.
- K. All exterior windows shall be designed and comply with the requirements of FM Global 1-28 requirements.

1.5 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each product used. Provide certifications stating that windows comply with requirements.
- B. Shop Drawings: Provide large scale shop drawings for fabrication, installation and erection of all parts of the work. Provide elevations and details of anchorages, connections, operators and accessory items. Provide glazing details. Provide installation templates for work installed by others.
- C. Verification Samples: Submit representative samples of each material that is to be exposed in the finished work, showing the full range of color and finish variations expected. Provide samples having minimum area of 144 square inches.
- D. Test Reports: Submit certified reports for tests required.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Reference Standard: Comply with applicable requirements of AAMA Aluminum Curtain Wall Manual Volume 10, Care and Handling of Architectural Aluminum from Shop to Site.
- B. Storage: Remove wrappings that are wet or could become wet. Store in a well drained, protected area free from dust and corrosive fumes. Stack on edge to prevent trapping water and shim to promote water drainage and air circulation. Cover materials with durable coverings supported by frames to provide good air circulation and to prevent contaminants from contacting materials. Sequence deliveries to avoid delays, but minimize on-site storage.

1.7 SEQUENCING AND SCHEDULING

- A. Conference: Convene a pre-installation conference to establish procedures to maintain optimum working conditions and to coordinate this work with related and adjacent work.
- B. Complete mock-up for field testing and Engineer's review of visual qualities as early as possible. Coordinate with surrounding work.

1.8 WARRANTY

- A. Total Window System Warranty: Provide a written warranty assuming full responsibility for the satisfactory performance of the total window system including, but not limited to, windows, hardware, glass, glazing, anchorage, setting, perimeter sealing, flashing, and other work as it relates to the performance required by the Contract Documents. Repair or replace all work not meeting specified performance requirements including removal and replacement of covering or connected adjacent work.
1. Warranty Period: 5 years from date of Final Acceptance.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Provide products of one of the following manufacturers if they meet or exceed the requirements of these specifications:
1. Profile Systems, Inc.
 2. Wausau Metals Corporation
 3. Architectural Window Manufacturing Corporation.
 4. Custom Window Company.
 5. EFCO, a Pella Company.
 6. Graham Architectural Products Corp.
 7. Kawneer North America.
 8. Mannix; a Division of Interstate Window Corp.
 9. Peerless Products, Inc.

2.2 MATERIALS AND PRODUCTS

- A. Windows: Provide high performance architectural windows meeting specified performance requirements, finish requirements, and complying with referenced standards.
1. Types and Operation: Provide fixed, non-operable windows and operable windows as indicated.
 2. Profiles and Appearance: Provide windows matching profiles and appearance shown. Drawings and Specifications are based upon Wausau 4250 Low Profile Series. Provide units with site lines of operable units the same as fixed units. Site lines of intermediate horizontal and vertical members shall match site line of the perimeter frame.
 3. Glazing: Provide windows which are easily reglazable without disassembly from the inside (unless otherwise noted). Comply with Section 08801 – Glass and GLAZING.
 4. Provide units with removable stile as indicated on Drawings so that entire unit can be removed for equipment access.
- B. Aluminum Extrusions: Provide alloy and temper recommended by manufacturer for strength, corrosion resistance, and application indicated, but not less than 22,000,000 psi ultimate strength and not less than 0.125 in. thickness at any locations.
1. Sheet and Plate: ASTM B 209

2. Extruded Bars, Rods, Shapes, and Tubes: ASTM B 221
- C. Fasteners: Comply with referenced standards. Provide non-magnetic stainless steel fasteners. Conceal fasteners wherever possible; provide Phillips flat head screws for exposed fasteners.
- D. Aluminum Spandrel Panels: Provide 3/16" aluminum plate with concealed fasteners as indicated on Drawings.
- E. Aluminum Composite Trims and Panels: Provide aluminum composite trims and panels at areas indicated. Provide units complete with concealed fasteners and intermediate framing as required to complete the work.
- F. Screens: Provide manufacturer's standard 18 x 16 stainless steel wire, 0.009 in. diameter mesh.
- G. Hardware: Provide manufacturer's standard hardware fabricated from stainless steel, bronze, or other corrosion-resistant metal, of strength to perform intended function for size of window indicated and as follows:
 1. Casement Windows: Provide heavy-duty combination lever handle and cam-type lock, with balance-support arms with 5-nuckle hinges attached to jambs (two per sash).

2.3 GLAZING

- A. Insulating-Glass Units for Vertical Glazing: 1 inch thick insulating glass consisting of two lites of 1/4 inch glass, low e coating on the No. 2 surface and argon gas filled.

2.4 FABRICATION

- A. Fabricate windows to be truly straight and square within tolerances permitted by referenced standards. Provide work to sizes, shapes, and profiles indicated on Contract Documents and approved shop drawings. Where 3 in. window frame sight lines are indicated, 2-5/8 in. to 3- 5/8 in. would be acceptable; however, site lines of intermediate horizontal and vertical members are to match site line of the perimeter frame.
- B. Make work with uniform, tight joints free from sharp edges. Do not bridge thermal barriers with fasteners, welds, hardware, or metal items, unless the tested assembly had the same thermal bridges.
- C. Provide windows with effective means of draining water and condensation which may build- up in members. Fabricate windows with sealed insulating glass to prevent water from contacting glass edge seal.
- D. Provide subframes, sills, mullions, cover plates, and other components and accessories as needed for a complete weatherproof and waterproof assembly meeting specified performance requirements.
- E. All vent and frame corners shall be mitered and, at manufacturer's discretion, either corner blocked, using 6061 T6 structural aluminum alloy extruded corner blocks and stainless steel machine screws, or welded and ground smooth. The above attachment shall be made at both sides of the thermal break.

2.5 FINISHES

- A. Fluorocarbon Coating: Properly prepare substrates by inhibited chemical cleaning, conversion coating, and priming in compliance with coating manufacturer's instructions and recommendations. Provide minimum 1.0 dry film thickness of thermo-cured fluorocarbon coating containing minimum 70% of one of the following resins:

1. Hylar 5000; Ausimont USA, Inc., Morristown, NJ 07962-1838
 2. Kynar 500; Atochem North America, Inc., Philadelphia, PA 19102.
- B. Colors: Provide custom mixed colors, to match Engineer's sample.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The Installer shall examine substrates, supports, and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates, rough openings, and conditions.

3.2 INSTALLATION

- A. Manufacturer's Instructions: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.
- B. Installation: Install windows truly plumb, level, in alignment and plane without warp or rack. Install windows in one true plane for each wall plane on the building. Anchor securely in- place to maintain positions permanently when subjected to normal thermal and building movement and specified wind loads.
- C. Dissimilar Materials: Provide for effective means of isolating dissimilar materials. Comply with ANSI/AAMA 101, Appendix. Obtain Engineer's approval of method used.
- D. Sealants: Set sills and subframes in thick bed of sealant. Install sealants at all joints and intersections and at window perimeters. Comply with applicable requirements of Section 07920 - SEALANTS AND CAULKINGS.
- E. Flashings: Coordinate window installation with flashings to ensure weathertight construction and assembly. Thoroughly seal all penetrations through flashings with thick bed of sealant. Comply with applicable requirements of Section 07600 - FLASHINGS AND SHEET METAL.
- F. Glass and Glazing: Comply with applicable requirements of Section 08800 - GLAZING. Create a leak free installation.
- G. Insulation and Vapor Barriers: Provide insulation and vapor barriers between window perimeter and adjacent construction to ensure complete continuity. Comply with applicable requirements of Section 07210 - BUILDING INSULATION.

3.3 CLEANING, TOUCH-UP AND PROTECTION

- A. Touch-up damaged coatings and finishes and repair minor damage to eliminate all evidence of repair. Remove and replace work which cannot be satisfactorily repaired.
- B. Clean exposed surfaces using materials and methods recommended by window manufacturer. Remove labels. Remove and replace work that cannot be successfully cleaned.
- C. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 08801

GLASS AND GLAZING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

A. Work Included: This Section specifies glass and glazing for the following applications:

1. Exterior metal-framed openings.
2. Steel doors, frames and sidelights specified in Section 08111.
3. Interior borrowed lites.
4. Unframed mirrors.
5. Aluminum entrance doors.
6. Pre-fractured laminated glass (Art Program).
7. Tempered laminated wind screens.
8. Tempered laminated glass with custom ceramic ink artwork (Art Program).
9. Structural tempered, heat soaked, laminated glazing.
10. Comply with requirements in the Glass Matrix in this Section for glazing locations.

B. Related Work:

1. Section 01800 – SUSTAINABILITY REQUIREMENTS
2. Section 08130 – METAL FRAMED GLASS DOORS.
3. Section 08510 – STEEL WINDOWS.
4. Section 08511 – STAINLESS STEEL WINDOWS.
5. Section 08520 – ALUMINUM WINDOWS.
6. Section 08910 – GLAZED METAL FRAMED CURTAIN WALLS.
7. Section 08970 – STRUCTURAL GLASS WALLS.

C. Drawing Coordination: Refer to the Drawings for the following keynotes for this Section:

1. GL-01 GLAZING, 9/16" LAMINATED WITH TRANSLUCENT CERAMIC FRIT AND CLEAR INTERLAYER, TEMPERED
2. GL-02 GLAZING, 9/16" LAMINATED WITH CLEAR INTERLAYER, TEMPERED
3. GL-03 GLAZING, 9/16" LAMINATED WITH TRANSLUCENT CERAMIC FRIT AND CLEAR INTERLAYER, TEMPERED, BACK PAINTED
4. GL-04 NOT USED
5. GL-05 NOT USED
6. GL-06 GLAZING, 1" INSULATED, TEMPERED

7. GL-06A GLAZING 1" INSULATED WITH TRANSLUCENT CERAMIC FRIT, TEMPERED
8. GL-07 NOT USED
9. GL-08 GLAZING, 1" INSULATED WITH GRADUATION FROM TRANSLUCENT TO CLEAR
10. GL-09 NOT USED
11. GL-10 NOT USED
12. GL-11 GLAZING, LAMINATED WITH SECURITY INTERLAYER, TEMPERED
13. GL-12 GLAZING, 9/16" LAMINATED WITH PATTERNED CERAMIC FRIT, SECURITY INTERLAYER
14. GL-13 GLAZING BULLET-PROOF

1.2 DEFINITIONS

- A. Manufacturers of Glass Products: Firms that produce primary glass, fabricated glass, or both, as defined in referenced glazing publications.
- B. Glass Thicknesses: Indicated by thickness designations in millimeters according to ASTM C 1036.
- C. Interspace: Space between lites of an insulating-glass unit that contains dehydrated air or a specified gas.
- D. Deterioration of Coated Glass: Defects developed from normal use that are attributed to the manufacturing process and not to causes other than glass breakage and practices for maintaining and cleaning coated glass contrary to manufacturer's written instructions. Defects include peeling, cracking, and other indications of deterioration in metallic coating.
- E. Deterioration of Insulating Glass: Failure of hermetic seal under normal use that is attributed to the manufacturing process and not to causes other than glass breakage and practices for maintaining and cleaning insulating glass contrary to manufacturer's written instructions. Evidence of failure is the obstruction of vision by dust, moisture, or film on interior surfaces of glass.
- F. Deterioration of Laminated Glass: Defects developed from normal use that are attributed to the manufacturing process and not to causes other than glass breakage and practices for maintaining and cleaning laminated glass contrary to manufacturer's written instructions. Defects include edge separation, delamination materially obstructing vision through glass, and blemishes exceeding those allowed by referenced laminated-glass standard.

1.3 PERFORMANCE REQUIREMENTS

- A. General: Provide glazing systems capable of withstanding normal thermal movement and wind and impact loads (where applicable) without failure, including loss or glass breakage attributable to the following: defective manufacture, fabrication, and installation; failure of sealants or gaskets to remain watertight and airtight; deterioration of glazing materials; or other defects in construction.
- B. Glass Design: Glass thickness designations indicated are minimums and are for detailing only. Confirm glass thicknesses by analyzing Project loads and in-service conditions. Provide glass lites in

the thickness designations indicated for various size openings, but not less than thicknesses and in strengths (annealed or heat treated) required to meet or exceed the following criteria:

1. Glass Thicknesses: Select minimum glass thicknesses to comply with ASTM E 1300, according to the following requirements:
 - a. Specified Design Wind Loads: As required by Code.
 - b. Probability of Breakage for Vertical Glazing: 8 lites per 1000 for lites set vertically or not more than 15 degrees off vertical and under wind action.
 1. Load Duration: 60 seconds minimum.
 - c. Maximum Lateral Deflection: For the following types of glass supported on all 4 edges, provide thickness required that limits center deflection at design wind pressure to 1/50 times the short side length or 1 inch, whichever is less.
 1. For monolithic-glass lites heat treated to resist wind loads.
 2. For insulating glass.
 3. For laminated-glass lites.
 - d. Minimum Glass Thickness for Exterior Lites: Not less than 6 mm.
- C. Thermal Movements: Provide glazing that allows for thermal movements resulting from the following maximum change (range) in ambient and surface temperatures acting on glass framing members and glazing components. Base engineering calculation on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.
 1. Temperature Change (Range): 120 deg F, ambient; 180 deg F, material surfaces.
- D. Thermal and Optical Performance Properties: Provide glass with performance properties specified based on manufacturer's published test data, as determined according to procedures indicated below:
 1. For laminated-glass lites, properties are based on products of construction indicated.
 2. For insulating-glass units, properties are based on units with lites 6.0 mm thick and a nominal 1/2-inch-wide interspace.
 3. Center-of-Glass Values: Based on using LBL-44789 WINDOW 5.0 computer program for the following methodologies:
 - a. U-Factors: NFRC 100 expressed as Btu/ sq. ft. x h x deg F.
 - b. Solar Heat Gain Coefficient: NFRC 200.
 - c. Solar Optical Properties: NFRC 300.
- E. All exterior glazing shall be designed and comply with the requirements of FM Global 1-28 requirements.

1.4 SUBMITTALS

- A. Product Data: For each glass product and glazing material indicated. Submit manufacturer's printed product data, specifications, standard details, installation instructions, use limitations and recommendations for each material used. Provide certifications that materials and systems comply with specified requirements.
- B. Samples: For the following products, in the form of 12-inch- square Samples for glass.

1. Coated vision glass.
 2. Ceramic-coated spandrel glass.
 3. Each pattern and color of ceramic-coated vision glass.
 4. Each type of glass clad polycarbonate, in insulated and non-insulated panels
 5. Insulating glass for each designation indicated.
 6. For each color (except black) of exposed glazing sealant indicated.
- C. Glazing Schedule: Use same designations indicated on Drawings for glazed openings in preparing a schedule listing glass types and thicknesses for each size opening and location.
- D. Product Certificates: Signed by manufacturers of glass and glazing products certifying that products furnished comply with requirements. For solar-control low-e-coated glass, provide documentation demonstrating that manufacturer of coated glass is certified by coating manufacturer.
- E. Qualification Data: For installers, in accordance with Par. 1.5A.
- F. Preconstruction Adhesion and Compatibility Test Report: From glazing sealant manufacturer indicating glazing sealants were tested for adhesion to glass and glazing channel substrates and for compatibility with glass and other glazing materials.
- G. Delegated Design: For point supported glass used in conjunction with structural steel: Employ a Professional Engineer licensed in the Commonwealth of Massachusetts to supervise and coordinate the design for the entire glass assembly as well as preparing signed and sealed drawings and calculations including gravity, lateral and seismic loading. This Professional Engineer shall have 10 years experience in projects with composite structural assemblies of this type scope and complexity.
- H. Product Test Reports: For each of the following types of glazing products:
1. Monolithic glass.
 2. Laminated tempered glass Panels.
 3. Laminated, tempered insulating glass.
 4. Glass clad polycarbonate.
 5. Insulating glass.
 6. Point Supported Glass
 7. Glazing sealants.
 8. Glazing gaskets.
- I. Calculations: Provide wind load charts, calculations and certification of performance of this Work. Indicate how design requirements for loading and other performance criteria have been satisfied. All calculations shall bear the stamp of a Professional Engineer licensed and registered in the Commonwealth of Massachusetts.
- J. Affidavit of Experience: Installer to submit work experience as specified herein.
- K. Warranties: Special warranties specified in this Section.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: An experienced installer with a minimum of three years experience who has completed glazing similar in material, design, and extent to that indicated for this Project; whose work has resulted in glass installations with a record of successful in-service performance..
- B. Source Limitations for Glass: Obtain the following through one source from a single manufacturer for each glass type: clear float glass, laminated glass and insulating glass.
- C. Source Limitations for Glass Sputter-Coated with Solar-Control Low-E Coatings: Where solar-control low-e coatings of a primary glass manufacturer that has established a certified fabricator program is specified, obtain sputter-coated solar-control low-e-coated glass in fabricated units from a manufacturer that is certified by coated-glass manufacturer.
- D. Source Limitations for Glazing Accessories: Obtain glazing accessories through one source from a single manufacturer for each product and installation method indicated.
- E. Elastomeric Glazing Sealant Product Testing: Obtain sealant test results for product test reports in Part 1 "Submittals" Article from a qualified testing agency based on testing current sealant formulations within a 36-month period.
 - 1. Sealant Testing Agency Qualifications: An independent testing agency qualified according to ASTM C 1021 to conduct the testing indicated, as documented according to ASTM E 548.
 - 2. Test elastomeric glazing sealants for compliance with requirements specified by reference to ASTM C 920, and where applicable, to other standard test methods.
- F. Hold Point - Preconstruction Adhesion and Compatibility Testing: Submit to elastomeric glazing sealant manufacturers, for testing indicated below, samples of each glazing material type, tape sealant, gasket, glazing accessory, and glass-framing member that will contact or affect elastomeric glazing sealants:
 - 1. Use ASTM C 1087 to determine whether priming and other specific joint preparation techniques are required to obtain rapid, optimum adhesion of glazing sealants to glass, tape sealants, gaskets, and glazing channel substrates.
 - 2. Submit not fewer than eight pieces of each type of material, including joint substrates, shims, joint-sealant backings, secondary seals, and miscellaneous materials.
 - 3. Schedule sufficient time for testing and analyzing results to prevent delaying the Work.
 - 4. For materials failing tests, obtain sealant manufacturer's written instructions for corrective measures, including the use of specially formulated primers.
 - 5. Testing will not be required if elastomeric glazing sealant manufacturers submit data based on previous testing of current sealant products for adhesion to, and compatibility with, glazing materials matching those submitted.
- G. Safety Glazing Products: Comply with testing requirements in 16 CFR 120 and, for wired glass, ANSI Z97.1.
 - 1. Subject to compliance with requirements, obtain safety glazing products permanently marked with certification label of the Safety Glazing Certification Council or another certification agency acceptable to authorities having jurisdiction.
 - 2. Where glazing units, including Kind FT glass and laminated glass, are specified in Part 2 articles for glazing lites more than 9 sq. ft. in exposed surface area of one side, provide glazing

products that comply with Category II materials, for lites 9 sq. ft. or less in exposed surface area of one side, provide glazing products that comply with Category I or II materials, except for hazardous locations where Category II materials are required by 16 CFR 1201 and regulations of authorities having jurisdiction.

- H. Glazing Publications: Comply with published recommendations of glass product manufacturers and organizations below, unless more stringent requirements are indicated. Refer to these publications for glazing terms not otherwise defined in this Section or in referenced standards.
 - 1. GANA Publications: GANA Laminated Division's "Laminated Glass Design Guide" and GANA's "Glazing Manual."
 - 2. IGMA Publication for Insulating Glass: SIGMA TM-3000, "Glazing Guidelines for Sealed Insulating Glass Units."
- I. Insulating-Glass Certification Program: Permanently marked either on spacers or on at least one component lite of units with appropriate certification label of the following testing and inspecting agency: Insulating Glass Certification Council.
- J. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Protect glazing materials according to manufacturer's written instructions and as needed to prevent damage to glass and glazing materials from condensation, temperature changes, direct exposure to sun, or other causes.
- B. For insulating-glass units that will be exposed to substantial altitude changes, comply with insulating-glass manufacturer's written recommendations for venting and sealing to avoid hermetic seal ruptures.

1.7 PROJECT CONDITIONS

- A. Environmental Limitations: Do not proceed with glazing when ambient and substrate temperature conditions are outside limits permitted by glazing material manufacturers and when glazing channel substrates are wet from rain, frost, condensation, or other causes. Do not install liquid glazing sealants when ambient and substrate temperature conditions are outside limits permitted by glazing sealant manufacturer or below 40 deg F.

1.8 PRE-CONSTRUCTION MEETING

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

1.9 WARRANTY

- A. Manufacturer's Special Warranty for Coated-Glass Products: Manufacturer's standard form, made out to the Authority and signed by coated-glass manufacturer agreeing to replace coated-glass units that deteriorate as defined in "Definitions" Article, f.o.b. the nearest shipping point to Project site, within specified warranty period indicated below.
1. Warranty Period: Ten years from date of Substantial Completion.
- B. Manufacturer's Special Warranty on Laminated Glass: Manufacturer's standard form, made out to the Authority and signed by laminated-glass manufacturer agreeing to replace laminated-glass units that deteriorate as defined in Part 1 "Definitions" Article, f.o.b. the nearest shipping point to Project site, within specified warranty period indicated below.
1. Warranty Period: Five years from date of Substantial Completion.
- C. Manufacturer's Special Warranty on Mirrors: Manufacturer's standard form in which mirror manufacturer agrees to replace mirrors that deteriorate within specified warranty period. Deterioration of mirrors is defined as defects developed from normal use that are not attributed to mirror breakage or to maintaining and cleaning mirrors contrary to manufacturer's written instructions. Defects include discoloration, black spots, and clouding of the silver film.
1. Warranty Period: Five years from date of Substantial Completion.
- D. Manufacturer's Special Warranty on Insulating Glass: Manufacturer's standard form, made out to the Authority and signed by insulating-glass manufacturer agreeing to replace insulating-glass units that deteriorate as defined in "Definitions" Article, f.o.b. the nearest shipping point to Project site, within specified warranty period indicated below.
1. Warranty Period: Ten years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 INSULATING-GLASS UNITS

- A. Insulating-Glass Units for Vertical Glazing: 1 inch thick insulating glass consisting of two lites of 1/4 inch glass, low e coating on the No. 2 surface and argon gas filled. Provide one of the following or equal:
1. VE1-2M by Viracon.
 - a. Visible Light Transmittance: 70 percent.
 - b. Reflectance Visible Light: 11 percent.
 - c. U Value (Winter): 0.25.
 - d. Shading Coefficient: 0.43.
 - e. Solar Heat Gain Coefficient: 0.37.
 2. Solarban 60 by PPG Industries.
 - a. Visible Light Transmittance: 70 percent.
 - b. Reflectance Visible Light: 11 percent.
 - c. U Value (Winter): 0.29.

- d. Shading Coefficient: 0.44.
 - e. Solar Heat Gain Coefficient: 0.38.
3. SN-68 by Guardian Industries.
- a. Visible Light Transmittance: 68 percent.
 - b. Reflectance Visible Light: 10 percent.
 - c. U Value (Winter): 0.29.
 - d. Shading Coefficient: 0.43.
 - e. Solar Heat Gain Coefficient: 0.37.
- B. Insulating-Glass Units, General: Factory-assembled units consisting of sealed lites of glass separated by a dehydrated interpane air space, and complying with ASTM E2190 and with requirements specified in this Section.
- 1. Provide Kind HS (heat-strengthened) float glass in place of annealed glass where needed to resist thermal stresses induced by differential shading of individual glass lites and to comply with glass design requirements specified in Part 1 "Performance Requirements" paragraph.
 - 2. Provide Kind FT (fully tempered) glass lites where safety glass is indicated.
 - 3. Overall Unit Thickness and Thickness of Each Lite: Dimensions indicated for insulating-glass units are nominal and the overall thicknesses of units are measured perpendicularly from outer surfaces of glass lites at unit's edge.
 - 4. Sealing System: Dual seal, with primary and secondary sealants as follows:
 - a. Manufacturer's Standard Sealants. Butyl primary and silicone secondary sealants. Secondary sealant shall cover entire spacer bar at IGU perimeter.
 - 5. Spacer Specifications: Manufacturer's standard spacer material. Spacer corners shall be bent, soldered, or welded. Keyed spacer corners will not be accepted. Spacer may have a mid-span spacer key located at the midpoint of the insulating glass unit head. Where a mid-span spacer key is used, the key must be fully embedded (all sides) in butyl sealant.

2.2 GLASS PRODUCTS

- A. Float Glass: ASTM C 1036, Type I, Quality-Q3, Class I (clear) unless otherwise indicated.

2.3 LAMINATED GLASS

- A. Laminated Glass: ASTM C 1172, and complying with testing requirements in 16 CFR 1201 for Category II materials, and with other requirements specified. Use materials that have a proven record of no tendency to bubble, discolor, or lose physical and mechanical properties after fabrication and installation.
 - 1. Construction: Laminate glass with one of the following to comply with interlayer manufacturer's written recommendations.
 - a. DuPont™ SentryGlas® Ionoplast Interlayer
 - b. Polyvinyl butyral interlayer.
 - 2. Interlayer Thickness: Minimum 0.060 clear interlayer..
 - 3. Interlayer Color: Clear, translucent, opaque, patterned, and custom graphics may be required.. Refer to Drawings.

B. Laminated Glass Units:

1. Low-E Laminated Glass: 9/16 inch laminated vision glass with two plies of 1/4 inch clear tempered glass, low e coating on the No. 3 surface with 0.060 inch clear interlayer.
 - a. VLE1-70 by Viracon.
 1. Visible Light Transmittance: 68 percent.
 2. Reflectance Visible Light: 13 percent.
 3. U Value (Winter): 0.96.
 4. Shading Coefficient: 0.50.
 5. Solar Heat Gain Coefficient: 0.43.
2. Etched Laminated Glass: 1 inch laminated etched glass with two plies of 1/4 inch etched safety dichroic glass, with 0.030 inch interlayer.
 - a. Product: ALICE ceramic ink on No. 2 surface as specified elsewhere in this Section.
3. Laminate Low Iron Glass: 9/16 inch laminated vision glass with one ply of 1/4 inch OptiWhite tempered glass, one ply 1/4 inch OptiWhite tempered glass, with 0.060 inch clear interlayer.
 - a. Optiwhite by Viracon.
 1. Visible Light Transmittance: 90 percent
 2. Reflectance Visible Light: 8 percent
 3. U Value (Winter): 0.95.
 4. Shading Coefficient: 0.95
 5. Solar Heat Gain Coefficient: 0.83

2.4 LAMIANTED TEMPERED GLASS

- A. Laminated Fully Tempered glass panels - ASTM C 1048 Standard Specification for Heat-Strengthened and Fully Tempered Flat.
- B. Structural Glass, Point Supported: Lamianted panels shall be fully tempered glass. Provide a test result which warrants that heat soaked tempered glass will not break spontaneously as a result of Nickel Sulfide (NiS) inclusions at a rate exceeding 0.5% (5/1000) for a period of five years from the date of manufacture for each panel.
- C. Thickness: Provide thickness as determined by engineering requirements, as determined sizes and loads.

2.5 INTERIOR GLAZING

- A. Tempered Float Glass: ASTM C 1048; Type I (transparent flat glass); Quality-Q3; Kind FT; 1/4 inch thick unless indicated otherwise.
- B. Mirrors: ASTM C 1503. Mirror Glazing Quality, for blemish requirements; and comply with ASTM C 1048 for Kind FT, Condition A, tempered float glass before silver coating is applied.
 1. Nominal Thickness: 6.0 mm.

2.6 TRANSLUCENT GLASS UNITS

- A. Translucent Glass Unit: Air filled pre-assembled units consisting of 3 inch thick translucent glass consisting of two lites of 1/4 clear inch annealed glass, light diffusing veil on the No. 2 and 3 surfaces, with honeycomb transparent insulation aligned perpendicular to glazing and filled with Lumira aerogel.
1. Available Product: Provide Advanced Glazings Limited, Solera+ Lumira Aerogel R18 or approved equal.

2.7 GLASS CLAD POLYCARBONATE

- A. Polycarbonate Sheet: ASTM C 1349, Appendix X1, Type II, coated, mar-resistant, UV-stabilized polycarbonate with coating on exposed surfaces and Type I, standard, UV-stabilized polycarbonate where no surfaces are exposed.
- B. Glass-Clad Polycarbonate: ASTM C 1349, and other requirements specified.
1. Basis of Design: Viracon; GuardVue, physical attack resistant glass clad polycarbonate.
 - a. 13/16 inch thick, GuardVue 400.
 - b. 3/4 inch thick, GuardVue 350.
 2. Provide glass-clad polycarbonate that complies with testing requirements in 16 CFR 1201 for Category II materials, and with other requirements specified.
 3. Performance Requirements:
 - a. Safety Glazing: ANSI Z97.1.
 - b. Forced Entry Resistance: H.P. White TP-0500.02 - Level II.
 - c. Ballistics Resistance: H.P. White Level B Ballistics - 9 mm (low spall).
 - d. Physical Attack Resistance: WMFL Level III - 30 minutes.

2.8 GLAZING SEALANTS

- A. General: Provide products of type indicated, complying with the following requirements:
1. Compatibility: Verify glazing sealants that are compatible with one another and with other materials they will contact, including glass products, seals of insulating-glass units, and glazing channel substrates, under conditions of service and application, as demonstrated by sealant manufacturer based on testing and field experience.
 2. Suitability: Comply with sealant and glass manufacturers' written instructions for selecting glazing sealants suitable for applications indicated and for conditions existing at time of installation.
 3. Colors of Exposed Glazing Sealants: As selected by Engineer from manufacturer's full range.
- B. Elastomeric Glazing Sealants: Comply with ASTM C 920 and other requirements indicated for each liquid-applied chemically curing sealant specified, including those referencing ASTM C 920 classifications for type, grade, class, and uses related to exposure and joint substrates.
1. Single-Component Neutral- and Basic-Curing Silicone Glazing Sealants:

- a. Dow Corning Corporation; 790.
- b. GE Silicones; SilPruf LM SCS2700.
- c. Tremco; Spectrem 1 (Basic).

2.9 GLAZING TAPES

- A. Back-Bedding Mastic Glazing Tapes: Preformed, butyl-based elastomeric tape with a solids content of 100 percent; nonstaining and nonmigrating in contact with nonporous surfaces; with or without spacer rod as recommended in writing by tape and glass manufacturers for application indicated; packaged on rolls with a release paper backing; and complying with ASTM C 1281 and AAMA 800 for project conditions.
- B. Expanded Cellular Glazing Tapes: Closed-cell, PVC foam tapes; factory coated with adhesive on both surfaces; packaged on rolls with release liner protecting adhesive; and complying with AAMA 800 for the following types:
 1. Type 1, for glazing applications in which tape acts as the primary sealant.
 2. Type 2, for glazing applications in which tape is used in combination with a full bead of liquid sealant.

2.10 MISCELLANEOUS GLAZING MATERIALS

- A. General: Provide products of material, size, and shape complying with referenced glazing standard, requirements of manufacturers of glass and other glazing materials for application indicated, and with a proven record of compatibility with surfaces contacted in installation.
- B. Cleaners, Primers, and Sealers: Types recommended by sealant or gasket manufacturer.
- C. Setting Blocks: Elastomeric material with a Shore, Type A durometer hardness of 85, plus or minus 5.
- D. Spacers: Elastomeric blocks or continuous extrusions with a Shore, Type A durometer hardness required by glass manufacturer to maintain glass lites in place for installation indicated.
- E. Edge Blocks: Elastomeric material of hardness needed to limit glass lateral movement (side walking).
- F. Perimeter Insulation for Fire-Resistive Glazing: Identical to product used in test assembly to obtain fire-resistance rating.
- G. Mirror Mastic: An adhesive setting compound, asbestos-free, produced specifically for setting mirrors and certified by both mirror manufacturer and mastic manufacturer as compatible with glass coating and substrates on which mirrors will be installed.
 1. Adhesive shall have a VOC content of not more than 70 g/L when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- H. Mirror Hardware: Aluminum extrusions with a return deep enough to produce a glazing channel to accommodate mirrors of thickness indicated and in lengths required to cover bottom and top edges of each mirror in a single piece.

2.11 FABRICATION OF GLAZING UNITS

- A. Fabricate glazing units in sizes required to glaze openings indicated for Project, with edge and face clearances, edge and surface conditions, and bite complying with written instructions of product manufacturer and referenced glazing publications, to comply with system performance requirements.
- B. Clean-cut or flat-grind vertical edges of butt-glazed monolithic lites in a manner that produces square edges with slight kerfs at junctions with outdoor and indoor faces.
- C. Grind smooth and polish exposed glass edges and corners.

2.12 GRAPHICS ON GLASS

- A. Graphics Printer for Images on Glass: ALICE printer by GeneralGlass or equal:
 - 1. Print resolution: Up to 360 dpi..
 - 2. Ink type: Ceramic enamel frit.
 - 3. Equipment: Flat bed digital printing unit.
 - 4. Drying: Infrared drying.
 - 5. Image format: All standard graphic formats including PDF, PS, EPS, TIFF, BMP and JPEG.
 - 6. Drop Fixation: Droplets dried immediately to prevent drop gain.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine framing glazing, with Installer present, for compliance with the following:
 - 1. Manufacturing and installation tolerances, including those for size, squareness, and offsets at corners.
 - 2. Presence and functioning of weep system.
 - 3. Minimum required face or edge clearances.
 - 4. Effective sealing between joints of glass-framing members.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Clean glazing channels and other framing members receiving glass immediately before glazing. Remove coatings not firmly bonded to substrates.

3.3 GLAZING, GENERAL

- A. Comply with combined written instructions of manufacturers of glass, sealants, gaskets, and other glazing materials, unless more stringent requirements are indicated, including those in referenced glazing publications.
- B. Glazing channel dimensions, as indicated on Drawings, provide necessary bite on glass, minimum edge and face clearances, and adequate sealant thicknesses, with reasonable tolerances. Adjust as required by Project conditions during installation.
- C. Protect glass edges from damage during handling and installation. Remove damaged glass from Project site and legally dispose of off Project site. Damaged glass is glass with edge damage or other imperfections that, when installed, could weaken glass and impair performance and appearance.
- D. Apply primers to joint surfaces where required for adhesion of sealants, as determined by preconstruction sealant-substrate testing.
- E. Install setting blocks in sill rabbets, sized and located to comply with referenced glazing publications, unless otherwise required by glass manufacturer. Set blocks in thin course of compatible sealant suitable for heel bead.
- F. Do not exceed edge pressures stipulated by glass manufacturers for installing glass lites.
- G. Provide spacers for glass lites where length plus width is larger than 50 inches as follows:
 - 1. Locate spacers directly opposite each other on both inside and outside faces of glass. Install correct size and spacing to preserve required face clearances, unless gaskets and glazing tapes are used that have demonstrated ability to maintain required face clearances and to comply with system performance requirements.
 - 2. Provide 1/8-inch minimum bite of spacers on glass and use thickness equal to sealant width. With glazing tape, use thickness slightly less than final compressed thickness of tape.
- H. Provide edge blocking where indicated or needed to prevent glass lites from moving sideways in glazing channel, as recommended in writing by glass manufacturer and according to requirements in referenced glazing publications.
- I. Set glass lites in each series with uniform pattern, draw, bow, and similar characteristics.

3.4 TAPE GLAZING

- A. Position tapes on fixed stops so that, when compressed by glass, their exposed edges are flush with or protrude slightly above sightline of stops.
- B. Install tapes continuously, but not necessarily in one continuous length. Do not stretch tapes to make them fit opening.
- C. Cover vertical framing joints by applying tapes to heads and sills first and then to jambs. Cover horizontal framing joints by applying tapes to jambs and then to heads and sills.
- D. Place joints in tapes at corners of opening with adjoining lengths butted together, not lapped. Seal joints in tapes with compatible sealant approved by tape manufacturer.

- E. Do not remove release paper from tape until just before each glazing unit is installed.
- F. Center glass lites in openings on setting blocks and press firmly against tape by inserting dense compression gaskets formed and installed to lock in place against faces of removable stops. Start gasket applications at corners and work toward centers of openings.

3.5 SEALANT GLAZING (WET)

- A. Install continuous spacers, or spacers combined with cylindrical sealant backing, between glass lites and glazing stops to maintain glass face clearances and to prevent sealant from extruding into glass channel and blocking weep systems until sealants cure. Secure spacers or spacers and backings in place and in position to control depth of installed sealant relative to edge clearance for optimum sealant performance.
- B. Force sealants into glazing channels to eliminate voids and to ensure complete wetting or bond of sealant to glass and channel surfaces.
- C. Tool exposed surfaces of sealants to provide a substantial wash away from glass.

3.6 CLEANING AND PROTECTION

- A. Protect exterior glass from damage immediately after installation by attaching crossed streamers to framing held away from glass. Do not apply markers to glass surface. Remove nonpermanent labels, and clean surfaces.
- B. Protect glass from contact with contaminating substances resulting from construction operations, including weld splatter. If, despite such protection, contaminating substances do come into contact with glass, remove substances immediately as recommended by glass manufacturer.
- C. Examine glass surfaces adjacent to or below exterior concrete and other masonry surfaces at frequent intervals during construction, but not less than once a month, for buildup of dirt, scum, alkaline deposits, or stains; remove as recommended in writing by glass manufacturer.
- D. Remove and replace glass that is broken, chipped, cracked, or abraded or that is damaged from natural causes, accidents, and vandalism, during construction period.

3.7 GLASS MATRIX

Station	Location	Glass Types														
		GL-01 9/16" Lam w/ Transl Cer Frit & Clear Interlayer, Temp.	GL-02 9/16" Laminated w/ Clear Inter-layer, Tempered	GL-03 9/16" Lam with Transl Cer Frit & Clear Interl, Temp, Back Ptd	GL-04 NOT USED	GL-05 NOT USED	GL-06 1" Insulated, Tempered	GL-06A 1 Ins w/ Transl CerFrit, Temp	GL-07 NOT USED	GL-08 1" Insulated w/ Graduated Frit	GL-09 NOT USED	GL-10 NOT USED	GL-11 Laminated w/ Security Interlayer***, Temp	GL-11A NOT USED	GL-12 9/16 Lam w/ Patterned Ceramic Frit Security Interlayer***	GL-13 Bullet Proof
Lechmere	Point Supported Glass												X			
	North Headhouse Curtainwall		X	X												
	Platform Wind Screens Viaduct Wind Screens											X			X	
	North Headhouse Curtainwall/Art Panels*		X													
	Bus Ops							X		X						
	Elevators		X													
	Police Reporting Station							X		X						X
	South Headhouse Curtainwall	X	X	X												
	South Headhouse Curtainwall/Art Panels*		X													
Washington	Gallery											X				
	CSA Booth							X								
	Concourse		X													
	Elevators		X													
	Lobby - Upper facing north											X				
	Lobby -Lower facing west											X				

Station	Location	Glass Types													
		GL-01 9/16" Lam w/ Trans Cer Frit & Clear Interlayer, Temp.	GL-02 9/16" Laminated w/ Clear Inter-layer, Tempered	GL-03 9/16" Lam with Transl Cer Frit & Clear Interl, Temp, Back Ptd	GL-04 NOT USED	GL-05 NOT USED	GL-06 1" Insulated, Tempered	GL-06A 1 Ins w/ Transl CerFrit, Temp	GL-07 NOT USED	GL-08 1" Insulated w/ Graduated Frit	GL-09 NOT USED	GL-10 NOT USED	GL-11 Laminated w/ Security Interlayer ***; Temp	GL-11A NOT USED	GL-12 9/16 Lam w/ Patterned Ceramic Frit Security Interlayer***
Union	Upper Lobby Structural Glazed System											X			
	Elevators		X												
	Lower Lobby		X												
	Starters Booth						X								
	CSA Booths						X								
	Concourse		X												
	Glass Canopy											X			
Gilman	Medford Street Head House											X			
	CSA Booth						X								
	Elevators		X												
	Concourse		X												
	Community Path Head House											X			
	Bridge		X												
Lowell	Lobby		X												
	Bicycle Storage		X												
	CSA Booth						X								
	Concourse		X												
	Elevators		X												
Ball Square	Headhouse and Concourse Curtainwall	X	X	X											

Station	Location	Glass Types														
		GL-01 9/16" Lam w/ Trans Cer Frit & Clear Interlayer, Temp.	GL-02 9/16" Laminated w/ Clear Inter-layer, Tempered	GL-03 9/16" Lam with Transl Cer Frit & Clear Interl, Temp, Back Ptd	GL-04 NOT USED	GL-05 NOT USED	GL-06 1" Insulated, Tempered	GL-06A 1 Ins w/ Transl CerFrit, Temp	GL-07 NOT USED	GL-08 1" Insulated w/ Graduated Frit	GL-09 NOT USED	GL-10 NOT USED	GL-11 Laminated w/ Security Interlayer ***; Temp	GL-11A NOT USED	GL-12 " 9/16 Lam w/ Patterned Ceramic Frit Security Interlayer***	GL-13 Bullet Proof
College	Headhouse and Con-course Curtainwall	X	X	X												
	Elevators		X													
	Operator Lounge						X									
	Bathrooms						X									

* with Custom Ceramic Ink Fritted Graphic

** Glass Thickness Nominal - Actual

*** Basis of Design

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09220

PORTLAND CEMENT PLASTER

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items:
 - 1. Exterior Portland cement plasterwork (stucco) with integral color on metal lath.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
 - 1. Section 05411 – LIGHT GAUGE METAL FRAMING; steel studs that support lath and portland cement plaster.
 - 2. Section 06100 - CARPENTRY; wood furring included in portland cement plaster assemblies.
 - 3. Section 07920 - JOINT SEALANTS; sealants installed with exterior portland cement plaster.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: Show locations and installation of control and expansion joints including plans, elevations, sections, details of components, and attachments to other work.
- C. Samples for Verification: For each type of finish coat indicated; 12 by 12 inches and prepared on rigid backing.

1.3 QUALITY ASSURANCE

- A. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 1.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Store materials inside under cover and keep them dry and protected against damage from weather, direct sunlight, surface contamination, corrosion, construction traffic, and other causes.

1.5 PROJECT CONDITIONS

- A. Comply with ASTM C 926 requirements.

- B. Exterior Plasterwork:
 - 1. Apply and cure plaster to prevent plaster drying out during curing period. Use procedures required by climatic conditions, including moist curing, providing coverings, and providing barriers to deflect sunlight and wind.
 - 2. Apply plaster when ambient temperature is greater than 40 deg F.
 - 3. Protect plaster coats from freezing for not less than 48 hours after set of plaster coat has occurred.
- C. Factory-Prepared Finishes: Comply with manufacturer's written recommendations for environmental conditions for applying finishes.

PART 2 - PRODUCTS

2.1 METAL LATH

- A. Expanded-Metal Lath: ASTM C 847 with ASTM A 653/A 653M, G60, hot-dip galvanized zinc coating.

2.2 ACCESSORIES

- A. General: Comply with ASTM C 1063 and coordinate depth of trim and accessories with thicknesses and number of plaster coats required.
- B. Zinc and Zinc-Coated (Galvanized) Accessories: ASTM A 653/A 653M, G60 zinc coating.

2.3 MISCELLANEOUS MATERIALS

- A. Water for Mixing: Potable and free of substances capable of affecting plaster set or of damaging plaster, lath, or accessories.
- B. Bonding Compound: ASTM C 932.
- C. Steel Drill Screws: For metal-to-metal fastening, ASTM C 1002 or ASTM C 954, as required by thickness of metal being fastened; with pan head that is suitable for application; in lengths required to achieve penetration through joined materials of not fewer than three exposed threads.
- D. Fasteners for Attaching Metal Lath to Substrates: Complying with ASTM C 1063.
- E. Isolation Strip at Exterior Walls: ASTM D 226, Type I (No. 15 asphalt felt), unperforated.

2.4 PLASTER MATERIALS

- A. Portland Cement: ASTM C 150, Type I, white color for finish coats.
- B. Plastic Cement: ASTM C 1328.

- C. Colorants for Job-Mixed Finish-Coats: Colorfast mineral pigments that produce finish plaster color to match Engineer's sample.
- D. Lime: ASTM C 206, Type S; or ASTM C 207, Type S.
- E. Sand Aggregate: ASTM C 897.
- F. Ready-Mixed Finish-Coat Plaster: Mill-mixed portland cement, aggregates, coloring agents, and proprietary ingredients.
 - 1. Available Products:
 - a. California Stucco Products Corp.; Conventional Portland Cement Stucco.
 - b. Florida Stucco Corp.
 - c. United States Gypsum Co.; Oriental Exterior Finish Stucco.
 - 2. Color: As selected by Engineer from manufacturer's full range.

2.5 PLASTER MIXES

- A. General: Comply with ASTM C 926 for applications indicated.
 - 1. Fiber Content: Add fiber to base-coat mixes after ingredients have mixed at least two minutes. Comply with fiber manufacturer's written instructions for fiber quantities in mixes, but do not exceed 1 lb of fiber/cu. ft. of cementitious materials. Reduce aggregate quantities accordingly to maintain workability.
- B. Base-Coat Mixes for Use over Metal Lath: Scratch and brown coats for three-coat plasterwork as follows:
 - 1. Portland Cement Mixes:
 - a. Scratch Coat: For cementitious material, mix 1 part portland cement and 0 to 3/4 parts lime. Use 2-1/2 to 4 parts aggregate per part of cementitious material (sum of separate volumes of each component material).
 - b. Brown Coat: For cementitious material, mix 1 part portland cement and 0 to 3/4 parts lime. Use 3 to 5 parts aggregate per part of cementitious material (sum of separate volumes of each component material).
- C. Factory-Prepared Finish-Coat Mixes: For ready-mixed finish-coat plasters, comply with manufacturer's written instructions.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and substrates, with Installer present, and including welded hollow-metal frames, cast-in anchors, and structural framing, for compliance with requirements and other conditions affecting performance.

1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Protect adjacent work from soiling, spattering, moisture deterioration, and other harmful effects caused by plastering.

3.3 INSTALLING METAL LATH

- A. Expanded-Metal Lath: Install according to ASTM C 1063.

3.4 INSTALLING ACCESSORIES

- A. Install according to ASTM C 1063 and at locations indicated on Drawings.
- B. Reinforcement for External Corners:
 1. Install lath-type external-corner reinforcement at exterior locations.
 2. Install cornerbead at interior and exterior locations.
- C. Control Joints: Install control joints in specific locations approved by Engineer for visual effect as follows:
 1. As required to delineate plasterwork into areas (panels) of the following maximum sizes:
 - a. Vertical Surfaces: 144 sq. ft.
 - b. Horizontal and other Non-vertical Surfaces: 100 sq. ft.
 2. At distances between control joints of not greater than 18 feet o.c.
 3. As required to delineate plasterwork into areas (panels) with length-to-width ratios of not greater than 2-1/2:1.
 4. Where control joints occur in surface of construction directly behind plaster.
 5. Where plasterwork areas change dimensions, to delineate rectangular-shaped areas (panels) and to relieve the stress that occurs at the corner formed by the dimension change.

3.5 PLASTER APPLICATION

- A. General: Comply with ASTM C 926.
 1. Do not deviate more than plus or minus 1/4 inch in 10 feet from a true plane in finished plaster surfaces, as measured by a 10-foot straightedge placed on surface.
 2. Grout hollow-metal frames, bases, and similar work occurring in plastered areas, with base-coat plaster material, before lathing where necessary. Except where full grouting is indicated or required for fire-resistance rating, grout at least 6 inches at each jamb anchor.
 3. Finish plaster flush with metal frames and other built-in metal items or accessories that act as a plaster ground, unless otherwise indicated. Where casing bead does not terminate plaster at metal

frame, cut base coat free from metal frame before plaster sets and groove finish coat at junctures with metal.

4. Provide plaster surfaces that are ready to receive field-applied finishes indicated.

B. Plaster Finish Coats: Apply to provide finish to match Engineer's sample.

3.6 CUTTING AND PATCHING

A. Cut, patch, replace, and repair plaster as necessary to accommodate other work and to restore cracks, dents, and imperfections. Repair or replace work to eliminate blisters, buckles, crazing and check cracking, dry outs, efflorescence, sweat outs, and similar defects and where bond to substrate has failed.

3.7 CLEANING AND PROTECTION

A. Remove temporary protection and enclosure of other work. Promptly remove plaster from doorframes, windows, and other surfaces not indicated to be plastered. Repair floors, walls, and other surfaces stained, marred, or otherwise damaged during plastering.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment."

END OF SECTION

SECTION 09260

GYPSUM BOARD ASSEMBLIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items:
 - 1. Interior gypsum wallboard.
 - 2. Tile backing panels.
 - 3. Exterior sheathing board.
 - 4. Non-load-bearing steel framing.
 - 5. Installation of access doors in gypsum board assemblies, furnished under mechanical and electrical sections.

- B. Related Work:
 - 1. Section 05411, LIGHT GAGE METAL FRAMING.
 - 2. Section 07210, BUILDING INSULATION
 - 3. Section 09281, CEMENT BOARD
 - 4. Section 09270, GYPSUM VENEER PLASTERING
 - 5. Section 09900, PAINTING

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.

- B. Samples: For the following products:
 - 1. Trim Accessories: Full-size Sample in 12-inch-long length for each trim accessory indicated.

1.3 QUALITY ASSURANCE

- A. Fire-Resistance-Rated Assemblies: For fire-resistance-rated assemblies, provide materials and construction identical to those tested in assembly indicated according to ASTM E 119 by an independent testing agency.

- B. Sound Transmission Coefficient Rated Assemblies: For STC-rated assemblies, provide materials and construction identical to those tested in assembly indicated according to ASTM E 90 and classified according to ASTM E 413 by an independent testing agency.

1.4 STORAGE AND HANDLING

- A. Store materials inside under cover and keep them dry and protected against damage from weather, condensation, direct sunlight, construction traffic, and other causes. Stack panels flat to prevent sagging.

1.5 PROJECT CONDITIONS

- A. Environmental Limitations: Comply with ASTM C 840 requirements or gypsum board manufacturer's written recommendations, whichever are more stringent.
- B. Do not install interior products until installation areas are enclosed and conditioned.
- C. Do not install panels that are wet, those that are moisture damaged, and those that are mold damaged.
 - 1. Indications that panels are wet or moisture damaged include, but are not limited to, discoloration, sagging, or irregular shape.
 - 2. Indications that panels are mold damaged include, but are not limited to, fuzzy or splotchy surface contamination and discoloration.

PART 2 - PRODUCTS

2.1 NON-LOAD-BEARING STEEL FRAMING, GENERAL

- A. Framing Members, General: Comply with ASTM C 754 for conditions indicated.
 - 1. Steel Sheet Components: Comply with ASTM C 645 requirements for metal, unless otherwise indicated.
 - 2. Protective Coating: manufacturer's standard corrosion-resistant zinc coating, unless otherwise indicated.

2.2 SUSPENSION SYSTEM COMPONENTS

- A. Tie Wire: ASTM A 641/A 641M, Class 1 zinc coating, soft temper, 0.0625-inch-diameter wire, or double strand of 0.0475-inch-diameter wire.
- B. Hanger Attachments to Concrete:
 - 1. Anchors: Fabricated from corrosion-resistant materials with holes or loops for attaching wire hangers and capable of sustaining, without failure, a load equal to 5 times that imposed by construction as determined by testing according to ASTM E 488 by an independent testing agency.
 - a. Type: Postinstalled, expansion anchor.
- C. Wire Hangers: ASTM A 641/A 641M, Class 1 zinc coating, soft temper, 0.162-inch diameter.
- D. Carrying Channels: Cold-rolled, commercial-steel sheet with a base-metal thickness of 0.0538 inch and minimum 1/2-inch- wide flanges with depth as required for span and loading and indicated on Drawings.
- E. Furring Channels (Furring Members): 0.0538-inch bare-steel thickness, with minimum 1/2-inch- wide flanges, 3/4 inch deep.
- F. Grid Suspension System for Ceilings: ASTM C 645, direct-hung system composed of main beams and cross-furring members that interlock.

1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Armstrong World Industries, Inc.; Drywall Grid Systems.
 - b. Chicago Metallic Corporation; Drywall Furring System.
 - c. USG Corporation; Drywall Suspension System.

2.3 STEEL FRAMING FOR FRAMED ASSEMBLIES

- A. Steel Studs and Runners: ASTM C 645.
 1. Minimum Base-Metal Thickness: 0.0312 inch.
- B. Slip-Type Head Joints: Where indicated, provide one of the following:
 1. Single Long-Leg Runner System: ASTM C 645 top runner with 2-inch- deep flanges in thickness not less than indicated for studs, installed with studs friction fit into top runner and with continuous bridging located within 12 inches of the top of studs to provide lateral bracing.
 2. Double-Runner System: ASTM C 645 top runners, inside runner with 2-inch-deep flanges in thickness not less than indicated for studs and fastened to studs, and outer runner sized to friction fit inside runner.
 3. Deflection Track: Steel sheet top runner manufactured to prevent cracking of finishes applied to interior partition framing resulting from deflection of structure above; in thickness not less than indicated for studs and in width to accommodate depth of studs.
 - a. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - 1) Steel Network Inc. (The); VertiClip Series.
 - 2) Superior Metal Trim; Superior Flex Track System (SFT).
- C. Flat Strap and Backing Plate: Steel sheet for blocking and bracing in length and width indicated.
 1. Minimum Base-Metal Thickness: 0.0312 inch.
- D. Cold-Rolled Channel Bridging: 0.0538-inch bare-steel thickness, with minimum 1/2-inch- wide flanges.
 1. Depth: 1-1/2 inches.
 2. Clip Angle: Not less than 1-1/2 by 1-1/2 inches, 0.068-inch-thick, galvanized steel.
- E. Hat-Shaped, Rigid Furring Channels: ASTM C 645.
 1. Minimum Base Metal Thickness: 0.0312 inch.
 2. Depth: 7/8 inches.
- F. Resilient Furring Channels: 1/2-inch-deep, steel sheet members designed to reduce sound transmission.
 1. Configuration: Asymmetrical or hat shaped.

- G. Z-Shaped Furring: With slotted or non-slotted web, face flange of 1-1/4 inches wall attachment flange of 7/8 inch, minimum bare-metal thickness of 0.0179 inch, and depth required to fit insulation thickness indicated.

2.4 GLASS-MAT GYPSUM SHEATHING BOARD

- A. Glass-Mat Gypsum Sheathing Board: ASTM C 1177.
 - 1. Available Products: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - a. CertainTeed Corp.; GlasRoc.
 - b. Georgia-Pacific Gypsum LLC; Dens-Glass Gold.
 - c. National Gypsum Company; Gold Bond, e²XP.
 - d. USG Corporation; Securock.
 - 2. Type and Thickness: 5/8 inch, Type X.
- B. Screws for Fastening Gypsum Sheathing to Cold-Formed Metal Framing: Steel drill screws, in length recommended by sheathing manufacturer for thickness of sheathing board to be attached, with organic-polymer or other corrosion-protective coating having a salt-spray resistance of more than 800 hours according to ASTM B 117.
 - 1. For steel framing from 0.033 to 0.112 inch thick, attach sheathing to comply with ASTM C 954.

2.5 AUXILIARY MATERIALS

- A. General: Provide auxiliary materials that comply with referenced installation standards.
 - 1. Fasteners for Metal Framing: Of type, material, size, corrosion resistance, holding power, and other properties required to fasten steel members to substrates.
- B. Isolation Strip at Exterior Walls: Provide one of the following:
 - 1. Asphalt-Saturated Organic Felt: ASTM D 226, Type I (No. 15 asphalt felt), non-perforated.
 - 2. Foam Gasket: Adhesive-backed, closed-cell vinyl foam strips that allow fastener penetration without foam displacement, 1/8 inch thick, in width to suit steel stud size.

2.6 INTERIOR GYPSUM BOARD

- A. General: Complying with ASTM C 36/C 36M or ASTM C 1396/C 1396M, as applicable to type of gypsum board indicated and whichever is more stringent.
 - 1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. USG Corporation.
 - b. G-P Gypsum.
 - c. National Gypsum Company.

- B. Fire-Resistant Type X:
 - 1. Thickness: 5/8 inch.
 - 2. Long Edges: Tapered.
- C. Ceiling Type: Manufactured to have more sag resistance than regular-type gypsum board.
 - 1. Thickness: 1/2 inch.
 - 2. Long Edges: Tapered.
- D. Abuse-Resistant Type: Manufactured to produce greater resistance to surface indentation and through-penetration (impact resistance) than standard, regular-type and Type X gypsum board.
 - 1. Core: 5/8 inch, Type X.
 - 2. Long Edges: Tapered.

2.7 TILE BACKING PANELS

- 1. Refer to Section 09281 Cement Board

2.8 TRIM ACCESSORIES

- A. Interior Trim: ASTM C 1047.
 - 1. Material: Galvanized or aluminum-coated steel sheet or rolled zinc.
 - 2. Shapes:
 - a. Cornerbead.
 - b. Bullnose bead.
 - c. LC-Bead: J-shaped; exposed long flange receives joint compound.
 - d. Expansion (Control) Joint.
 - e. Curved-Edge Cornerbead: With notched or flexible flanges.
- B. Exterior Trim: ASTM C 1047.
 - 1. Material: Hot-dip galvanized steel sheet, plastic, or rolled zinc.
 - 2. Shapes:
 - a. Cornerbead.
 - b. LC-Bead: J-shaped; exposed long flange receives joint compound.
 - c. Expansion (Control) Joint: One-piece, rolled zinc with V-shaped slot and removable strip covering slot opening.
- C. Aluminum Trim: Extruded accessories of profiles and dimensions indicated.
 - 1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fry Reglet Corp.
 - b. Gordon, Inc.
 - c. Pittcon Industries.

2. Aluminum: Alloy and temper with not less than the strength and durability properties of ASTM B 221, Alloy 6063-T5.
3. Finish: Corrosion-resistant primer compatible with joint compound and finish materials specified.

2.9 JOINT TREATMENT MATERIALS

- A. General: Comply with ASTM C 475/C 475M.
- B. Joint Tape:
 1. Interior Gypsum Wallboard: Fiberglass mesh..
 2. Exterior Gypsum Soffit Board: Fiberglass mesh..
 3. Glass-Mat Gypsum Sheathing Board: 10-by-10 glass mesh.
 4. Tile Backing Panels: As recommended by panel manufacturer.
- C. Joint Compound for Interior Gypsum Wallboard: For each coat use formulation that is compatible with other compounds applied on previous or for successive coats.
 1. Prefilling: At open joints, rounded or beveled panel edges, and damaged surface areas, use setting-type taping compound.
 2. Embedding and First Coat: For embedding tape and first coat on joints, fasteners, and trim flanges, use setting-type taping compound.
 3. Fill Coat: For second coat, use setting-type, sandable topping compound.
 4. Finish Coat: For third coat, use setting-type, sandable topping compound.
 5. Skim Coat: For final coat of Level 5 finish, use setting-type, sandable topping compound.

2.10 AUXILIARY MATERIALS

- A. General: Provide auxiliary materials that comply with referenced installation standards and manufacturer's written recommendations.
- B. Laminating Adhesive: Adhesive or joint compound recommended for directly adhering gypsum panels to continuous substrate.
 1. Use adhesives that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- C. Steel Drill Screws: ASTM C 1002, unless otherwise indicated.
 1. Use screws complying with ASTM C 954 for fastening panels to steel members from 0.033 to 0.112 inch thick.
 2. For fastening cementitious backer units, use screws of type and size recommended by panel manufacturer.
- D. Sound Attenuation Blankets: ASTM C 665, Type I (blankets without membrane facing) produced by combining thermosetting resins with mineral fibers manufactured from glass, slag wool, or rock wool.
 1. Fire-Resistance-Rated Assemblies: Comply with mineral-fiber requirements of assembly.

- E. Acoustical Sealant: Subject to compliance with requirements, products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Acoustical Sealant for Exposed and Concealed Joints:
 - a. Pecora Corp.; AC-20 FTR Acoustical and Insulation Sealant.
 - b. United States Gypsum Co.; SHEETROCK Acoustical Sealant.
 - 2. Acoustical Sealant for Concealed Joints:
 - a. Ohio Sealants, Inc.; Pro-Series SC-170 Rubber Base Sound Sealant.
 - b. Pecora Corp.; BA-98.
 - c. Tremco, Inc.; Tremco Acoustical Sealant.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and substrates, with Installer present, and including welded hollow-metal frames and framing, for compliance with requirements and other conditions affecting performance.
- B. Examine panels before installation. Reject panels that are wet, moisture damaged, and mold damaged.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Suspended Assemblies: Coordinate installation of suspension systems with installation of overhead structure to ensure that inserts and other provisions for anchorages to building structure have been installed to receive hangers at spacing required to support the Work and that hangers will develop their full strength.
 - 1. Furnish concrete inserts and other devices indicated to other trades for installation in advance of time needed for coordination and construction.
- B. Coordination with Sprayed Fire-Resistive Materials:
 - 1. Before sprayed fire-resistive materials are applied, attach offset anchor plates or ceiling tracks to surfaces indicated to receive sprayed fire-resistive materials. Where offset anchor plates are required, provide continuous plates fastened to building structure not more than 24 inches o.c.
 - 2. After sprayed fire-resistive materials are applied, remove them only to extent necessary for installation of non-load-bearing steel framing. Do not reduce thickness of fire-resistive materials below that required for fire-resistance ratings indicated. Protect adjacent fire-resistive materials from damage.

3.3 INSTALLATION, GENERAL

- A. Installation Standard: ASTM C 754. Also comply with requirements in ASTM C 840 that apply to framing installation.
- B. Install supplementary framing, and blocking to support fixtures, equipment services, heavy trim, grab bars, toilet accessories, furnishings, or similar construction.
- C. Install bracing at terminations in assemblies.
- D. Do not bridge building control and expansion joints with non-load-bearing steel framing members. Frame both sides of joints independently.

3.4 INSTALLING SUSPENSION SYSTEMS

- A. Install suspension system components in sizes and spacings indicated on Drawings, but not less than those required by referenced installation standards for assembly types and other assembly components indicated.
- B. Isolate suspension systems from building structure where they abut or are penetrated by building structure to prevent transfer of loading imposed by structural movement.
- C. Suspend hangers from building structure as follows:
 - 1. Install hangers plumb and free from contact with insulation or other objects within ceiling plenum that are not part of supporting structural or suspension system.
 - a. Splay hangers only where required to miss obstructions and offset resulting horizontal forces by bracing, countersplaying, or other equally effective means.
 - 2. Where width of ducts and other construction within ceiling plenum produces hanger spacings that interfere with locations of hangers required to support standard suspension system members, install supplemental suspension members and hangers in the form of trapezes or equivalent devices.
 - a. Size supplemental suspension members and hangers to support ceiling loads within performance limits established by referenced installation standards.
 - 3. Wire Hangers: Secure by looping and wire tying, either directly to structures or to inserts, eye screws, or other devices and fasteners that are secure and appropriate for substrate, and in a manner that will not cause hangers to deteriorate or otherwise fail.
 - 4. Flat Hangers: Secure to structure, including intermediate framing members, by attaching to inserts, eye screws, or other devices and fasteners that are secure and appropriate for structure and hanger, and in a manner that will not cause hangers to deteriorate or otherwise fail.
 - 5. Do not attach hangers to steel roof deck.
 - 6. Do not attach hangers to permanent metal forms. Furnish cast-in-place hanger inserts that extend through forms.
 - 7. Do not attach hangers to rolled-in hanger tabs of composite steel floor deck.
 - 8. Do not connect or suspend steel framing from ducts, pipes, or conduit.
- D. Fire-Resistance-Rated Assemblies: Wire tie furring channels to supports.

- E. Seismic Bracing: Sway-brace suspension systems with hangers used for support.
- F. Grid Suspension Systems: Attach perimeter wall track or angle where grid suspension systems meet vertical surfaces. Mechanically join main beam and cross-furring members to each other and butt-cut to fit into wall track.
- G. Installation Tolerances: Install suspension systems that are level to within [1/8 inch in 12 feet measured lengthwise on each member that will receive finishes and transversely between parallel members that will receive finishes.

3.5 INSTALLING FRAMED ASSEMBLIES

- A. Where studs are installed directly against exterior masonry walls or dissimilar metals at exterior walls, install isolation strip between studs and exterior wall.
- B. Install studs so flanges within framing system point in same direction.
- C. Install tracks (runners) at floors and overhead supports. Extend framing full height to structural supports or substrates above suspended ceilings, except where partitions are indicated to terminate at suspended ceilings. Continue framing around ducts penetrating partitions above ceiling.
 - 1. Slip-Type Head Joints: Where framing extends to overhead structural supports, install to produce joints at tops of framing systems that prevent axial loading of finished assemblies.
 - 2. Door Openings: Screw vertical studs at jambs to jamb anchor clips on door frames; install runner track section (for cripple studs) at head and secure to jamb studs.
 - a. Install two studs at each jamb, unless otherwise indicated.
 - b. Install cripple studs at head adjacent to each jamb stud, with a minimum 1/2-inch clearance from jamb stud to allow for installation of control joint in finished assembly.
 - c. Extend jamb studs through suspended ceilings and attach to underside of overhead structure.
 - 3. Other Framed Openings: Frame openings other than door openings the same as required for door openings, unless otherwise indicated. Install framing below sills of openings to match framing required above door heads.
 - 4. Fire-Resistance-Rated Partitions: Install framing to comply with fire-resistance-rated assembly indicated and support closures and to make partitions continuous from floor to underside of solid structure.
 - a. Firestop Track: Where indicated, install to maintain continuity of fire-resistance-rated assembly indicated.
 - 5. Sound-Rated Partitions: Install framing to comply with sound-rated assembly indicated.
- D. Direct Furring: Attach to concrete or masonry with stub nails, screws designed for masonry attachment, or powder-driven fasteners spaced 24 inches o.c.
- E. Z-Furring Members:
 - 1. Erect insulation (specified in Section 07210 "Building Insulation") vertically and hold in place with Z-furring members spaced 24 inches o.c.

2. Except at exterior corners, securely attach narrow flanges of furring members to wall with concrete stub nails, screws designed for masonry attachment, or powder-driven fasteners spaced 24 inches o.c.
3. At exterior corners, attach wide flange of furring members to wall with short flange extending beyond corner; on adjacent wall surface, screw-attach short flange of furring channel to web of attached channel. At interior corners, space second member no more than 12 inches from corner and cut insulation to fit.

3.6 APPLYING AND FINISHING PANELS, GENERAL

- A. Comply with ASTM C 840.
- B. Install ceiling panels across framing to minimize the number of abutting end joints and to avoid abutting end joints in central area of each ceiling. Stagger abutting end joints of adjacent panels not less than one framing member.
- C. Install panels with face side out. Butt panels together for a light contact at edges and ends with not more than 1/16 inch of open space between panels. Do not force into place.
- D. Locate edge and end joints over supports, except in ceiling applications where intermediate supports or gypsum board back-blocking is provided behind end joints. Do not place tapered edges against cut edges or ends. Stagger vertical joints on opposite sides of partitions. Do not make joints other than control joints at corners of framed openings.
- E. Form control and expansion joints with space between edges of adjoining gypsum panels.
- F. Cover both faces of support framing with gypsum panels in concealed spaces, above ceilings and similar locations, except in chases braced internally.
 1. Unless concealed application is indicated or required for sound, fire, air, or smoke ratings, coverage may be accomplished with scraps of not less than 8 sq. ft. in area.
 2. Fit gypsum panels around ducts, pipes, and conduits.
 3. Where partitions intersect structural members projecting below underside of floor/roof slabs and decks, cut gypsum panels to fit profile formed by structural members; allow 1/4- to 3/8-inch-wide joints to install sealant.
- G. Isolate perimeter of gypsum board applied to non-load-bearing partitions at structural abutments, except floors. Provide 1/4- to 1/2-inch- wide spaces at these locations, and trim edges with edge trim where edges of panels are exposed. Seal joints between edges and abutting structural surfaces with acoustical sealant.
- H. Attachment to Steel Framing: Attach panels so leading edge or end of each panel is attached to unsupported open edges of stud flanges first.

3.7 APPLYING INTERIOR GYPSUM BOARD

- A. Single-Layer Application:
 1. On ceilings, apply gypsum panels before wall/partition board application to greatest extent possible and at right angles to framing, unless otherwise indicated.
 2. On partitions/walls, apply gypsum panels to minimize end joints.

3. On Z-furring members, apply gypsum panels vertically (parallel to framing) with no end joints. Locate edge joints over furring members.
 4. Fastening Methods: Apply gypsum panels to supports with steel drill screws.
- B. Multilayer Application:
1. On ceilings, apply gypsum board indicated for base layers before applying base layers on walls/partitions; apply face layers in same sequence. Apply base layers at right angles to framing members and offset face-layer joints 1 framing member, 16 inches minimum, from parallel base-layer joints, unless otherwise indicated or required by fire-resistance-rated assembly.
 2. On partitions/walls, apply gypsum board indicated for base layers and face layers vertically (parallel to framing) with joints of base layers located over stud or furring member and face-layer joints offset at least one stud or furring member with base-layer joints, unless otherwise indicated or required by fire-resistance-rated assembly. Stagger joints on opposite sides of partitions.
 3. On Z-furring members, apply base layer vertically (parallel to framing) and face layer either vertically (parallel to framing) or horizontally (perpendicular to framing) with vertical joints offset at least one furring member. Locate edge joints of base layer over furring members.
 4. Fastening Methods: Fasten base layers and face layers separately to supports with screws.
- C. Laminating to Substrate: Where gypsum panels are indicated as directly adhered to a substrate (other than studs, joists, furring members, or base layer of gypsum board), comply with gypsum board manufacturer's written recommendations and temporarily brace or fasten gypsum panels until fastening adhesive has set.

3.8 APPLYING TILE BACKING PANELS

- A. Cementitious Backer Units: ANSI A108.1, at locations indicated to receive tile.
- B. Areas Not Subject to Wetting: Install regular-type gypsum wallboard panels to produce a flat surface except at showers, tubs, and other locations indicated to receive water-resistant panels.
- C. Where tile backing panels abut other types of panels in same plane, shim surfaces to produce a uniform plane across panel surfaces.

3.9 APPLYING GYPSUM SHEATHING

- A. General: Install gypsum sheathing to comply with GA-253 and manufacturer's written instructions.
- B. Cut boards at penetrations, edges, and other obstructions of the work; fit tightly against abutting construction, except provide a 3/8-inch setback where non-load-bearing construction abuts structural elements.
- C. Coordinate sheathing installation with flashing and joint sealant installation so these materials are installed in the sequence and manner that prevent exterior moisture from passing through completed exterior wall assembly.
- D. Apply fasteners so screw heads bear tightly against face of sheathing boards but do not cut into facing.

- E. Do not bridge building expansion joints with sheathing; cut and space edges to match spacing of structural support elements.
- F. Vertical Installation: Install 48-inch- wide gypsum sheathing boards vertically with vertical edges centered over flanges of steel studs. Abut ends and edges of each board with those of adjacent boards. Screw-attach boards at perimeter and within field of board to each steel stud:
 - 1. Perimeter: 6 inches on center.
 - 2. Field: 8 inches on center.

3.10 INSTALLING TRIM ACCESSORIES

- A. General: For trim with back flanges intended for fasteners, attach to framing with same fasteners used for panels. Otherwise, attach trim according to manufacturer's written instructions.
- B. Control Joints: Install control joints according to ASTM C 840 and in specific locations approved by Architect for visual effect.
- C. Interior Trim: Install in the following locations:
 - 1. Cornerbead: Use at outside corners, unless otherwise indicated.
 - 2. LC-Bead: Use at exposed panel edges.
 - 3. Curved-Edge Cornerbead: Use at curved openings.
- D. Exterior Trim: Install in the following locations:
 - 1. Cornerbead: Use at outside corners.
 - 2. LC-Bead: Use at exposed panel edges.
- E. Aluminum Trim: Install in locations indicated on Drawings.

3.11 FINISHING GYPSUM BOARD

- A. General: Treat gypsum board joints, interior angles, edge trim, control joints, penetrations, fastener heads, surface defects, and elsewhere as required to prepare gypsum board surfaces for decoration. Promptly remove residual joint compound from adjacent surfaces.
- B. Prefill open joints, rounded or beveled edges, and damaged surface areas.
- C. Apply joint tape over gypsum board joints, except those with trim having flanges not intended for tape.
- D. Gypsum Board Finish Levels: Finish panels to levels indicated below:
 - 1. Level 1: Ceiling plenum areas, concealed areas, and where indicated.
 - 2. Level 2: Panels that are substrate for tile.
 - 3. Level 4: At panel surfaces that will be exposed to view, unless otherwise indicated.
 - 4. Level 5: Where indicated on Drawings.
- E. Cementitious Backer Units: Finish according to manufacturer's written instructions.

3.12 PROTECTION

- A. Protect installed products from damage from weather, condensation, direct sunlight, construction, and other causes during remainder of the construction period.
- B. Remove and replace panels that are wet, moisture damaged, or exhibit mold growth. Repair of damaged panels in place is not acceptable.
 - 1. Indications that panels are wet or moisture damaged include, but are not limited to, discoloration, sagging, or irregular shape.
 - 2. Indications that panels are mold damaged include, but are not limited to, fuzzy or splotchy surface contamination and discoloration.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09265

GYPSUM BOARD SHAFT WALL ASSEMBLIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies gypsum board shaft wall assemblies.
- B. Related Work:
 - 1. Section 09260 - GYPSUM BOARD ASSEMBLIES for non-shaft-wall gypsum board assemblies, and for applying and finishing panels in gypsum board assemblies.

1.2 DEFINITIONS

- A. Gypsum Board Construction Terminology: Refer to ASTM C 11 for definitions of terms for gypsum board construction not defined in this Section or in other referenced standards.

1.3 PERFORMANCE REQUIREMENTS

- A. Structural Performance:
 - 1. Provide gypsum board shaft wall assemblies capable of withstanding the full air-pressure loads indicated for maximum heights of partitions without failing and while maintaining an airtight and smoke-tight seal. Evidence of failure includes deflections exceeding limits indicated, bending stresses causing studs to break or to distort, and end-reaction shear causing track (runners) to bend or to shear and studs to become crippled.
 - 2. Provide gypsum board shaft wall assemblies for horizontal duct enclosures capable of spanning distances indicated within deflection limits indicated.
- B. Marking and Identification for Fire- and Smoke-Partitions: Fire walls, fire barriers, fire partitions, smoke barriers, smoke partitions and other walls required to have protected openings or penetrations shall be effectively and permanently identified with signs or stenciling. Such identification shall:
 - 1. Be located in accessible concealed floor, floor-ceiling or attic spaces; and
 - 2. Be repeated at intervals not exceeding 30 feet measured horizontally along the wall or partition; and
 - 3. Include lettering not less than 0.5 inch in height, incorporating the suggested wording: "FIRE AND/OR SMOKE BARRIER-PROTECT ALL OPENINGS," or other wording.

1.4 SUBMITTALS

- A. Product Data: For each gypsum board shaft wall assembly indicated.
- B. Fire-Test-Response Reports: From a qualified independent testing and inspecting agency substantiating each gypsum board shaft wall assembly's required fire-resistance rating.
 - 1. Include data substantiating that elevator entrances and other items that penetrate each gypsum board shaft wall assembly do not negate fire-resistance rating.

1.5 QUALITY ASSURANCE

- A. Fire-Resistance-Rated Assemblies: Provide materials and construction identical to those tested in assembly indicated according to ASTM E 119 by an independent testing and inspecting agency acceptable to authorities having jurisdiction.
 - 1. Fire-Resistance-Rated Assemblies: Indicated by design designations from FM's "Approval Guide, Building Products," UL's "Fire Resistance Directory," or ITS's "Directory of Listed Products."
- B. STC-Rated Assemblies: For gypsum board shaft wall assemblies indicated to have STC ratings, provide assembly materials and construction complying with requirements of assemblies whose STC ratings were determined according to ASTM E 90 and classified according to ASTM E 413 by a qualified independent testing agency.
- C. Preinstallation Conference: Conduct conference at Project site to comply with requirements of Division 01. Review methods and procedures for installing work related to gypsum board shaft wall assemblies including, but not limited to, the following:
 - 1. Fasteners proposed for anchoring steel framing to building structure.
 - 2. Sprayed fire-resistive materials applied to structural framing.
 - 3. Elevator equipment, including hoistway doors, elevator call buttons, and elevator floor indicators.
 - 4. Wiring devices in shaft wall assemblies.
 - 5. Doors and other items penetrating shaft wall assemblies.
 - 6. Items supported by shaft wall-assembly framing.
 - 7. Mechanical work enclosed within shaft wall assemblies.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials in original packages, containers, and bundles bearing brand name and identification of manufacturer or supplier.
- B. Store materials inside under cover and keep them dry and protected against damage from weather, direct sunlight, surface contamination, corrosion, construction traffic, and other causes. Stack gypsum panels flat on leveled supports off the ground to prevent sagging.

1.7 PROJECT CONDITIONS

- A. Comply with requirements for environmental conditions, room temperatures, and ventilation specified in Section 092110 - GYPSUM BOARD ASSEMBLIES.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. American Gypsum Co.
 - 2. G-P Gypsum Corp.

3. National Gypsum Company.
4. United States Gypsum Co.

2.2 ASSEMBLY MATERIALS

- A. General: Provide materials and components complying with requirements of fire-resistance-rated assemblies indicated.
 1. Provide panels in maximum lengths available to eliminate or minimize end-to-end butt joints.
 2. Provide auxiliary materials complying with gypsum board shaft wall assembly manufacturer's written recommendations.
- B. Steel Framing: ASTM C 645.
 1. Protective Coating: ASTM A 653/A 653M, G40, hot-dip galvanized coating.
- C. Gypsum Liner Panels: Manufacturer's proprietary liner panels in 1-inch thickness and with moisture-resistant paper faces.
- D. Gypsum Wallboard: ASTM C 1396, core type as required by fire-resistance-rated assembly indicated.
- E. Accessories: Cornerbead, edge trim, and control joints of material and shapes specified in Section 09260 - GYPSUM BOARD ASSEMBLIES comply with gypsum board shaft wall assembly manufacturer's written recommendations for application indicated.
- F. Gypsum Wallboard Joint-Treatment Materials: ASTM C 475 and as specified in Section 09260 - GYPSUM BOARD ASSEMBLIES.
- G. Steel Drill Screws: ASTM C 1002, unless otherwise indicated.
- H. Track (Runner) Fasteners: Power-driven fasteners of size and material required to withstand loading conditions imposed on shaft wall assemblies without exceeding allowable design stress of track, fasteners, or structural substrates in which anchors are embedded.
 1. Powder-Actuated Fasteners: Provide powder-actuated fasteners with capability to sustain, without failure, a load equal to 10 times that imposed by shaft wall assemblies, as determined by testing conducted by a qualified independent testing agency according to ASTM E 1190.
 2. Postinstalled Expansion Anchors: Where indicated, provide expansion anchors with capability to sustain, without failure, a load equal to 5 times that imposed by shaft wall assemblies, as determined by testing conducted by a qualified independent testing agency according to ASTM E 488.
- I. Laminating Adhesive: Adhesive or joint compound recommended by manufacturer for directly adhering gypsum face-layer panels and gypsum-base face-layer panels to backing-layer panels in multilayer construction.
- J. Acoustical Sealant: As recommended by gypsum board shaft wall assembly manufacturer for application indicated.

- K. Sound Attenuation Blankets: ASTM C 665 for Type I, unfaced mineral-fiber-blanket insulation produced by combining thermosetting resins with mineral fibers manufactured from slag or rock wool.

2.3 GYPSUM BOARD SHAFT WALL

- A. Basis-of-Design Product: As indicated on Drawings by design designation of a qualified testing and inspecting agency.
- B. Sustained Air-Pressure Loads: 5 lbf/sq. ft.
- C. Deflection Limit: L/240.
- D. Studs: Manufacturer's standard profile for repetitive members and corner and end members and for fire-resistance-rated assembly indicated.
 - 1. Depth: As indicated.
 - 2. Minimum Base Metal Thickness: Manufacturer's standard thicknesses that comply with structural performance requirements for stud depth indicated.
- E. Track (Runner): Manufacturer's standard J-profile track with long-leg length as standard with manufacturer, but at least 2 inches in depth matching studs.
 - 1. Minimum Base Metal Thickness: Manufacturer's standard thicknesses that comply with structural performance requirements for stud depth indicated.
- F. Jamb Struts: Manufacturer's standard J-profile strut with long-leg length of 3 inches, in depth matching studs, and not less than 0.0341 inch thick.
- G. Room-Side and Shaft-Side Finish: As indicated.
- H. STC Rating: As indicated.
- I. Cavity Insulation: Sound attenuation blankets.

2.4 IDENTIFICATION LABELS FOR FIRE- AND SMOKE-PARTITIONS

- A. Identification Labels: Vinyl adhesive signs, to comply with applicable local Code.
 - 1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire Wall Signs, Inc.
 - b. My Safety Sign.
 - c. Safety Supply Warehouse.
 - 2. Text: "FIRE AND SMOKE BARRIER-PROTECT ALL OPENINGS"

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates to which gypsum board shaft wall assemblies attach or abut, with Installer present, including hollow-metal frames, elevator hoistway doorframes, cast-in anchors, and structural framing.

Examine for compliance with requirements for installation tolerances and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Sprayed Fire-Resistive Materials: Coordinate with gypsum shaft wall assemblies so both elements of Work remain complete and undamaged. Patch or replace sprayed fire-resistive materials removed or damaged during installation of shaft wall assemblies to comply with requirements specified in Section 078100 - APPLIED FIREPROOFING.

1. Before sprayed fire-resistive materials are applied, attach offset anchor plates or ceiling runners (tracks) to surfaces indicated to receive sprayed fire-resistive materials. Where offset anchor plates are required, provide continuous plates fastened to building structure not more than 24 inches o.c.

2. After sprayed fire-resistive materials are applied, remove them only to extent necessary for installation of gypsum board assemblies and without reducing the fire-resistive material thickness below that which is required to obtain fire-resistance rating indicated. Protect remaining fire-resistive materials from damage.

3.3 INSTALLATION

- A. General: Install gypsum board shaft wall assemblies to comply with requirements of fire-resistance-rated assemblies indicated, manufacturer's written installation instructions, and the following:

1. ASTM C 754 for installing steel framing and gypsum shaft wallboard.

- B. Do not bridge building expansion joints with shaft wall assemblies; frame both sides of joints with furring and other support.

- C. Install supplementary framing in gypsum board shaft wall assemblies around openings and as required for blocking, bracing, and support of gravity and pullout loads of fixtures, equipment, services, heavy trim, furnishings, and similar items that cannot be supported directly by shaft wall assembly framing.

1. At elevator hoistway doorframes, provide jamb struts on each side of doorframe.

2. Where handrails directly attach to gypsum board shaft wall assemblies, provide galvanized steel reinforcing strip with 0.0312-inch minimum thickness of base (uncoated) metal, accurately positioned and secured behind at least 1 face-layer panel.

- D. Integrate stair hanger rods with gypsum board shaft wall assemblies by locating cavity of assemblies where required to enclose rods.

- E. At penetrations in shaft wall, maintain fire-resistance rating of shaft wall assembly by installing supplementary steel framing around perimeter of penetration and fire protection behind boxes containing wiring devices, elevator call buttons, elevator floor indicators, and similar items.
- F. Isolate gypsum finish panels from building structure to prevent cracking of finish panels while maintaining continuity of fire-rated construction.
- G. Install control joints to maintain fire-resistance rating of assemblies.
- H. Seal gypsum board shaft walls with acoustical sealant at perimeter of each assembly where it abuts other work and at joints and penetrations within each assembly. Install acoustical sealant to withstand dislocation by air-pressure differential between shaft and external spaces; maintain an airtight and smoke-tight seal; and comply with manufacturer's written instructions or ASTM C 919, whichever is more stringent.
- I. In elevator shafts where gypsum board shaft wall assemblies cannot be positioned within 2 inches of the shaft face of structural beams, floor edges, and similar projections into shaft, install 1/2- or 5/8- inch- thick, gypsum board cants covering tops of projections.
 - 1. Slope cant panels at least 75 degrees from horizontal. Set base edge of panels in adhesive and secure top edges to shaft walls at 24 inches o.c. with screws fastened to shaft wall framing.
 - 2. Where steel framing is required to support gypsum board cants, install framing at 24 inches o.c. and extend studs from the projection to the shaft wall framing.

3.4 FINISHING GYPSUM BOARD SHAFT WALL ASSEMBLIES

- A. General: Treat gypsum board joints, interior angles, edge trim, control joints, penetrations, fastener heads, surface defects, and elsewhere as required to prepare gypsum board surfaces for decoration. Promptly remove residual joint compound from adjacent surfaces.
- B. Prefill open joints, rounded or beveled edges, and damaged surface areas.
- C. Apply joint tape over gypsum board joints, except those with trim having flanges not intended for tape.
- D. Gypsum Board Finish Levels: Finish panels to levels indicated below:
 - 1. Level 1: Ceiling plenum areas and concealed areas not exposed to view.
 - 2. Level 2: Panels that are substrate for tile.
 - 3. Level 4: Panel surfaces that will be exposed to view (typical panels).
 - 4. Level 5: Where indicated on Drawings.

3.5 INSTALLING IDENTIFICATION FOR FIRE- AND SMOKE-PARTITIONS

- A. Marking and Identification for Fire- and Smoke-Partitions: Permanently install as required by Code.

3.6 PROTECTION

- A. Protect installed products from damage from weather, condensation, direct sunlight, construction, and other causes during remainder of the construction period.

- B. Remove and replace panels that are wet, moisture damaged, or exhibit mold growth. Repair of damaged panels in place is not acceptable.
 - 1. Indications that panels are wet or moisture damaged include, but are not limited to, discoloration, sagging, or irregular shape.
 - 2. Indications that panels are mold damaged include, but are not limited to, fuzzy or splotchy surface contamination and discoloration.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09281

CEMENT BOARD

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies decorative cement board.
- B. Related Work:
 - 1. Section 06100 – CARPENTRY.
 - 2. Section 09260 – GYPSUM BOARD ASSEMBLIES for tile backer units related requirements.

1.2 SUBMITTALS

- A. Product Data: For each type of process and factory-fabricated product. Indicate component materials and dimensions and include construction and application details.

1.3 QUALITY ASSURANCE

- A. Testing Agency Qualifications: For testing agency providing classification marking for fire-retardant-treated material, an inspection agency acceptable to authorities having jurisdiction that periodically performs inspections to verify that the material bearing the classification marking is representative of the material tested.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Stack panels flat with spacers beneath and between each bundle to provide air circulation. Protect cement board from weather by covering with waterproof sheeting, securely anchored. Provide for air circulation around stacks and under coverings.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Fire-Test-Response Characteristics: For assemblies with fire-resistance ratings, provide materials and construction identical to those of assemblies tested for fire resistance per ASTM E 119 by a testing and inspecting agency acceptable to authorities having jurisdiction.
 - 1. Fire-Resistance Ratings: Indicated by design designations from UL's "Fire Resistance Directory."

2.2 CEMENT BOARD

A. Decorative Cement Board:

1. Basis-of-Design: Geoboard Décor, Ameriform LLC, or approved equal.
2. Thickness: 5/8" (16 mm), minimum

2.3 FASTENERS

A. General: Provide fasteners of size and type indicated that comply with requirements specified in this article for material and manufacture.

1. Provide fasteners with hot-dip zinc coating complying with ASTM A 153/A 153M.

B. Nails, Brads, and Staples: ASTM F 1667.

C. Power-Driven Fasteners: NES NER-272.

D. Screws for Fastening Board to Cold-Formed Metal Framing: Steel drill screws, in length recommended by sheathing manufacturer for thickness of sheathing to be attached, with organic-polymer or other corrosion-protective coating having a salt-spray resistance of more than 800 hours according to ASTM B 117.

1. For steel framing less than 0.0329 inch (0.835 mm) thick, use screws that comply with ASTM C 1002.

PART 3 - EXECUTION

3.1 INSTALLATION, GENERAL

A. Do not use materials with defects that impair quality of cement board or pieces that are too small to use with minimum number of joints or optimum joint arrangement. Arrange joints so that pieces do not span between fewer than three support members.

B. Cut panels at penetrations, edges, and other obstructions of work; fit tightly against abutting construction unless otherwise indicated.

C. Securely attach to substrate by fastening as indicated, complying with the following:

1. NES NER-272 for power-driven fasteners.
2. Table 2304.9.1, "Fastening Schedule," in ICC's "International Building Code."

D. Coordinate wall board installation with joint-sealant installation so these materials are installed in sequence and manner that prevent moisture from passing through completed assembly. Do not bridge building expansion joints; cut and space edges of panels to match spacing of structural support elements.

3.2 CEMENT BOARD INSTALLATION

- A. Install panels and treat joints according to ANSI A108.11 and manufacturer's written instructions for type of application indicated.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09300

TILE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Wall tile, floor tile and base.
 - 2. Waterproof membrane for thin-set tile installations.
 - 3. Surface preparation for tile and accessories.
 - 4. Installation of access doors in gypsum board assemblies, furnished under mechanical and electrical sections.

- B. Related Work:
 - 1. Section 01420 – MOCK-UPS
 - 2. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 - 3. Section 07920 - JOINT SEALANTS; sealing of expansion, contraction, control, and isolation joints in tile surfaces.
 - 4. Section 09260 – GYPSUM BOARD ASSEMBLIES; cementitious backer units.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.

- B. Shop Drawings: Show locations of each type of tile and tile pattern. Show widths, details, and locations of expansion, contraction, control, and isolation joints in tile substrates and finished tile surfaces.

- C. Samples for Verification:
 - 1. Assembled samples with grouted joints for each type and composition of tile and for each color and finish required, at least 12 inches square and mounted on rigid panel. Use grout of type and in color or colors approved for completed work. Include sealant specified in Section 07920 - JOINT SEALANTS, in color approved for completed work.
 - 2. Full-size units of each type of trim and accessory for each color and finish required.

- D. Qualification Data: For Installer.

- E. Material Test Reports: For each tile-setting and -grouting product.

- F. Installation Bonding Report: Including dates sounding test performed and remedial action taken.

- G. Mock-ups: Provide up to one full-size 48"x48" area in-place mock-up for each tile type. Locations as determined by the Engineer/ Architect. Build mock-ups to comply with the specified requirements, using materials indicated for final unit of work. Approved mock-ups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.3 QUALITY ASSURANCE

- A. Source Limitations for Tile: Obtain all tile of same type and color or finish from one source or producer.
 - 1. Obtain tile from same production run and of consistent quality in appearance and physical properties for each contiguous area.
- B. Source Limitations for Setting and Grouting Materials: Obtain ingredients of a uniform quality for each mortar, adhesive, and grout component from a single manufacturer and each aggregate from one source or producer.
- C. Source Limitations for Other Products: Obtain each of the following products specified in this Section through one source from a single manufacturer for each product:
 - 1. Waterproofing.
 - 2. Joint sealants.
 - 3. Cementitious backer units.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Deliver and store packaged materials in original containers with seals unbroken and labels intact until time of use. Comply with requirement in ANSI A137.1 for labeling sealed tile packages.
- B. Store tile and cementitious materials on elevated platforms, under cover, and in a dry location.
- C. Store aggregates where grading and other required characteristics can be maintained and contamination avoided.
- D. Store liquid additives in unopened containers and protected from freezing.

1.5 PROJECT CONDITIONS

- A. Environmental Limitations: Do not install tile until construction in spaces is complete and ambient temperature and humidity conditions are maintained at the levels indicated in referenced standards and manufacturer's written instructions.

PART 2 - PRODUCTS

2.1 TILE GENERAL

- A. Wall Tile and Installation: Thin-set mortar on cementitious backer units; TCA W244.
 - 1. Tile Type: Rittenhouse Square, Price Group 3 Color, by Daltile or equal by American Olean or Summitville, nominal 3 by 6 by 5/16 inch nominal field tile size, with matching bullnose and cove base, color as selected by Architect.
 - 2. Thin-Set Mortar: Latex- portland cement mortar.
 - 3. Grout: Polymer-modified sanded.

- B. Floor Tile and Installation: Floor installation on concrete; thin-set mortar; TCA F113 on-ground and ANSI A108.5.
 - 1. Tile Type: Colorbody Porcelain Mosaic, Price Group 4 Color, by Daltile or equal by American Olean or Summitville, nominal 2 by 1 by 1/4 inch oblong (brickwork), color as selected by Architect.
 - 2. Thin-Set Mortar: Latex-portland cement mortar.
 - 3. Grout: Polymer-modified unsanded grout.
 - 4. Joint Width: 1/16 inch.

2.2 PRODUCTS, GENERAL

- A. ANSI Ceramic Tile Standard: Provide tile that complies with ANSI A137.1, "Specifications for Ceramic Tile," for types, compositions, and other characteristics indicated.
 - 1. Provide tile complying with Standard grade requirements, unless otherwise indicated.
- B. ANSI Standards for Tile Installation Materials: Provide materials complying with ANSI standards referenced in this Section.
- C. Factory Blending: For tile exhibiting color variations within ranges selected during Sample submittals, blend tile in factory and package so tile units taken from one package show same range in colors as those taken from other packages and match approved Samples.
- D. Mounting: For factory-mounted tile, provide back- or edge-mounted tile assemblies as standard with manufacturer, unless otherwise indicated.
- E. Tile Trim Units: Matching characteristics of adjoining flat tile and coordinated with sizes and coursing of adjoining flat tile where applicable. Provide shapes selected from manufacturer's standard shapes.
- F. Waterproofing: Manufacturer's standard product that complies with ANSI A118.10.
- G. Trowelable Underlayments and Patching Compounds: Latex-modified, Portland cement-based formulation provided or approved by manufacturer of tile-setting materials for installations indicated.
- H. Tile Cleaner: A neutral cleaner capable of removing soil and residue without harming tile and grout surfaces, specifically approved for materials and installations indicated by tile and grout manufacturers.

2.3 ELASTOMERIC SEALANTS

- A. General: Provide manufacturer's standard chemically curing, elastomeric sealants of base polymer and characteristics indicated that comply with applicable requirements in Section 07920 - JOINT SEALANTS.
- B. Colors: Provide colors of exposed sealants to match colors of grout in tile adjoining sealed joints, unless otherwise indicated.
- C. One-Part, Mildew-Resistant Silicone Sealant: ASTM C 920; Type S; Grade NS; Class 25; Uses NT, G, A, and, as applicable to nonporous joint substrates indicated, O; formulated with fungicide,

intended for sealing interior ceramic tile joints and other nonporous substrates that are subject to in-service exposures of high humidity and extreme temperatures.

1. Available Products or equal:

- a. Dow Corning Corporation; Dow Corning 786.
- b. GE Silicones; Sanitary 1700.
- c. Pecora Corporation; Pecora 898 Sanitary Silicone Sealant.
- d. Tremco, Inc.; Tremsil 600 White.

D. Multipart, Pourable Urethane Sealant for Use T: ASTM C 920; Type M; Grade P; Class 25; Uses T, M, A, and, as applicable to joint substrates indicated, O.

1. Available Products or equal:

- a. Bostik; Chem-Calk 550.
- b. Mameco International, Inc.; Vulkem 245.
- c. Pecora Corporation; NR-200 Urexpan.
- d. Tremco, Inc.; THC-900.

2.4 MIXING MORTARS AND GROUT

- A. Mix mortars and grouts to comply with referenced standards, compressive strength requirements and mortar and grout manufacturers' written instructions.
- B. Add materials, water, and additives in accurate proportions.
- C. Obtain and use type of mixing equipment, mixer speeds, mixing containers, mixing time, and other procedures to produce mortars and grouts of uniform quality with optimum performance characteristics for installations indicated.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions where tile will be installed, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of installed tile.
 1. Verify that substrates for setting tile are firm; dry; clean; free of oil, waxy films, and curing compounds; and within flatness tolerances required by referenced ANSI A108 Series of tile installation standards for installations indicated.
 2. Verify that installation of grounds, anchors, recessed frames, electrical and mechanical units of work, and similar items located in or behind tile has been completed before installing tile.
 3. Verify that joints and cracks in tile substrates are coordinated with tile joint locations; if not coordinated, adjust joint locations in consultation with Engineer.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Remove coatings, including curing compounds and other substances that contain soap, wax, oil, or silicone, that are incompatible with tile-setting materials.
- B. Provide concrete substrates for tile floors that comply with flatness tolerances specified in referenced ANSI A108 Series of tile installation standards.
 - 1. Fill cracks, holes, and depressions with trowelable leveling and patching compound according to tile-setting material manufacturer's written instructions. Use product specifically recommended by tile-setting material manufacturer.
 - 2. Remove protrusions, bumps, and ridges by sanding or grinding.
- C. Blending: For tile exhibiting color variations within ranges selected during Sample submittals, verify that tile has been factory blended and packaged so tile units taken from one package show same range of colors as those taken from other packages and match approved Samples. If not factory blended, either return to manufacturer or blend tiles at Project site before installing.

3.3 INSTALLATION, GENERAL

- A. ANSI Tile Installation Standards: Comply with parts of ANSI A108 Series "Specifications for Installation of Ceramic Tile" that apply to types of setting and grouting materials, to methods indicated in ceramic tile installation schedules, and resistance to deleterious substances.
- B. TCA Installation Guidelines: TCA's "Handbook for Ceramic Tile Installation." Comply with TCA installation methods indicated in ceramic tile installation schedules.
- C. Extend tile work into recesses and under or behind equipment and fixtures to form complete covering without interruptions, unless otherwise indicated. Terminate work neatly at obstructions, edges, and corners without disrupting pattern or joint alignments.
- D. Accurately form intersections and returns. Perform cutting and drilling of tile without marring visible surfaces. Carefully grind cut edges of tile abutting trim, finish, or built-in items for straight aligned joints. Fit tile closely to electrical outlets, piping, fixtures, and other penetrations so plates, collars, or covers overlap tile.
- E. Jointing Pattern: Lay tile in grid pattern, unless otherwise indicated. Align joints when adjoining tiles on floor, base, walls, and trim are same size. Lay out tile work and center tile fields in both directions in each space or on each wall area. Adjust to minimize tile cutting. Provide uniform joint widths, unless otherwise indicated.
 - 1. For tile mounted in sheets, make joints between tile sheets same width as joints within tile sheets so joints between sheets are not apparent in finished work.
- F. Lay out tile wainscots to next full tile beyond dimensions indicated.
- G. Expansion Joints: Locate expansion joints and other sealant-filled joints, including control, contraction, and isolation joints, where indicated during installation of setting materials, mortar beds, and tile. Do not saw-cut joints after installing tiles.
 - 1. Locate joints in tile surfaces directly above joints in concrete substrates.

2. Prepare joints and apply sealants to comply with requirements in Section 07920 - JOINT SEALANTS.
- H. Grout tile to comply with requirements of the following tile installation standards:
1. For ceramic tile grouts (sand-Portland cement; dry-set, commercial Portland cement; and latex-Portland cement grouts), comply with ANSI A108.10.
- I. At showers and where indicated, install cementitious backer units and treat joints to comply with ANSI A108.11 and manufacturer's written instructions for type of application indicated.

3.4 WATERPROOFING MEMBRANE INSTALLATION

- A. Install waterproofing to comply with ANSI A108.13 and waterproofing manufacturer's written instructions to produce waterproof membrane of uniform thickness bonded securely to substrate.
- B. Do not install tile over waterproofing until waterproofing has cured and been tested to determine that it is watertight.

3.5 WALL TILE INSTALLATION

- A. Install types of tile designated for wall installations to comply with requirements in the Wall Tile Installation Schedule, including those referencing TCA installation methods and ANSI setting-bed standards.

3.6 CLEANING AND PROTECTING

- A. Cleaning: On completion of placement and grouting, clean all ceramic tile surfaces so they are free of foreign matter.
 1. Remove grout residue from tile as soon as possible.
 2. Clean grout smears and haze from tile according to tile and grout manufacturer's written instructions, but no sooner than 10 days after installation. Use only cleaners recommended by tile and grout manufacturers and only after determining that cleaners are safe to use by testing on samples of tile and other surfaces to be cleaned. Protect metal surfaces and plumbing fixtures from effects of cleaning. Flush surfaces with clean water before and after cleaning.
 3. Remove temporary protective coating by method recommended by coating manufacturer that is acceptable to tile and grout manufacturer. Trap and remove coating to prevent it from clogging drains.
- B. When recommended by tile manufacturer, apply coat of neutral protective cleaner to completed tile walls and floors. Protect installed tile work with kraft paper or other heavy covering during construction period to prevent staining, damage, and wear.
- C. Prohibit foot and wheel traffic from tiled floors for at least seven days after grouting is completed. After seven days, cover areas subject to construction traffic with heavy cardboard.
- D. Before final inspection, remove protective coverings and rinse neutral cleaner from tile surfaces.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09510

ACOUSTICAL CEILINGS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies acoustical ceiling systems including suspension systems.
- B. Related Work:
 - 1. Division 15 - MECHANICAL; sprinklers, grilles, and diffusers located in ceilings.
 - 2. Division 16 - ELECTRICAL; light fixtures and alarm system components located in ceilings.

1.2 QUALITY ASSURANCE

- A. Source: For each type of material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.

1.3 TESTS

- A. Fire-Resistance: Where fire-resistance ratings are indicated or required by authorities having jurisdiction, provide materials and construction which are identical to assemblies whose fire-resistance rating has been tested in compliance with ASTM E119 by independent agencies acceptable to the Engineer and authorities having jurisdiction.
- B. Burning Characteristics: Provide materials whose surface burning characteristics, when tested in compliance with ASTM E84 are Class A or Class 1.

1.4 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material used. Provide certifications stating that materials comply with requirements.
- B. Initial Selection Samples: Submit samples showing complete range of colors, textures, and finishes available for each material used.
- C. Verification Samples: Submit representative samples of each material that is to be exposed in the finished work, showing the full range of color and finish variations expected. Provide samples having minimum area of 144 square inches.
- D. Test Reports: Submit certified reports for tests required.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Deliver materials and products in unopened factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from damage, moisture and direct sunlight. Sequence deliveries to avoid delays, but minimize on-site storage.

1.6 PROJECT CONDITIONS, SEQUENCING AND SCHEDULING

- A. Environment: Perform work only when conditions are within the limits established by manufacturers of the materials and products used.
- B. Conference: Convene a pre-installation conference to establish procedures to maintain optimum working conditions and to coordinate this work with related and adjacent work.
 - 1. Proceed with installation of ceiling tiles and panels only when construction above ceilings and penetrating work is complete. Delay installation of ceiling tiles or panels until near time of Substantial Completion.
 - 2. Perform work of this section to coordinate with the layout of light fixtures, HVAC equipment and fixtures, fire suppression system components and all other related work. In general, every penetration shall occur at the center of a ceiling tile or panel.

PART 2 - PRODUCTS

2.1 MATERIALS AND PRODUCTS

- A. Interior Ceiling Panels: Provide ceiling panels as follows:
 - 1. Interior Ceiling Panels Type I: Provide units with NRC, color and texture equal to Armstrong Beveled Tegular Cirrus, 24 in. x 24 in. x 3/4 in. lay-in, #589 (non-rated) and Armstrong Beveled Tegular Cirrus, 24" x 24" x 3/4 in. #577 (at rated conditions); for narrow 9/16 in. grid, or equal by USG or Celotex Corp.
- B. Suspension Systems: Provide suspension systems complying with requirements of ASTM C635.
 - 1. Suspension System Type I -Provide manufacturers narrow exposed "Tee", commercial quality cold-rolled, electro-galvanized steel grid system, equal to Armstrong 9/16 in. Suprafine, complying with ASTM C 635 for "Intermediate-Duty System" or equal by USG or Celotex Corp. Provide grid modules to match ceiling panel sizes. Provide manufacturer's standard white baked enamel finish on steel exposed surfaces. Grid and ceiling panels shall be manufactured by the same company.
- C. Attachment Devices: Provide and size for 5 times design load indicated in ASTM C635, Table 1, direct hung.
- D. Hanger Wire: ASTM A641, galvanized steel wire, soft temper, prestretched, class 1 coating, minimum 12 gage. Size wire so that stress at three times hanger design load given in ASTM C635, Table 1, Direct Hung, will be less than the yield stress of the wire.
- E. Moldings and Trim: Provide manufacturer's standard profiles to suit edge conditions, panel profile and penetrations. Provide custom fabricated work as necessary to provide exact fit.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The Installer shall examine substrates, supports, and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.

3.2 PREPARATION AND INSTALLATION

- A. General Requirement: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.
- B. Coordination: Coordinate installation with other work to ensure proper location of related work such as light fixtures, mechanical fixtures, fire protection systems and the like.
- C. Layout: Refer to drawings for layout and patterns of ceiling tiles.
- D. Suspension Installation: Erect suspension system to comply with ASTM C636 and supported only from building structure. Level main suspension members to within tolerance of 1/8" in 12'. Splay hangers where necessary and countersplay to balance resulting horizontal forces. Cross brace suspension to prevent lateral sway and displacement during full seismic load prescribed by code.
- E. Edge Moldings and Trim: Provide edge moldings at entire perimeter of ceiling, at columns, and wherever necessary to conceal edges of acoustical units. Miter corners of edge moldings accurately and connect securely, but do not use exposed fasteners nor pop rivets.
 - 1. Sealing: Provide a continuous bead of exposed acoustical sealant, specified in Section 07920 - JOINT SEALANTS, between edge moldings and walls.
- F. Ceiling Panel Installation: Use clean white gloves when handling ceiling materials. Install ceiling panels in coordination with suspension system. Scribe and cut panels to fit accurately.
 - 1. Orientation: Lay panels with grain running in one direction throughout the project.

3.3 ADJUSTING, TOUCH-UP AND CLEANING

- A. Adjust panels so that ceilings are in one plane and look uniform with no individual panels too high or too low.
- B. Touch-up damaged suspension system coatings and finishes and repair minor damage to eliminate all evidence of repair. Remove and replace work which cannot be satisfactorily repaired.
- C. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully cleaned.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09650
RESILIENT FLOORS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following item.
 - 1. Rubber floor tile.
 - 2. Vinyl composition tile.
 - 3. Resilient wall base and accessories.
 - 4. Resilient stair accessories.
 - 5. Substrate preparation for resilient flooring and accessories.

- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03300 - CAST-IN-PLACE CONCRETE: Concrete substrate.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Samples for Verification: Full-size units of each color and pattern of resilient floor tile required.
 - 1. Resilient Wall Base and Accessories: Manufacturer's standard-size Samples, but not less than 12 inches long, of each resilient product color and pattern required.
- C. Maintenance Data: For resilient products to include in maintenance manuals.

1.3 QUALITY ASSURANCE

- A. Fire-Test-Response Characteristics: Provide products identical to those tested for fire-exposure behavior per test method indicated. Tests to be performed by a testing and inspecting agency acceptable to authorities having jurisdiction.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Store resilient products and installation materials in dry spaces protected from the weather, with ambient temperatures maintained within range recommended by manufacturer, but not less than 50 deg F or more than 90 deg F. Store tiles on flat surfaces.

1.5 PROJECT CONDITIONS

- A. Maintain temperatures within range recommended by manufacturer, but not less than 70 deg F or more than 95 deg F in spaces to receive floor tile during the following time periods:
 - 1. 48 hours before installation.
 - 2. During installation.
 - 3. 48 hours after installation.
- B. After postinstallation period, maintain temperatures within range recommended by manufacturer, but not less than 55 deg F or more than 95 deg F.
- C. Close spaces to traffic during floor covering installation.
- D. Close spaces to traffic for 48 hours after floor covering installation.
- E. Install resilient products after other finishing operations, including painting, have been completed.

PART 2 - PRODUCTS

2.1 RUBBER FLOOR TILE

- A. Rubber Floor Tile: ASTM F 1344.
 - 1. Endura
 - 2. Johnsonite
 - 3. Mondo Rubber International, Inc.
 - 4. Nora Rubber Flooring, Freudenberg Building Systems, Inc.
- B. Style and Colors: As selected by Engineer.
- C. Thickness: 0.125 inch.
- D. Size: 24 by 24 inches nominal.

2.2 VINYL COMPOSITION TILE

- A. Vinyl Composition Tile (VCT): ASTM F 1066.
 - 1. Armstrong World Industries, Inc.
 - 2. Azrock Commercial Flooring, DOMCO
 - 3. Congoleum Corporation
 - 4. Tarkett Inc.
- B. Style and Colors: As selected by Engineer.
- C. Thickness: 0.125 inch.
- D. Size: 12 by 12 inches.

2.3 RESILIENT WALL BASE

- A. Wall Base: ASTM F 1861.
 - 1. Armstrong World Industries, Inc.
 - 2. Burke Mercer Flooring Products
 - 3. Johnsonite
 - 4. Nora Rubber Flooring, Freudenberg Building Systems, Inc.
 - 5. Roppe Corporation
- B. Style and Colors: As selected by Engineer.
- C. Type (Material Requirement): TS (rubber, vulcanized thermoset) or TP (rubber, thermoplastic).
- D. Shape: Straight (toeless) at carpet and coved at resilient flooring.
- E. Minimum Thickness: 0.125 inch.
- F. Height: 4 inches.
- G. Lengths: Cut lengths 48 inches long or coils in manufacturer's standard length].
- H. Outside Corners: Premolded.
- I. Inside Corners: Premolded.
- J. Surface: Smooth.

2.4 RESILIENT STAIR ACCESSORIES

- A. Treads and Risers: ASTM F 2169.
 - 1. Burke Flooring Products.
 - 2. Johnsonite, a division of Tarkett.
 - 3. Mondo Rubber International, Inc.
 - 4. Nora Systems, Inc.
 - 5. Roppe Corporation.
- B. Style and Colors: As indicated on the Finish Legend.
- C. Material: Rubber, Composition A.
- D. Size: Lengths and depths to fit each stair tread in one piece.
- E. Stringers: Of same thickness as risers, height and length after cutting to fit risers and treads and to cover stair stringers; produced by same manufacturer as treads and recommended by manufacturer for installation with treads.

2.5 RESILIENT MOLDING ACCESSORY

- A. Types Include the Following As Applicable: Cap for cove carpet, cap for cove resilient sheet floor covering, carpet edge for glue-down applications, nosing for carpet, nosing for resilient floor covering, reducer strip for resilient floor covering, joiner for tile and carpet
 - 1. Burke Mercer Flooring Products
 - 2. Johnsonite
 - 3. Marley Flexco (USA), Inc
 - 4. Roppe Corporation
- B. Material: Rubber.
- C. Profile and Dimensions: As indicated.

2.6 INSTALLATION MATERIALS

- A. Trowelable Leveling and Patching Compounds: Latex-modified, portland cement based or blended hydraulic cement based formulation provided or approved by resilient product manufacturer for applications indicated.
- B. Adhesives: Water-resistant type recommended by manufacturer to suit resilient products and substrate conditions indicated.
 - 1. Use adhesives that comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24):
 - a. VCT and Asphalt Tile Adhesives: 50 g/L.
 - b. Cove Base Adhesives: 50 g/L.
 - c. Rubber Floor Adhesives: 60 g/L.
- C. Stair-Tread-Nose Filler: Two-part epoxy compound recommended by resilient tread manufacturer to fill nosing substrates that do not conform to tread contours.
- D. Metal Edge Strips: Extruded aluminum with mill finish of width shown, of height required to protect exposed edges of tiles, and in maximum available lengths to minimize running joints.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, with Installer present, for compliance with requirements for installation tolerances, concrete curing progress, moisture content, and other conditions affecting performance.
 - 1. Verify that finishes of substrates comply with tolerances and other requirements specified in other Sections and that substrates are free of cracks, ridges, depressions, scale, and foreign deposits that might interfere with adhesion of resilient products.
 - 2. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Prepare substrates according to manufacturer's written recommendations to ensure adhesion of resilient products.
- B. Concrete Substrates: Prepare according to ASTM F 710.
 - 1. Verify that substrates are dry and free of curing compounds, sealers, and hardeners.
 - 2. Alkalinity and Adhesion Testing: Perform tests recommended by manufacturer. Proceed with installation only after substrates pass testing.
 - 3. Moisture Testing:
 - a. Perform anhydrous calcium chloride test, ASTM F 1869. Proceed with installation only after substrates have maximum moisture-vapor-emission rate of 3 lb of water/1000 sq. ft. in 24 hours.
 - b. Perform tests recommended by manufacturer. Proceed with installation only after substrates pass testing and PH is acceptable to manufacturer.
- C. Remove substrate coatings and other substances that are incompatible with adhesives and that contain soap, wax, oil, or silicone, using mechanical methods recommended by manufacturer. Do not use solvents.
- D. Access Flooring Panels: Remove protective film of oil or other coating using method recommended by access flooring manufacturer.
- E. Use trowelable leveling and patching compound to fill cracks, holes, and depressions in substrates.
- F. Move resilient products and installation materials into spaces where they will be installed at least 48 hours in advance of installation.
 - 1. Do not install resilient products until they are same temperature as space where they are to be installed.
- G. Sweep and vacuum clean substrates to be covered by resilient products immediately before installation. After cleaning, examine substrates for moisture, alkaline salts, carbonation, and dust. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 TILE INSTALLATION

- A. Lay out tiles from center marks established with principal walls, discounting minor offsets, so tiles at opposite edges of room are of equal width. Adjust as necessary to avoid using cut widths that equal less than one-half tile at perimeter.
 - 1. Lay tiles in pattern indicated.
- B. Match tiles for color and pattern by selecting tiles from cartons in the same sequence as manufactured and packaged, if so numbered. Discard broken, cracked, chipped, or deformed tiles.
- C. Scribe, cut, and fit tiles to butt neatly and tightly to vertical surfaces and permanent fixtures including built-in furniture, cabinets, pipes, outlets, edgings, door frames, thresholds, and nosings.

- D. Extend tiles into toe spaces, door reveals, closets, and similar openings.
- E. Maintain reference markers, holes, and openings that are in place or marked for future cutting by repeating on floor tiles as marked on substrates. Use chalk or other nonpermanent, nonstaining marking device.
- F. Install tiles on covers for telephone and electrical ducts and similar items in finished floor areas. Maintain overall continuity of color and pattern with pieces of tile installed on covers. Tightly adhere tile edges to substrates that abut covers and to cover perimeters.
- G. Adhere tiles to flooring substrates using a full spread of adhesive applied to substrate to produce a completed installation without open cracks, voids, raising and puckering at joints, telegraphing of adhesive spreader marks, and other surface imperfections.

3.4 RESILIENT WALL BASE INSTALLATION

- A. Apply wall base to walls, columns, pilasters, casework and cabinets in toe spaces, and other permanent fixtures in rooms and areas where base is required.
- B. Install wall base in lengths as long as practicable without gaps at seams and with tops of adjacent pieces aligned.
- C. Tightly adhere wall base to substrate throughout length of each piece, with base in continuous contact with horizontal and vertical substrates.
- D. Do not stretch wall base during installation.
- E. On masonry surfaces or other similar irregular substrates, fill voids along top edge of wall base with manufacturer's recommended adhesive filler material.
- F. Premolded Corners: Install premolded corners before installing straight pieces.

3.5 RESILIENT ACCESSORY INSTALLATION

- A. Resilient Stair Accessories:
 - 1. Use stair-tread-nose filler to fill nosing substrates that do not conform to tread contours.
 - 2. Tightly adhere to substrates throughout length of each piece.
 - 3. For treads installed as separate, equal-length units, install to produce a flush joint between units.
- B. Resilient Molding Accessories: Butt to adjacent materials and tightly adhere to substrates throughout length of each piece. Install reducer strips at edges of floor coverings that would otherwise be exposed.

3.6 CLEANING AND PROTECTION

- A. Perform the following operations immediately after completing resilient product installation:
 - 1. Remove adhesive and other blemishes from exposed surfaces.
 - 2. Sweep and vacuum surfaces thoroughly.

3. Damp-mop surfaces to remove marks and soil.
 - a. Do not wash surfaces until after time period recommended by manufacturer.
- B. Protect resilient products from mars, marks, indentations, and other damage from construction operations and placement of equipment and fixtures during remainder of construction period. Use protection methods recommended in writing by manufacturer.
 1. Apply protective floor polish to horizontal surfaces that are free from soil, visible adhesive, and surface blemishes if recommended in writing by manufacturer.
 - a. Coordinate selection of floor polish with the Authority's maintenance personnel.
 2. Cover products installed on horizontal surfaces with undyed, untreated building paper until Substantial Completion.
 3. Do not move heavy and sharp objects directly over surfaces. Place hardboard or plywood panels over flooring and under objects while they are being moved. Slide or roll objects over panels without moving panels.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09670

FLUID APPLIED FLOORING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies decorative resinous flooring systems.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include manufacturer's technical data, application instructions, and maintenance recommendations for each resinous flooring component required.
- B. Samples for Verification: For each resinous flooring system required, 6 inches (150 mm) square, applied to a rigid backing by Installer for this Project.

1.3 INFORMATIONAL SUBMITTALS

- A. Installer Certificates: Signed by manufacturer certifying that installers comply with specified requirements.
- B. Material Certificates: For each resinous flooring component, from manufacturer.
- C. Material Test Reports: For each resinous flooring system.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: Provide manufacturer's maintenance recommendations for resinous flooring to include in maintenance manuals.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of flooring systems required for this Project.
 - 1. Engage an installer who is certified in writing by resinous flooring manufacturer as qualified to apply resinous flooring systems indicated.
- B. Source Limitations: Obtain primary resinous flooring materials, including primers, resins, hardening agents, grouting coats, and topcoats, from single source from single manufacturer. Provide secondary

materials, including patching and fill material, joint sealant, and repair materials, of type and from source recommended by manufacturer of primary materials.

- C. Mockups: Apply mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.
 - 1. Apply full-thickness mockups on 48-inch- (1200-mm-) square floor area selected by Architect.
 - a. Include 48-inch (1200-mm) length of integral cove base with inside corner.
 - 2. Simulate finished lighting conditions for Architect's review of mockups.
 - 3. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver materials in original packages and containers, with seals unbroken, bearing manufacturer's labels indicating brand name and directions for storage and mixing with other components.

1.7 PROJECT CONDITIONS

- A. Environmental Limitations: Comply with resinous flooring manufacturer's written instructions for substrate temperature, ambient temperature, moisture, ventilation, and other conditions affecting resinous flooring application.
- B. Lighting: Provide permanent lighting or, if permanent lighting is not in place, simulate permanent lighting conditions during resinous flooring application.
- C. Close spaces to traffic during resinous flooring application and for not less than 24 hours after application unless manufacturer recommends a longer period.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Basis-of-Design Product: Subject to compliance with requirements, provide Sherwin Williams Company General Polymers; FastTop 12S-U1 or an approved equal.

2.2 MATERIALS

- A. VOC Content of Liquid-Applied Flooring Components: Not more than 100 g/L when calculated according to 40 CFR 59, Subpart D (EPA Method 24):

2.3 DECORATIVE RESINOUS FLOORING

- A. Resinous Flooring: Low odor, self-leveling, abrasion-, impact- and chemical-resistant, decorative-aggregate-filled, epoxy-resin-based, monolithic floor surfacing designed to produce a seamless floor and integral cove base.
- B. System Characteristics:
 - 1. Color and Pattern: As selected by Architect from manufacturer's full range.
 - 2. Wearing Surface: Textured for slip resistance
 - 3. Overall System Thickness: 1/4 inch (6.4 mm)
- C. Body Coats:
 - 1. Resin: Urethane
 - 2. Application Method: Self-leveling slurry with broadcast aggregates.
 - a. Thickness of Coats: 3/16 inch (4.8 mm)
 - b. Number of Coats: One.
 - 3. Aggregates: Colored quartz (ceramic-coated silica).
- D. Topcoat: Sealing or finish coats.
 - 1. Resin: Urethane.
 - 2. Type: Clear.
 - 3. Finish: Gloss.
 - 4. Number of Coats: One.
- E. System Physical Properties: Provide resinous flooring system with the following minimum physical property requirements when tested according to test methods indicated:
 - 1. Compressive Strength: 5,000 psi per ASTM C 579.
 - 2. Tensile Strength: 550-600 psi per ASTM C 307.
 - 3. Flexural Strength: 3,700 per ASTM C 580.
 - 4. Coefficient of Friction: >0.80 per ASTM D 2047.
 - 5. Abrasion Resistance: 20-30 maximum weight loss per ASTM D 4060.
 - 6. Flammability: Self-extinguishing per ASTM D 635.
 - 7. Hardness: 75, Shore D per ASTM D 2240.

2.4 ACCESSORIES

- A. Primer: Type recommended by manufacturer for substrate and body coats indicated.

PART 3 - EXECUTION

3.1 PREPARATION

- A. General: Prepare and clean substrates according to resinous flooring manufacturer's written instructions for substrate indicated. Provide clean, dry substrate for resinous flooring application.

- B. Resinous Materials: Mix components and prepare materials according to resinous flooring manufacturer's written instructions.

3.2 APPLICATION

- A. General: Apply components of resinous flooring system according to manufacturer's written instructions to produce a uniform, monolithic wearing surface of thickness indicated.
 - 1. Coordinate application of components to provide optimum adhesion of resinous flooring system to substrate, and optimum intercoat adhesion.
 - 2. Cure resinous flooring components according to manufacturer's written instructions. Prevent contamination during application and curing processes.
- B. Apply primer over prepared substrate at manufacturer's recommended spreading rate.
- C. Integral Cove Base: Apply cove base mix to wall surfaces before applying flooring. Apply according to manufacturer's written instructions and details including those for taping, mixing, priming, troweling, sanding, and topcoating of cove base. Round internal and external corners.
 - 1. Integral Cove Base: 4 inches (100 mm) high.
- D. Apply self-leveling slurry body coats in thickness indicated for flooring system.
 - 1. Broadcast aggregates at rate recommended by manufacturer and, after resin is cured, remove excess aggregates to provide surface texture indicated.
- E. Apply troweled or screeded body coats in thickness indicated for flooring system. Hand or power trowel and grout to fill voids. When cured, remove trowel marks and roughness using method recommended by manufacturer.
- F. Apply topcoats in number indicated for flooring system and at spreading rates recommended in writing by manufacturer.

3.3 FIELD QUALITY CONTROL

- A. Core Sampling: At the direction of Authority and at locations designated by Authority, take one core sample per 1,000 sq. ft. (92.9 sq. m) of resinous flooring, or portion of, to verify thickness. For each sample that fails to comply with requirements, take two additional samples. Repair damage caused by coring and correct deficiencies.
- B. Material Sampling: Authority may at any time and any number of times during resinous flooring application require material samples for testing for compliance with requirements.
 - 1. The Contractor will engage an independent testing agency to take samples of materials being used. Material samples will be taken, identified, sealed, and certified in presence of Engineer.
 - 2. Testing agency will test samples for compliance with requirements, using applicable referenced testing procedures or, if not referenced, using testing procedures listed in manufacturer's product data.
 - 3. If test results show applied materials do not comply with specified requirements, pay for testing, remove noncomplying materials, prepare surfaces coated with unacceptable materials, and reapply flooring materials to comply with requirements.

3.4 PROTECTION

- A. Protect resinous flooring from damage and wear during the remainder of construction period. Use protective methods and materials, including temporary covering, recommended in writing by resinous flooring manufacturer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are be included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09680

CARPETING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies carpet for direct-glue down installation, carpet accessories and substrate preparation for carpet and accessories.
- B. Related Work:
 - 1. Section 09650 - RESILIENT FLOORS for resilient wall base and accessories installed with carpet.
 - 2. Section 09681 - TILE CARPETING for carpet tiles and accessories.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include manufacturer's written data on physical characteristics, durability, and fade resistance. Include installation recommendations for each type of substrate required.
- B. Shop Drawings: Show the following:
 - 1. Columns, doorways, enclosing walls or partitions, built-in cabinets, and locations where cutouts are required in carpet.
 - 2. Carpet type, color, and dye lot.
 - 3. Seam locations, types, and methods.
 - 4. Type of subfloor.
 - 5. Type of installation.
 - 6. Pattern type, repeat size, location, direction, and starting point.
 - 7. Pile direction.
 - 8. Type, color, and location of insets and borders.
 - 9. Type, color, and location of edge, transition, and other accessory strips.
 - 10. Transition details to other flooring materials.
- C. Samples: For each of the following products and for each color and texture required. Label each Sample with manufacturer's name, material description, color, pattern, and designation indicated on Drawings and in schedules.
 - 1. Carpet: 12-inch- square Sample.
 - 2. Exposed Edge Stripping and Accessory: 12-inch-long Samples.
 - 3. Carpet Seam: 6-inch Sample.
- D. Product Schedule: Use same room and product designations indicated on Drawings and in schedules.
- E. Maintenance Data: For carpet to include in maintenance manuals specified in Division 01. Include the following:
 - 1. Methods for maintaining carpet, including cleaning and stain-removal products and procedures and manufacturer's recommended maintenance schedule.
 - 2. Precautions for cleaning materials and methods that could be detrimental to carpet.

1.3 QUALITY ASSURANCE

- A. Carpeting Standard: Comply with the Carpet and Rug Institute's "CRI Carpet Installation Standard," 2011 edition, formerly CRI 104 "Standard For Installation Specification Of Commercial Carpet."
- B. Installer Qualifications: An experienced installer who is certified by the Floor Covering Installation Board or who can demonstrate compliance with its certification program requirements.
- C. Fire-Test-Response Characteristics: Provide products with the critical radiant flux classification indicated in Part 2, as determined by testing identical products per ASTM E 648 by an independent testing and inspecting agency acceptable to authorities having jurisdiction.
- D. Mockups: Before installing carpet, build mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.
 - 1. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. General: Comply with CRI Carpet Installation Standard, Section 5, "Storage and Handling."

1.5 PROJECT CONDITIONS

- A. General: Comply with CRI Carpet Installation Standard, Section 7, "Site Conditions."
- B. Environmental Limitations: Do not install carpet until wet work in spaces is complete and dry, and ambient temperature and humidity conditions are maintained at the levels indicated for Project when occupied for its intended use.
- C. Do not install carpet over concrete slabs until slabs have cured and are sufficiently dry to bond with adhesive and concrete slabs have pH range recommended by carpet manufacturer.
- D. Where demountable partitions or other items are indicated for installation on top of carpet, install carpet before installing these items.

1.6 WARRANTY

- A. General Warranty: Special warranty specified in this Article shall not deprive the Authority of other rights the Authority may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by Contractor under requirements of the Contract Documents.
- B. Special Carpet Warranty: Written warranty, signed by carpet manufacturer agreeing to replace carpet that does not comply with requirements or that fails within specified warranty period. Warranty does not include deterioration or failure of carpet due to unusual traffic, failure of substrate, vandalism, or abuse. Failures include, but are not limited to, more than 10 percent loss of face fiber, edge raveling, snags, runs, and delamination.
 - 1. Warranty Period: Ten years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 CARPET

- A. Products: Subject to compliance with requirements, provide one of the following:
 - 1. Provide sheet carpet as indicated on the Finish Schedule and as approved by the Architect.
 - 2. Environmental Requirements: Provide carpet that complies with testing and product requirements of CRI Carpet and Rug Institute's "Green Label Plus" program.

2.2 INSTALLATION ACCESSORIES

- A. Trowelable Leveling and Patching Compounds: Latex-modified, hydraulic-cement-based formulation provided by or recommended by the carpet manufacturer.
- B. Adhesives: Water-resistant, mildew-resistant, nonstaining type to suit products and subfloor conditions indicated, that complies with flammability requirements for installed carpet and that is recommended by carpet manufacturer.
- C. Seaming Cement: Hot-melt adhesive tape or similar product recommended by carpet manufacturer for taping seams and butting cut edges at backing to form secure seams and to prevent pile loss at seams.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions for compliance with requirements for maximum moisture content, alkalinity range, installation tolerances, and other conditions affecting carpet performance. Verify that substrates and conditions are satisfactory for carpet installation and comply with requirements specified.
- B. Concrete Subfloors: Comply with CRI Carpet Installation Standard, Section 9, "Testing Concrete Substrates." Verify that concrete slabs comply with ASTM F 710 and the following:
 - 1. Slab substrates are dry and free of curing compounds, sealers, hardeners, and other materials that may interfere with adhesive bond. Determine adhesion and dryness characteristics by performing bond and moisture tests recommended by the carpet manufacturer.
 - 2. Subfloors are free of cracks, ridges, depressions, scale, and foreign deposits.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. General: Comply with CRI Carpet Installation Standard, Section 7.3, "Site Conditions; Floor Preparation," and carpet manufacturer's written installation instructions for preparing substrates indicated to receive carpet installation.
- B. Concrete Substrates: Prepare according to ASTM F 710.
 - 1. Verify that substrates are dry and free of curing compounds, sealers, and hardeners.
 - 2. Alkalinity and Adhesion Testing: Perform tests recommended by flooring manufacturer.

Proceed with installation only after substrate alkalinity falls within a range on pH scale not less than 5 or more than 9 pH, or as otherwise required in writing by manufacturer of flooring.

3. Moisture Vapor Emission Testing:

- a. Perform anhydrous calcium chloride test, ASTM F 1869. Proceed with installation only after substrates have maximum moisture-vapor-emission rate of 3 lb of water/1000 sq. ft. in 24 hours, or as otherwise required in writing by manufacturer of flooring.

4. Relative Humidity Testing:

- a. Perform relative humidity test, ASTM F 2170. Proceed with installation only after substrates have a maximum relative humidity level of 75 percent, or as otherwise required in writing by manufacturer of flooring.

5. Perform tests indicated above and as recommended by flooring manufacturer. Proceed with installation only after substrates pass testing.

C. Use trowelable leveling and patching compounds, according to manufacturer's written instructions, to fill cracks, holes, and depressions in substrates.

D. Broom and vacuum clean substrates to be covered immediately before installing carpet. After cleaning, examine substrates for moisture, alkaline salts, carbonation, or dust. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 INSTALLATION

A. Direct-Glue-Down Installation: Comply with CRI Carpet Installation Standard, Section 13, "Direct Glue-Down Installation."

B. Comply with carpet manufacturer's written recommendations for seam locations and direction of carpet; maintain uniformity of carpet direction and lay of pile. At doorways, center seams under the door in closed position.

C. Do not bridge building expansion joints with carpet.

D. Cut and fit carpet to butt tightly to vertical surfaces, permanent fixtures, and built-in furniture including cabinets, pipes, outlets, edgings, thresholds, and nosings. Bind or seal cut edges as recommended by carpet manufacturer.

E. Extend carpet into toe spaces, door reveals, closets, open-bottomed obstructions, removable flanges, alcoves, and similar openings.

F. Maintain reference markers, holes, and openings that are in place or marked for future cutting by repeating on finish flooring as marked on subfloor. Use nonpermanent, nonstaining marking device.

G. Install pattern parallel to walls and borders.

3.4 CLEANING AND PROTECTION

- A. Perform the following operations immediately after installing carpet:
 - 1. Remove excess adhesive, seam sealer, and other surface blemishes using cleaner recommended by carpet manufacturer.
 - 2. Remove yarns that protrude from carpet surface.
 - 3. Vacuum carpet using commercial machine with face-beater element and HEPA filter.
- B. Protect installed carpet to comply with CRI Carpet Installation Standard, Section 20, "Protecting Indoor Installations."
- C. Protect carpet against damage from construction operations and placement of equipment and fixtures during the remainder of construction period. Use protection methods indicated or recommended in writing by carpet manufacturer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09681

TILE CARPETING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies carpet tile including preparation of concrete floor slabs and fills, except leveling and repair of faulty surfaces and those not constructed to stated tolerance.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include manufacturer's written data on physical characteristics, durability, and fade resistance. Include installation methods.
- B. Shop Drawings: Show the following:
 - 1. Columns, doorways, enclosing walls or partitions, built-in cabinets, and locations where cutouts are required in carpet tiles.
 - 2. Carpet tile type, color, and dye lot.
 - 3. Type of subfloor.
 - 4. Type of installation.
 - 5. Pattern of installation.
 - 6. Pattern type, location, and direction.
 - 7. Pile direction.
 - 8. Type, color, and location of insets and borders.
 - 9. Type, color, and location of edge, transition, and other accessory strips.
 - 10. Transition details to other flooring materials.
- C. Samples: For each of the following products and for each color and texture required. Label each Sample with manufacturer's name, material description, color, pattern, and designation indicated on Drawings and in schedules.
 - 1. Carpet Tile: Full-size Sample.
 - 2. Exposed Edge Stripping and Accessory: 12-inch- (300-mm-) long Samples.
- D. Product Schedule: Use same room and product designations indicated on Drawings and in schedules.
- E. Maintenance Data: For carpet tile to include in maintenance manuals specified in Division 1. Include the following:
 - 1. Methods for maintaining carpet tile, including cleaning and stain-removal products and procedures and manufacturer's recommended maintenance schedule.
 - 2. Precautions for cleaning materials and methods that could be detrimental to carpet tile.

1.3 QUALITY ASSURANCE

- A. **Installer Qualifications:** An experienced installer who is certified by the Floor Covering Installation Board or who can demonstrate compliance with its certification program requirements.
- B. **Fire-Test-Response Characteristics:** Provide products with the critical radiant flux classification indicated in Part 2, as determined by testing identical products per ASTM E 648 by an independent testing and inspecting agency acceptable to authorities having jurisdiction.
- C. **Product Options:** Products and manufacturers named in Part 2 establish requirements for product quality in terms of appearance, construction, and performance. Other manufacturers' products comparable in quality to named products and complying with requirements may be considered.
- D. **Mockups:** Before installing carpet tile, install mockups for each type of carpet tile installation required to demonstrate aesthetic effects and qualities of materials and execution. Install mockups to comply with the following requirements, using materials indicated for the completed Work:
 - 1. Install mockups in the location and of the size indicated or, if not indicated, as directed by Architect.
 - 2. Notify Architect seven days in advance of dates and times when mockups will be installed.
 - 3. Demonstrate the proposed range of aesthetic effects and workmanship.
 - 4. Obtain Architect's approval of mockups before starting work.
 - 5. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
 - 6. Remove mockups when directed.
 - 7. Approved mockups may become part the completed Work if undamaged at time of Substantial Completion.
- E. **Moisture-Vapor Emissions Test and Relative Humidity Test:** Before purchasing carpet tile, provide moisture-vapor emissions test and relative humidity test as specified under Article 3.1 of this Section. Report results of the tests to carpet tile manufacturer for approval.

1.4 STORAGE, AND HANDLING

- A. **General:** Comply with CRI 104, Section 5, "Storage and Handling."

1.5 PROJECT CONDITIONS

- A. **General:** Comply with CRI 104, Section 6.1, "Site Conditions; Temperature and Humidity."
- B. **Environmental Limitations:** Do not install carpet tile until wet work in spaces is complete and dry, and ambient temperature and humidity conditions are maintained at the levels indicated for Project when occupied for its intended use.
- C. Do not install carpet tile over concrete slabs until slabs have cured and are sufficiently dry to bond with adhesive and concrete slabs have pH range recommended by carpet tile manufacturer.
- D. Where demountable partitions or other items are indicated for installation on top of carpet tile, install carpet tile before installing these items.

1.6 WARRANTY

- A. General Warranty: Special warranty specified in this Article shall not deprive Authority of other rights Authority may have under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by Contractor under requirements of the Contract Documents.
- B. Special Carpet Tile Warranty: Written warranty, signed by carpet tile manufacturer agreeing to replace carpet tile that does not comply with requirements or that fails within specified warranty period. Warranty does not include deterioration or failure of carpet tile due to unusual traffic, failure of substrate, vandalism, or abuse. Failures include, but are not limited to, more than 10 percent loss of face fiber, edge raveling, snags, runs, and delamination.
 - 1. Warranty Period: 10 years from date of Substantial Completion.

1.7 EXTRA MATERIALS

- A. Furnish extra materials described below, before installation begins, that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Carpet Tile: Full-size units equal to 5 percent of amount installed for each type indicated, but not less than 10 sq. yd. (8.3 sq. m).

PART 2 - PRODUCTS

2.1 CARPET TILE

- A. Carpet Tile Materials: Basis-Of-Design, provide as follows, or approved equal:
 - 1. Milliken "Plan A", #P/6675, Pie; color shall be #216 Grape.
- B. Carpet Tile Requirements: Provide carpet tile meeting the following requirements:
 - 1. Construction: Tufted, Textured Loop Pile
 - 2. Face Fiber: 100% Milliken-Certified WearOn® Type 6,6 Nylon
 - 3. Stain Repel / Stain Resist / Soil Release: StainSmart®
 - 4. Antimicrobial : AlphaSan® Built-In Protection
 - 5. Dye Method: DCP (Digital Color Placement)
 - 6. Finished Face Weight: 21 oz./sq.yd. (712.1 g./sq.m.)
 - 7. Gauge: 1/8 (31.5/10 cm.)
 - 8. Rows: 14.0/in. (55.1/10 cm.)
 - 9. Tufts: 112.0/sq.in. (1,735.7/100 sq. cm.)
 - 10. Finished Pile Height: 0.09 in. (2.3 mm.) avg.
 - 11. Density Factor: 543,994
 - 12. Average Density: 8,400
 - 13. Standard Backing: PVC-Free Comfort Plus® ES cushion
 - 14. Tile Size: 50cm x 50cm (19.7 x 19.7 in.)

2.2 INSTALLATION MATERIALS

- A. Trowelable Leveling and Patching Compounds: Latex-modified, hydraulic-cement-based formulation provided by or recommended by carpet tile manufacturer, with a VOC content of 65 g/L or less when calculated according to 40 CFR 59, Subpart D.
- B. Adhesives for Carpets: Water-resistant, mildew-resistant, nonstaining type to suit products and subfloor conditions indicated, that complies with flammability requirements for installed carpet and is recommended or provided by carpet manufacturer.
 - 1. Limits: Provide adhesives that comply with the following limits for VOC content when tested according to ASTM D 5116:
 - a. Total VOCs: 10.00 mg/sq. m x h.
 - b. Formaldehyde: 0.05 mg/sq. m x h.
 - c. 2-Ethyl-1-Hexanol: 3.00 mg/sq. m x h.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions for compliance with requirements for maximum moisture content, alkalinity range, installation tolerances, and other conditions affecting carpet tile performance. Verify that substrates and conditions are satisfactory for carpet tile installation and comply with requirements specified.
- B. Concrete Subfloors: Verify that concrete slabs comply with ASTM F 710 and the following:
 - 1. Slab substrates are dry and free of curing compounds, sealers, hardeners, and other materials that may interfere with adhesive bond. Determine adhesion and dryness characteristics by performing bond and moisture tests recommended by carpet tile manufacturer.
 - 2. Subfloors are free of cracks, ridges, depressions, scale, and foreign deposits.
- C. Provide sound concrete surfaces free of laitance, glaze, efflorescence, curing compounds, form-release agents, dust, dirt, grease, oil, and other contaminants incompatible with tile carpeting.
 - 1. Repair damaged and deteriorated concrete according to tile carpeting manufacturer's written instructions.
 - 2. Verify that concrete substrates are dry and moisture-vapor emissions are within acceptable levels according to manufacturer's written instructions.
 - a. Perform anhydrous calcium chloride test, ASTM F 1869. Proceed with application of tile carpeting only after substrates have maximum moisture-vapor-emission rate of 3 lb of water/1000 sq. ft. (1.36 kg of water/92.9 sq. m) of slab area in 24 hours.
 - b. Perform relative humidity test using in situ probes, ASTM F 2170. Proceed with installation only after substrates have a maximum 75 percent relative humidity level measurement.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. General: Comply with CRI 104, Section 6.2, "Site Conditions; Floor Preparation," and carpet tile manufacturer's written installation instructions for preparing substrates indicated to receive carpet tile installation.
- B. Use trowelable leveling and patching compounds, according to manufacturer's written instructions, to fill cracks, holes, and depressions in substrates.
- C. Remove coatings, including curing compounds, and other substances that are incompatible with adhesives and that contain soap, wax, oil, or silicone, without using solvents. Use mechanical methods recommended in writing by carpet tile manufacturer.
- D. Broom and vacuum clean substrates to be covered immediately before installing carpet tile. After cleaning, examine substrates for moisture, alkaline salts, carbonation, or dust. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 INSTALLATION

- A. General: Comply with CRI 104, Section 13, "Carpet Modules (Tiles)."
- B. Glue-down installations are appropriate for wheel traffic; partial glue-down, for carpet tiles of moderate dimensional stability and moderate weight and mass; and free-lay, for dimensionally stable carpet tiles with heavy backings.
- C. Installation Method: As recommended in writing by carpet tile manufacturer.
- D. Cut and fit carpet tile to butt tightly to vertical surfaces, permanent fixtures, and built-in furniture including cabinets, pipes, outlets, edgings, thresholds, and nosings. Bind or seal cut edges as recommended by carpet tile manufacturer.
- E. Extend carpet tile into toe spaces, door reveals, closets, open-bottomed obstructions, removable flanges, alcoves, and similar openings.
- F. Maintain reference markers, holes, and openings that are in place or marked for future cutting by repeating on finish flooring as marked on subfloor. Use nonpermanent, nonstaining marking device.
- G. Install pattern parallel to walls and borders.

3.4 CLEANING AND PROTECTION

- A. Perform the following operations immediately after installing carpet tile:
 - 1. Remove excess adhesive, seam sealer, and other surface blemishes using cleaner recommended by carpet tile manufacturer.
 - 2. Remove yarns that protrude from carpet tile surface.
 - 3. Vacuum carpet tile using commercial machine with face-beater element.
- B. Protect installed carpet tile to comply with CRI 104, Section 15, "Protection of Indoor Installations."

- C. Protect carpet tile against damage from construction operations and placement of equipment and fixtures during the remainder of construction period. Use protection methods indicated or recommended in writing by carpet tile manufacturer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09840

ACOUSTICAL PANEL SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies direct-applied acoustical panel systems at interior underside of decking.
- B. Related Work:
 - 1. Division 15 - MECHANICAL; sprinklers, grilles, and diffusers located in ceilings.
 - 2. Division 16 - ELECTRICAL; light fixtures and alarm system components located in ceilings.

1.2 QUALITY ASSURANCE

- A. Source: For each type of material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.

1.3 TESTS

- A. Fire-Resistance: Where fire-resistance ratings are indicated or required by authorities having jurisdiction, provide materials and construction which are identical to assemblies whose fire-resistance rating has been tested in compliance with ASTM E119 by independent agencies acceptable to the Engineer and authorities having jurisdiction.
- B. Burning Characteristics: Provide materials whose surface burning characteristics, when tested in compliance with ASTM E84 are Class A or Class 1.

1.4 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material used. Provide certifications stating that materials comply with requirements.
- B. Shop Drawings: For acoustical panels. Include mounting devices and details; details at panel head, base, joints, and corners; and details at ceiling, floor base, and wall intersections. Include elevations showing panel sizes. Indicate panel edge and core materials.
- C. Coordination Drawings: Show intersections with adjacent and penetrating work.
- D. Verification Samples: Submit representative samples of each material that is to be exposed in the finished work, showing the full range of color and finish variations expected. Provide samples having minimum area of 144 square inches.

- E. Test Reports: Submit certified reports for tests required.

1.5 DELIVERY, STORAGE AND HANDLING

- A. Deliver materials and products in unopened factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from damage, moisture and direct sunlight. Sequence deliveries to avoid delays, but minimize on-site storage.

1.6 PROJECT CONDITIONS, SEQUENCING AND SCHEDULING

- A. Environment: Perform work only when conditions are within the limits established by manufacturers of the materials and products used.
- B. Conference: Convene a pre-installation conference to establish procedures to maintain optimum working conditions and to coordinate this work with related and adjacent work.
 - 1. Proceed with installation of ceiling tiles and panels only when construction above ceilings and penetrating work is complete. Delay installation of ceiling tiles or panels until near time of Substantial Completion.
 - 2. Perform work of this section to coordinate with the layout of light fixtures, HVAC equipment and fixtures, fire suppression system components and all other related work. In general, every penetration shall occur at the center of a ceiling tile or panel.

1.7 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of acoustical panels that fail in performance, materials, or workmanship within specified warranty period.
 - 1. Failure in performance includes, but is not limited to, acoustical performance.
 - 2. Failures in materials include, but are not limited to, warping of core.
 - 3. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MATERIALS AND PRODUCTS

- A. Acoustic Panel: Recycled wood and cementitious panels with factory painted finish.
 - 1. Basis of Design: Tectum Inc.; Finale Panel, or approved equal.
 - 2. Nominal Core Thickness: 2 inches.
 - 3. Overall System NRC: Not less than 0.80, for Type A mounting per ASTM E 795.
 - 4. Panel Size: 4' x 8' typical.
 - 5. Corner Detail: As indicated on Drawings.
 - 6. Factory Finish: Manufacturer's standard painted finish; custom color to be selected by Architect.

- B. Fasteners: Provide exposed steel drywall screws, to extend at least 1 inch into substrate, painted to match panel.

2.2 FABRICATION

- A. Sound-Absorption Performance: Provide acoustical panels with minimum NRCs indicated, as determined by testing per ASTM C 423 for mounting type specified.
- B. Dimensional Tolerances of Finished Units: Plus or minus 1/16 inch for the following:
 - 1. Thickness.
 - 2. Edge straightness.
 - 3. Overall length and width.
 - 4. Squareness from corner to corner.
 - 5. Chords, radii, and diameters.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The Installer shall examine substrates, supports, and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.

3.2 INSTALLATION

- A. Install acoustical panels in locations indicated with surfaces and edges plumb, top edges level and in alignment with other panels, faces flush, and scribed to fit adjoining work accurately at borders and at penetrations.
- B. Comply with acoustical panel manufacturer's written instructions for installation of panels using type of mounting accessories indicated or, if not indicated, as recommended by manufacturer. Anchor panels securely to supporting substrate.
 - 1. Acoustical Panels: Mechanically fasten directly to ceiling substrates, as indicated on Drawings.
- C. Installation Tolerances: As follows:
 - 1. Variation from Level and Plumb: Plus or minus 1/16 inch.
 - 2. Variation of Panel Joints from Hairline: Not more than 1/16 inch wide.

3.3 PROTECTION

- A. Provide final protection and maintain conditions, in a manner acceptable to manufacturer and Installer, to ensure that acoustical panels are without damage or deterioration at time of Substantial Completion.

- B. Replace acoustical panels that cannot be cleaned and repaired, in a manner approved by Architect, before time of Substantial Completion.
- C. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully cleaned.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 09861

ANTI-GRAFFITI COATINGS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies anti-graffiti (AG) coatings on exposed structural substrates on fixed property and in rights-of way under the purview of MBTA.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03300 – CAST IN-PLACE CONCRETE
 - 3. Section 03450 – ARCHITECTURAL PRECAST CONCRETE
- C. The basic technical concept involves installing protective coatings to prevent permanent marking of surfaces via convenient removal of graffiti markings on a repeated basis. Coatings with non-wetting or other physico-chemically properties that discourage graffiti marking may warrant preferred selection.
- D. Affected substrates include:
 - 1. Bare and painted concrete, concrete block.
 - 2. Cast-in-place concrete and precast concrete.
 - 3. Architectural precast concrete.
- E. At the discretion of the MBTA Engineer, the anti-graffiti coating shall be a clear material that does not significantly alter the appearance of the substrate.

1.2 NOT USED

1.3 DESIGN GUIDANCE

- A. Surface texture:
 - 1. Surface cleanability depends on roughness and porosity. Architectural surface textures range from super-smooth glaze finishes on tiles and glass to coarsely fractured concrete block. Porosity of the surfaces also ranges from zero for glass and metal to significant for concrete and masonry.
 - 2. Rough surfaces should get an AG coating that permanently seals surface porosity. Conversely, smooth surfaces may need to be roughened/profiled in a controlled manner in order for the AG coating to bond adequately to the surface.
- B. Recoating:
 - 1. The number of times a coated surface can be cleaned before it is recoated depends on the coating durability and the cleaning procedure. Cleaning procedures should follow the coating manufacturer's instructions unless these are superseded by specific MBTA Engineer's instructions for that specific AG coated surface.
 - 2. Coatings for specific surfaces should be selected with an approximate expected number

of cleaning cycles to recoat in mind, depending on such factors as work location and accessibility, surface preparation requirements for recoating, and other coating application considerations, including compatibility and adhesion between the old and new AG coatings.

- C. New construction:
 - 1. Anti-graffiti measures should be an architectural design consideration in selecting materials and surface textures. At a minimum, graffiti-susceptible surfaces should be amenable to sealing with a clear or pigmented AG coating, or incorporate other anti-graffiti measures approved by the MBTA Engineer.

1.4 CERTIFICATION AND REGULATIONS

- A. Contractor certification:
- B. Contractors installing anti-graffiti coatings shall be certified in writing by the manufacturer as a trained installer of the specified coating materials.
- C. Handling, storing, disposal, and installation of coating materials and solvents: Contractor is responsible for fully meeting health, occupational safety and environmental requirements of all applicable local, state, or federal codes, regulations, and ordinances. Contractor shall ascertain what local, state and federal codes, regulations, and ordinances are in effect.
- D. To ensure full product compatibility, primary materials for each coating system installed in accordance with this Section shall be sourced from a single manufacturer. Secondary materials and solvents from other sources shall be approved by the coating system manufacturer.
- E. Coating materials shall meet Federal and State requirements for Volatile Organic Compound (VOC) content.

1.5 SUBMITTALS

- A. Product Data Sheets:
 - 1. Coating manufacturer's product data sheets, including installation instructions and service limitations for each material used shall be submitted to the MBTA Project Engineer.
- B. Certified test reports shall be provided for all specified coating performance test claims.
- C. Performance test reports:
 - 1. Submit evidence the AG coating has successfully performed or been field-tested for AG purposes for a minimum of six months. Longer performance and testing shall work in the coating's favor. Descriptions of test conditions and performance criteria shall be sufficiently detailed for results to be comparatively evaluated by the MBTA Engineer and for testing to be repeated by others.

1.6 PRODUCT STORAGE, HANDLING AND DISPOSAL

- A. Deliver materials and products in sealed, factory-labeled containers.
- B. Store the materials in a safe place that cannot be accessed by unauthorized people.
- C. Store, handle and prepare all coating materials under cover and protect from weather damage, strictly complying with the product manufacturer's directions and temperature limits.

- D. Collected, package and dispose of spoiled, unused and waste materials and product debris in total compliance with MBTA rules for chemical and solvent disposal.

1.7 INSTALLATION WORK RESTRICTIONS

- A. Weather:
 - 1. Perform anti-graffiti coating installation work, including surface preparation and curing, only when ambient weather conditions definitely will remain within temperature and humidity limits specified by the coating manufacturer.
- B. Temperature:
 - 1. Unless otherwise approved by the product manufacturer, apply the coating materials only when substrate surface and ambient temperatures are between 50°F - 85°F and will not be out of this range during the entire work period.
 - 2. Unless otherwise approved by the product manufacturer, store base materials and mixed products between 60°F and 80°F during application.
 - 3. Do not apply materials that are hotter than permitted by the product manufacturer.
- C. Schedule coating installation work to avoid interference between construction work, surface preparation and to minimize exposure of pedestrian and auto traffic.
- D. Spills and overspray:
 - 1. Deliberately avoid overspray on nearby surfaces and public property.
 - 2. Divert and protect pedestrian and auto traffic that could be affected by inhalation and overspray exposure during coating preparation and installation. Remove misapplied material, spills and overspray immediately.
- E. Personnel safety:
 - 1. Contractor employees installing the coating shall fully comply with all applicable personnel safety and health rules and procedures (see 1.02 B) and with the coating manufacturer's health and safety directions and recommendations.
 - 2. Do not use flammable products near fire or extreme heat.
 - 3. Always work in adequately ventilated conditions. Applicators shall wear NIOSH/MSHA approved respirators, eye protection, and protective clothing. Read material safety data sheets for additional toxicity and product hazard information.
 - 4. The public and all people not employed by the Contractor and MBTA shall be adequately protected from inhalation and overspray exposure to the coating materials.

1.8 PRE-CONSTRUCTION MEETING

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 COATINGS

- A. Anti-graffiti (AG) coatings for concrete, masonry, stone, suitable for repeated cleaning:
 - 1. Tnemec; Chemprobe V626 Dur A Plus GS
 - 2. QC Construction Products Anti-Graffiti
 - 3. Prosoco Blok-Guard and Graffiti Control

2.2 CLEANING SOLUTIONS

- A. Cleaning solutions shall be as approved or recommended by the AG coating manufacturer to maximize cleaning effect without harming the AG coating.
- B. Cleaning solutions and procedures shall not damage the substrate beneath the AG coating except where this is approved by the MBTA Engineer (e.g., because the substrate will be newly coated.)
- C. Cleaning solutions shall meet MBTA requirements for personnel exposure, safe handling and disposal.

PART 3 - EXECUTION

3.1 WORK AREA SUBSTRATE INSPECTION

- A. Examine substrates and identify conditions that could impede successful and smooth execution of the work. Factors to consider:
 - 1. Type of surface, including texture and porosity – influences surface preparation and coating system selection.
 - 2. Time windows and worker access for required sequence of surface preparation, coating installation (number of coats); curing.
 - 3. Potential effects of changes in ambient conditions in the work area and dryness of the substrate.
 - 4. Health and safety protection requirements for Contractor and public.
- B. Do not start work until job conditions are satisfactory to complete all required tasks in the available time.

3.2 COATING SELECTION

- A. Protected substrates shall be adequately sealed and non-porous before the anti-graffiti coating is applied.
- B. To select the right anti-graffiti product, the MBTA Engineer shall adequately weigh the following criteria:
 - 1. Selection for simpler application with fewer chemical exposure concerns from solvents.
 - 2. Selection for higher hardness to resist repeat cleaning performance.
 - 3. Selection for longer gloss retention in UV exposure.

4. Highest anti-graffiti performance.
- C. Clear coating shall be used to preserve architectural/aesthetic surface appearance, as directed by the MBTA Engineer.

3.3 APPLICATION

- A. General Application procedures:
1. Strictly follow the coating manufacturer's surface preparation, application and curing instructions, unless more restrictive requirements are specified in this Section. The coating manufacturer's limits for thinning, additives, pot-life, wet film thickness per coat and recoat time shall be known and carefully followed.
- B. Masking and overspray protection:
1. Protect contingent surfaces that should not be coated, oversprayed or contacted by cleaning or coating chemicals. Normally this is done with strippable masking materials, plastic sheeting and waterproof tape, or masking materials barriers approved by the MBTA Engineer.
- C. Surface Preparation: The substrate shall be flat and smooth enough to be thoroughly prepared and for the coating material to be evenly applied everywhere. NOTE: Coarsely profiled substrates like fractured concrete block require extra measures to benefits from anti-graffiti coatings.
1. Cavities and protuberances that can cause shadowing shall be filled or removed. Substrate roughness shall allow the method of application (brush, roller or spray) to provide uniform film thickness everywhere.
 2. Materials used to clean, patch, caulk and fill the substrate shall be approved by the coating manufacturer. Compatibility of existing materials shall be patch-tested before the coating is applied or painted with a primer or tie-coat from the coating manufacturer.
 3. The surface shall be thoroughly cleaned, dust-free, with no dirt, loose material, oil, water and other residues or contaminants.
 4. Masonry, tile and concrete surfaces shall be power-washed with high pressure water and appropriate chemical additives to remove surface contamination.
 5. Visible moisture is not permitted. Dampness shall not exceed the coating manufacturer's limits.
- D. Sample Preparation:
1. At the MBTA Engineer's discretion, the Contractor shall provide portable, finished samples of the final product on the target substrate(s) that are prepared in the specified manner. The resulting samples shall be used for comparative acceptance of actual work at the MBTA Engineer's discretion.

3.4 FIELD QUALITY CONTROL

- A. The Contractor shall establish and maintain throughout the work of this Section effective quality control measures described in a written scheme to ensure that all coating related work is performed as required by the Contract Documents.

- B. Quality-related test and inspection procedures, acceptance criteria and test reporting requirements for all phases of coating installation shall be defined by the MBTA Engineer before the work commences.

3.5 GRAFFITI REMOVAL

- A. Main objectives in removing graffiti from surfaces protected with AG coatings installed as described in this Section shall be to use experience and engineering judgment of all parties – MBTA, Contractor and AG coating manufacturer to:
 - 1. Minimize the physical and chemical harshness of the cleaning procedure so as to minimize environmental and health effects and preserve as much of the AG coating as practical during the cleaning operation.
 - 2. Clean with water, including hydro-blasting up to 5,000psi, wherever possible. Increase the solvent power of water by adding low concentrations of detergent or non-toxic emulsifier, such as tri-sodium phosphate (TSP), sodium carbonate (soda ash) or approved proprietary cleaning surfactants.
 - 3. Use only commercial organic solvent cleaners specified by the AG coating manufacturer for their specific coatings. These must contain non-toxic, biodegradable chemicals that do not require special containment and disposal.
- B. Use an escalating scale of more aggressive cleaning procedures on a systematic basis, using test cleaning to select the cleaning procedure.
- C. Carefully follow recoat time limits if new AG coating material is applied to surfaces freshly cleaned with solvent cleaners.
- D. Keep a complete log of cleaning events and procedures used to remove graffiti on every project doing work in accordance with this Section.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 10160

TOILET COMPARTMENTS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies stainless steel toilet compartments configured as toilet enclosures and urinal screens.
- B. Related Work:
 - 1. Section 05500 - MISCELLANEOUS METALS for supports that attach floor-and-ceiling-anchored compartments to overhead structural system.
 - 2. Section 06100 - CARPENTRY for blocking overhead support of floor-and-ceiling-anchored compartments.
 - 3. Section 10801 - TOILET ACCESSORIES for toilet tissue dispensers, grab bars, and similar accessories.

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
- B. Shop Drawings: For toilet compartments. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Show locations of cutouts for compartment-mounted toilet accessories.
 - 2. Show locations of reinforcements for compartment-mounted grab bars.
 - 3. Show locations of centerlines of toilet fixtures.
 - 4. Show ceiling grid and overhead support or bracing locations.
- C. Samples for Verification: For the following products, in manufacturer's standard sizes unless otherwise indicated:
 - 1. Each type of material, color, and finish required for units, prepared on 6-inch- square Samples of same thickness and material indicated for Work.
 - 2. Each type of hardware and accessory.

1.3 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each type of toilet compartment, from manufacturer.

1.4 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For toilet compartments to include in maintenance manuals.

1.5 QUALITY ASSURANCE

- A. Comply with requirements in GSA's CID-A-A-60003, "Partitions, Toilets, Complete."
- B. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84, or another standard acceptable to authorities having jurisdiction, by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1. Flame-Spread Index 75 or less.
 - 2. Smoke-Developed Index: 450 or less.
- C. Regulatory Requirements: Comply with applicable provisions in the U.S. Architectural & Transportation Barriers Compliance Board's "Americans with Disabilities Act (ADA) and Architectural Barriers Act (ABA) Accessibility Guidelines for Buildings and Facilities" and ICC/ANSI A117.1 for toilet compartments designated as accessible.

1.6 PROJECT CONDITIONS

- A. Field Measurements: Verify actual locations of toilet fixtures, walls, columns, ceilings, and other construction contiguous with toilet compartments by field measurements before fabrication.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Stainless-Steel Sheet: ASTM A 666, Type 304, stretcher-leveled standard of flatness.
- B. Stainless-Steel Castings: ASTM A 743/A 743M.

2.2 STAINLESS STEEL UNITS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
- B. Basis-of-Design Product: Subject to compliance with requirements, provide stainless steel partitions by Bradley Company, or comparable product by one of the following:
 - 1. Accurate Partitions Corporation.
 - 2. Comtec Industries/Capitol Partitions.
 - 3. General Partitions Mfg. Corp.
 - 4. Global Steel Products Corp.
 - 5. Hadrian Manufacturing Inc.
 - 6. Metpar Corp.
 - 7. Santana Products, Inc.
 - 8. Weis-Robart Partitions, Inc.
- C. Toilet-Enclosure Style: Floor and ceiling anchored.
- D. Urinal-Screen Style: Wall hung.
- E. Door, Panel, and Pilaster Construction: Stainless steel panels 1, not less than 1 inch (25 mm) thick, seamless.

1. Integral Hinges: Configure doors and pilasters to receive integral hinges.
- F. Pilaster Shoes: Manufacturer's standard design; stainless steel.
- G. Brackets (Fittings):
1. Full-Height (Continuous) Type: Manufacturer's standard design; stainless steel.

2.3 ACCESSORIES

- A. Hardware and Accessories: Manufacturer's standard design, heavy-duty operating hardware and accessories.
1. Material: Stainless steel.
 2. Hinges: Manufacturer's standard continuous, spring-loaded type.
 3. Latch and Keeper: Manufacturer's standard recessed latch unit designed for emergency access and with combination rubber-faced door strike and keeper. Provide units that comply with regulatory requirements for accessibility at compartments designated as accessible.
 4. Coat Hook: Manufacturer's standard combination hook and rubber-tipped bumper, sized to prevent in-swinging door from hitting compartment-mounted accessories.
 5. Door Bumper: Manufacturer's standard rubber-tipped bumper at out-swinging doors.
 6. Door Pull: Manufacturer's standard unit at out-swinging doors that complies with regulatory requirements for accessibility. Provide units on both sides of doors at compartments designated as accessible.
- B. Anchorages and Fasteners: Manufacturer's standard exposed fasteners of stainless steel or chrome-plated steel or brass, finished to match the items they are securing, with theft-resistant-type heads. Provide sex-type bolts for through-bolt applications. For concealed anchors, use stainless steel, hot-dip galvanized steel, or other rust-resistant, protective-coated steel.

2.4 FABRICATION

- A. Floor-and-Ceiling-Anchored Units: Provide manufacturer's standard stainless steel anchoring assemblies with leveling adjustment at tops and bottoms of pilasters. Provide shoes and sleeves (caps) at pilasters to conceal anchorage.
- B. Door Size and Swings: Unless otherwise indicated, provide 24-inch- (610-mm-) wide, in-swinging doors for standard toilet compartments and 36-inch- (914-mm-) wide, out-swinging doors with a minimum 32-inch- (813-mm-) wide, clear opening for compartments designated as accessible.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. General: Comply with manufacturer's written installation instructions. Install units rigid, straight, level, and plumb. Secure units in position with manufacturer's recommended anchoring devices.
 - 1. Maximum Clearances:
 - a. Pilasters and Panels: 1/2 inch (13 mm).
 - b. Panels and Walls: 1 inch (25 mm).
- B. Floor-and-Ceiling-Anchored Units: Secure pilasters to supporting construction and level, plumb, and tighten. Hang doors and adjust so doors are level and aligned with panels when doors are in closed position.
- C. Urinal Screens: Attach with anchoring devices to suit supporting structure. Set units level and plumb, rigid, and secured to resist lateral impact.

3.2 ADJUSTING

- A. Hardware Adjustment: Adjust and lubricate hardware according to hardware manufacturer's written instructions for proper operation. Set hinges on in-swinging doors to hold doors open approximately 30 degrees from closed position when unlatched. Set hinges on out-swinging doors to return doors to fully closed position.

PART 4 - MEASUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10200

ARCHITECTURAL LOUVERS AND GRILLES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies fixed extruded-aluminum, stainless steel and galvanized steel formed-metal louvers and frames. Work includes louvers set within curtain wall frames without the louver having its own frame.
- B. Related Work:
 - 1. Section 05500 – MISCELLANEOUS METALS.
 - 2. Section 07920 – JOINT SEALANTS; sealants installed in perimeter joints between louver frames and adjoining construction.
 - 3. Division 15 – MECHANICAL; louvers that are a part of mechanical equipment.
 - 4. Section 08111 – STEEL DOORS AND FRAMES
 - 5. Section 08120 – STAINLESS STEEL DOORS AND FRAMES

1.2 DEFINITIONS

- A. Louver Terminology: Definitions of terms for metal louvers contained in AMCA 501 apply to this Section unless otherwise defined in this Section or in referenced standards.
- B. Drainable-Blade Louver: Louver with blades having gutters that collect water and drain it to channels in jambs and mullions, which carry it to bottom of unit and away from opening.

1.3 PERFORMANCE REQUIREMENTS

- A. Structural Performance: Provide louvers capable of withstanding the effects of gravity loads and wind loads and stresses within limits and under conditions indicated without permanent deformation of louver components, noise or metal fatigue caused by louver blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act on vertical projection of louvers. Loads as required by Code.
- B. Seismic Performance: Provide louvers capable of withstanding the effects of earthquake motions as required by code.
- C. Thermal Movements: Provide louvers that allow for thermal movements resulting from the following maximum change (range) in ambient and surface temperatures by preventing buckling, opening of joints, overstressing of components, failure of connections, and other detrimental effects. Base engineering calculation on surface temperatures of materials due to both solar heat gain and nighttime-sky heat loss.
 - 1. Temperature Change (Range): 120 deg F ambient; 180 deg F material surfaces.

1.4 SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For louvers and accessories. Include plans, elevations, sections, details, and attachments to other Work. Show blade profiles, angles, and spacing.
 - 1. For installed louvers indicated to comply with design loads, include structural analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
- C. Samples for Verification: For each type of metal finish required.
- D. Qualification Data: For professional engineer performing services required by paragraph 1.3.
- E. Product Test Reports: Based on evaluation of comprehensive tests performed by a qualified testing agency or by manufacturer and witnessed by a qualified testing agency, for each type of louver.

1.5 QUALITY ASSURANCE

- A. Source Limitations: Obtain louvers and vents through one source from a single manufacturer where indicated to be of same type, design, or factory-applied color finish.
- B. Welding: Qualify procedures and personnel according to the following:
 - 1. AWS D1.2, "Structural Welding Code--Aluminum."
 - 2. AWS D1.3, "Structural Welding Code--Sheet Steel."
- C. SMACNA Standard: Comply with recommendations in SMACNA's "Architectural Sheet Metal Manual" for fabrication, construction details, and installation procedures.

1.6 PROJECT CONDITIONS

- A. Field Measurements: Verify louver openings by field measurements before fabrication and indicate measurements on Shop Drawings.
 - 1. Established Dimensions: Where field measurements cannot be made without delaying the Work, establish opening dimensions and proceed with fabricating louvers without field measurements. Coordinate construction to ensure that actual opening dimensions correspond to established dimensions.

1.7 PRE-CONSTRUCTION MEETING

- A. Arrange a pre-construction conference meeting to be attended by interested parties including contractor, architect, engineer, insurance agent and others whose installed work is specified under this section. Discuss conditions, interrelated responsibilities, schedule, applications, installation procedures, inspection procedures, specification requirements and other related matters. Conditions that exceed or contradict building code requirements should be discussed and mutual agreed upon between engineer, architect, insurance carriers and building code officials prior to construction or installation.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. Louvers:
 - a. Airline Products Co.
 - b. Airolite Company (The).
 - c. Construction Specialties, Inc.
 - d. Greenheck.
 - e. Industrial Louvers, Inc.
 - f. Ruskin Company; Tomkins PLC

2.2 FIXED, EXTRUDED-ALUMINUM LOUVERS

- A. High-Performance Drainable Fixed Mullion Louvers at Lechmere Station
1. Basis-of-Design Product: Subject to compliance with requirements, provide Model A2097 by Construction Specialties or equal by Ruskin or Airolite.
- B. Horizontal, High Performance Louver at Union and Washington Stations:
1. Basis-of-Design Product: Subject to compliance with requirements, provide Model A6177 by Construction Specialties or equal by Ruskin or Airolite.
 2. Louver Depth: 6 inches.
 3. Blade Profile: Drainable blades positioned at 37.5 degree angle and spaced approximately 5 29/32" center to center.
 4. Frame and Blade Nominal Thickness: Not less than 0.081 inch for blades and .125 inches perforated panel and for frames.
 5. Louver Performance Ratings:
 - a. Free Area: 57% free area.
 - b. Point of Beginning Water Penetration: Not less than 700 fpm (4.1 m/s).
 - c. Air Performance: Not more than 0.13-inch wg static pressure drop at 822-fpm free-area exhaust velocity.
- C. High-Performance Drainable Fixed Frameless Mullion Louvers
1. Basis-of-Design Product: Subject to compliance with requirements, provide Model K609HP by Airolite or equal by Construction Specialties or Ruskin.
 - a. Provide louver with "frameless" mullion frame. Louver blades shall be notched to extend past the face of the vertical frame members.

2.3 FIXED, FORMED-METAL LOUVERS

- A. Horizontal, Drainable-Blade Louver
1. Basis-of-Design Product: Subject to compliance with requirements, provide Ruskin Company; Tomkins PLC; Model L6375D or approved equal.

2. Louver Depth: 6 inches (150 mm).
 3. Frame and Blade Material and Nominal Thickness: Galvanized-steel sheet, not less than 0.052 inch (1.32 mm).
 4. Mullion Type: Exposed.
 5. Louver Performance Ratings:
 - a. Free Area: Not less than 54 percent for 48-inch- (1220-mm-) wide by 48-inch- (1220-mm-) high louver.
 - b. Point of Beginning Water Penetration: Not less than 850 fpm (4.3 m/s).
 - c. Air Performance: Not more than 0.10-inch wg (25-Pa) static pressure drop at 896-fpm free-area velocity.
- B. Flush-mounted Transom Louvers
1. Basis of Design Product: Air Louvers model 700TL
 2. Louver depth 1 13/16"
 3. Frame and Blade Material and Nominal Thickness: 20 Gauge stainless steel

2.4 STAINLESS STEEL GRILLES

- A. Fixed, Stainless Steel Grilles: Model AG10 A-frame by Architectural Grille or equal, welded stainless steel with 7/8 inch frame depth and 3/4 inch grille depth with satin finish.

2.5 MATERIALS

- A. Aluminum Extrusions: ASTM B 221, alloy 6063-T5 or T-52.
- B. Aluminum Sheet: ASTM B 209, alloy 3003 or 5005 with temper as required for forming, or as otherwise recommended by metal producer for required finish.
- C. Galvanized-Steel Sheet: ASTM A 653/A 653M, G60 (Z180) zinc coating, mill phosphatized.
- D. Fasteners: Of same basic metal and alloy as fastened metal or 300 Series stainless steel, unless otherwise indicated. Do not use metals that are incompatible with joined materials.
- E. Postinstalled Fasteners for Concrete and Masonry: Torque-controlled expansion anchors, made from stainless-steel components, with capability to sustain, without failure, a load equal to 4 times the loads imposed, for concrete, or 6 times the load imposed, for masonry, as determined by testing per ASTM E 488, conducted by a qualified independent testing agency.
- F. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

2.6 FABRICATION, GENERAL

- A. Assemble louvers in factory to minimize field splicing and assembly. Disassemble units as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation.
- B. Maintain equal louver blade spacing, including separation between blades and frames at head and sill, to produce uniform appearance.
- C. Fabricate frames, including integral sills, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

- D. Include supports, anchorages, and accessories required for complete assembly.
- E. Provide vertical mullions of type and at spacings indicated, but not more than recommended by manufacturer, or 72 inches o.c., whichever is less.
 - 1. Fully Recessed Mullions: Provide mullions fully recessed behind louver blades. Where length of louver exceeds fabrication and handling limitations, fabricate with close-fitting blade splices designed to permit expansion and contraction.
 - 2. Exposed Mullions: Where indicated, provide units with exposed mullions of same width and depth as louver frame. Where length of louver exceeds fabrication and handling limitations, provide interlocking split mullions designed to permit expansion and contraction.
- F. Join frame members to each other and to fixed louver blades with fillet welds concealed from view, unless otherwise indicated or size of louver assembly makes bolted connections between frame members necessary.

2.7 LOUVER SCREENS

- A. General: Provide screen at each exterior louver.
 - 1. Screen Location for Fixed Louvers: Interior face.
 - 2. Screening Type: Bird screening.
- B. Secure screens to louver frames with stainless-steel machine screws, spaced a maximum of 6 inches from each corner and at 12 inches o.c.
- C. Louver Screen Frames: Fabricate with mitered corners to louver sizes indicated.
- D. Louver Screening for Aluminum Louvers: Bird screening, aluminum, 1/2-inch-square mesh, 0.063-inch wire.
- E. Louver Screening for Galvanized-Steel Louvers: Bird screening, galvanized steel, 1/2-inch-square mesh, 0.041-inch wire.

2.8 BLANK-OFF PANELS

- A. Insulated, Blank-off Panels: Laminated metal-faced panels consisting of insulating core surfaced on back and front with metal sheets.
 - 1. Thickness: 1 inch.
 - 2. Metal Facing Sheets:
 - a. Aluminum Louvers: Aluminum sheet, not less than 0.032-inch nominal thickness.
 - b. Galvanized Steel Louvers: Galvanized-steel sheet for galvanized-steel louvers, not less than 0.040-inch nominal thickness.
 - 3. Insulating Core: Rigid insulation board.
 - 4. Seal perimeter joints between panel faces and louver frames with 1/8-by-1-inch PVC compression gaskets.

5. Panel Finish: Same finish applied to louvers.

2.9 ALUMINUM FINISHES

- A. High-Performance Organic-Coating Finish: AA-C12C42R1x (Chemical Finish: cleaned with inhibited chemicals; Chemical Finish: acid-chromate-fluoride-phosphate conversion coating; Organic Coating: as specified below). Prepare, pretreat, and apply coating to exposed metal surfaces to comply with coating and resin manufacturers' written instructions.
 1. Fluoropolymer Three-Coat Coating System: Manufacturer's standard three-coat, thermocured system consisting of specially formulated inhibitive primer, fluoropolymer color coat, and clear fluoropolymer topcoat, with both color coat and clear topcoat containing not less than 70 percent polyvinylidene fluoride resin by weight; complying with AAMA 2605.
 - a. Color and Gloss: As selected by Engineer from manufacturer's full range.

2.10 GALVANIZED-STEEL SHEET FINISHES

- A. Finish louvers after assembly.
- B. Surface Preparation: Clean surfaces with nonpetroleum solvent so surfaces are free of oil and other contaminants. After cleaning, apply a conversion coating compatible with the organic coating to be applied over it. Clean welds, mechanical connections, and abraded areas and repair according to ASTM A 780.
- C. Baked-Enamel or Powder-Coat Finish: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked-on finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of 2 mils (0.05 mm).
 1. Color and Gloss: As selected by Architect from manufacturer's full range.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and openings, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Coordinate setting drawings, diagrams, templates, instructions, and directions for installation of anchorages that are to be embedded in concrete or masonry construction. Coordinate delivery of such items to Project site.

3.3 INSTALLATION

- A. Locate and place louvers and vents level, plumb, and at indicated alignment with adjacent work.
- B. Use concealed anchorages where possible. Provide brass or lead washers fitted to screws where required to protect metal surfaces and to make a weathertight connection.

- C. Form closely fitted joints with exposed connections accurately located and secured.
- D. Provide perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.
- E. Repair finishes damaged by cutting, welding, soldering, and grinding. Restore finishes so no evidence remains of corrective work. Return items that cannot be refinished in the field to the factory, make required alterations, and refinish entire unit or provide new units.
- F. Protect galvanized and nonferrous-metal surfaces from corrosion or galvanic action by applying a heavy coating of bituminous paint on surfaces that will be in contact with concrete, masonry, or dissimilar metals.
- G. Install concealed gaskets, flashings, joint fillers, and insulation as louver installation progresses, where weathertight louver joints are required. Comply with Division 7 Section "Joint Sealants" for sealants applied during louver installation.

3.4 ADJUSTING AND CLEANING

- A. Clean exposed surfaces of louvers and vents that are not protected by temporary covering, to remove fingerprints and soil during construction period. Do not let soil accumulate until final cleaning.
- B. Before final inspection, clean exposed surfaces with water and a mild soap or detergent not harmful to finishes. Thoroughly rinse surfaces and dry.
- C. Restore louvers and vents damaged during installation and construction so no evidence remains of corrective work. If results of restoration are unsuccessful, as determined by Engineer, remove damaged units and replace with new units.
 - 1. Touch up minor abrasions in finishes with air-dried coating that matches color and gloss of, and is compatible with, factory-applied finish coating.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10213
FIXED LOUVERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. Section Includes:
 - 1. Fixed, extruded-aluminum louvers.

1.3 DEFINITIONS

- A. Louver Terminology: Definitions of terms for metal louvers contained in AMCA 501 apply to this Section unless otherwise defined in this Section or in referenced standards.
- B. Horizontal Louver: Louver with horizontal blades (i.e., the axes of the blades are horizontal).
- C. Drainable-Blade Louver: Louver with blades having gutters that collect water and drain it to channels in jambs and mullions, which carry it to bottom of unit and away from opening.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. For louvers specified to bear AMCA seal, include printed catalog pages showing specified models with appropriate AMCA Certified Ratings Seals.
- B. Shop Drawings: For louvers and accessories. Include plans, elevations, sections, details, and attachments to other work. Show frame profiles and blade profiles, angles, and spacing.
 - 1. Show weep paths, gaskets, flashing, sealant, and other means of preventing water intrusion.
 - 2. Show mullion profiles and locations.
- C. Delegated-Design Submittal: For louvers indicated to comply with structural and seismic performance requirements, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Test Reports: Based on evaluation of comprehensive tests performed according to AMCA 500-L by a qualified testing agency or by manufacturer and witnessed by a qualified

testing agency, for each type of louver and showing compliance with performance requirements specified.

1.6 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."

1.7 FIELD CONDITIONS

A. Field Measurements: Verify actual dimensions of openings by field measurements before fabrication.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Source Limitations: Obtain louvers from single source from a single manufacturer where indicated to be of same type, design, or factory-applied color finish.

2.2 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design louvers, including comprehensive engineering analysis by a qualified professional engineer, using structural and seismic performance requirements and design criteria indicated.

B. Structural Performance: Louvers shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated without permanent deformation of louver components, noise or metal fatigue caused by louver-blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act normal to the face of the building.

1. Wind Loads: Determine loads based on a uniform pressure of 20 lbf/sq. ft., acting inward or outward.

C. Seismic Performance: Louvers, including attachments to other construction, shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

D. Louver Performance Ratings: Provide louvers complying with requirements specified, as demonstrated by testing manufacturer's stock units identical to those provided, except for length and width according to AMCA 500-L.

E. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes.

1. Temperature Change (Range): 120 deg F, ambient; 180 deg F, material surfaces.

- F. SMACNA Standard: Comply with recommendations in SMACNA's "Architectural Sheet Metal Manual" for fabrication, construction details, and installation procedures.

2.3 **FIXED, EXTRUDED-ALUMINUM LOUVERS**

A. Horizontal, Drainable-Blade Louver:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Greenheck Fan Corporation.
 - b. Louvers & Dampers; a division of Mestek, Inc.
2. Louver Depth: 6 inches.
3. Frame and Blade Nominal Thickness: Not less than 0.125 inch.
4. Mullion Type: Exposed.
5. Louver Performance Ratings:
 - a. Free Area: Not less than 9.03 sq. ft. for 48-inch-wide by 48-inch-high louver.
 - b. Point of Beginning Water Penetration: Not less than 1000 fpm.
 - c. Air Performance: Not more than 0.10-inch wg static pressure drop at 850-fpm free-area exhaust and intake velocity.
6. AMCA Seal: Mark units with AMCA Certified Ratings Seal.

2.4 **LOUVER SCREENS**

A. General: Provide screen at each exterior louver.

1. Screen Location for Fixed Louvers: Interior face.
2. Screening Type: Bird screening.

B. Secure screen frames to louver frames with stainless-steel machine screws, spaced a maximum of 6 inches from each corner and at 12 inches o.c.

C. Louver Screen Frames: Fabricate with mitered corners to louver sizes indicated.

1. Metal: Same type and form of metal as indicated for louver to which screens are attached. Reinforce extruded-aluminum screen frames at corners with clips.
2. Finish: Same finish as louver frames to which louver screens are attached.
3. Type: Rewirable frames with a driven spline or insert.

D. Louver Screening for Aluminum Louvers:

1. Bird Screening: Stainless steel, 1/2-inch- square mesh, 0.047-inch wire.

2.5 BLANK-OFF PANELS (IF NOTED ON DRAWINGS)

- A. Insulated, Blank-Off Panels: Laminated panels consisting of an insulating core surfaced on back and front with metal sheets and attached to back of louver.
 - 1. Metal Facing Sheets: Aluminum sheet, not less than 0.032-inch nominal thickness.
 - 2. Metal Facing Sheets: Galvanized-steel sheet, not less than 0.028-inch nominal thickness.
 - 3. Metal Facing Sheets: Stainless-steel sheet, not less than 0.031-inch nominal thickness.
 - 4. Insulating Core: Rigid, glass-fiber-board insulation.
 - 5. Edge Treatment: Trim perimeter edges of blank-off panels with louver manufacturer's standard extruded-aluminum-channel frames, not less than 0.080-inch nominal thickness, with corners mitered and with same finish as panels.
 - 6. Seal perimeter joints between panel faces and louver frames with gaskets or sealant.
 - 7. Panel Finish: Same finish applied to louvers.
 - 8. Attach blank-off panels with sheet metal screws.

2.6 MATERIALS

- A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5, T-52, or T6.
- B. Aluminum Sheet: ASTM B 209, Alloy 3003 or 5005 with temper as required for forming, or as otherwise recommended by metal producer for required finish.
- C. Fasteners: Use types and sizes to suit unit installation conditions.
 - 1. Use tamper-resistant screws for exposed fasteners unless otherwise indicated.
 - 2. For fastening aluminum, use aluminum or 300 series stainless-steel fasteners.
 - 3. For color-finished louvers, use fasteners with heads that match color of louvers.
- D. Postinstalled Fasteners for Concrete and Masonry: Torque-controlled expansion anchors, made from stainless-steel components, with capability to sustain, without failure, a load equal to 4 times the loads imposed, for concrete, or 6 times the load imposed for masonry, as determined by testing according to ASTM E 488, conducted by a qualified independent testing agency.

2.7 FABRICATION

- A. Factory assemble louvers to minimize field splicing and assembly. Disassemble units as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation.
- B. Maintain equal louver blade spacing, including separation between blades and frames at head and sill, to produce uniform appearance.
- C. Fabricate frames, including integral sills, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.
 - 1. Frame Type: Exterior flange unless otherwise indicated.
- D. Include supports, anchorages, and accessories required for complete assembly.

- E. Provide vertical mullions of type and at spacings indicated, but not more than is recommended by manufacturer, or 72 inches o.c., whichever is less.
 - 1. Fully Recessed Mullions: Where indicated, provide mullions fully recessed behind louver blades. Where length of louver exceeds fabrication and handling limitations, fabricate with close-fitting blade splices designed to permit expansion and contraction.
 - 2. Exterior Corners: Prefabricated corner units with mitered and welded blades and with fully recessed mullions at corners.
- F. Provide subsills made of same material as louvers for recessed louvers.
- G. Join frame members to each other and to fixed louver blades with fillet welds concealed from view unless otherwise indicated or size of louver assembly makes bolted connections between frame members necessary.

2.8 ALUMINUM FINISHES

- A. Finish louvers after assembly.
- B. Color Anodic Finish: AAMA 611, AA-M12C22A42/A44, Class I, 0.018 mm or thicker.
 - 1. Color: Black.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and openings, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Coordinate setting drawings, diagrams, templates, instructions, and directions for installation of anchorages that are to be embedded in concrete or masonry construction. Coordinate delivery of such items to Project site.

3.3 INSTALLATION

- A. Locate and place louvers level, plumb, and at indicated alignment with adjacent work.
- B. Use concealed anchorages where possible. Provide brass or lead washers fitted to screws where required to protect metal surfaces and to make a weathertight connection.
- C. Form closely fitted joints with exposed connections accurately located and secured.

- D. Provide perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.
- E. Protect unpainted galvanized and nonferrous-metal surfaces that are in contact with concrete, masonry, or dissimilar metals from corrosion and galvanic action by applying a heavy coating of bituminous paint or by separating surfaces with waterproof gaskets or nonmetallic flashing.
- F. Install concealed gaskets, flashings, joint fillers, and insulation as louver installation progresses, where weathertight louver joints are required. Comply with Section 07920 "Joint Sealants" for sealants applied during louver installation.

3.4 ADJUSTING AND CLEANING

- A. Clean exposed louver surfaces that are not protected by temporary covering, to remove fingerprints and soil during construction period. Do not let soil accumulate during construction period.
- B. Before final inspection, clean exposed surfaces with water and a mild soap or detergent not harmful to finishes. Thoroughly rinse surfaces and dry.
- C. Restore louvers damaged during installation and construction so no evidence remains of corrective work. If results of restoration are unsuccessful, as determined by Architect, remove damaged units and replace with new units.
 - 1. Touch up minor abrasions in finishes with air-dried coating that matches color and gloss of, and is compatible with, factory-applied finish coating.

PART 4 - EXECUTION

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10261

MISCELLANEOUS SPECIALTIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items:
1. Platform and lobby benches.
 2. Art Benches (MBTA approved artist).
 3. Bomb-mitigating trash containers.
 4. Tables, Desks and Seating.

1.2 SUBMITTALS

- A. Shop Drawings: Submit complete shop drawings of all work of this Section to Engineer for approval, showing all pertinent details of construction and installation.
- B. Product Data: Submit complete manufacturer's product data of all work of this Section to Engineer for approval, consisting of complete product description and specifications, catalog cuts, and other descriptive data required for complete product and product use information.
- C. Samples: Provide samples of all materials to be exposed in the completed work.

1.3 PRODUCT DELIVERY, STORAGE AND HANDLING

- A. Deliver miscellaneous specialties to Project site, fully identified, and protected by padded blankets, scheduled to arrive at time of installation sequence requirements.
- B. Store units off ground, under cover, protected from weather and construction operations.
- C. Handle units during transportation and installation in a manner that prevents racking or damage to finish or adjacent construction.

PART 2 - PRODUCTS

2.1 BOMB-MITIGATING TRASH CONTAINER

- A. Provide bomb-mitigating trash containers for installation at areas indicated on Drawings. All bomb- mitigating trash containers shall be manufactured by the same manufacturer. Bomb mitigating trash containers shall conform to the following:
1. Exterior Finish: Provide Stainless Steel.
 2. Size: 40 gallon.
 3. Standard: Provide bomb mitigating trash containers that conform to ASTM E2740 and ASTM E2639.

4. Approvals: Provide bomb mitigating trash containers that have been Safety Act approved by the Department of Homeland Security.
5. Provide units with manufacturer's optional frame with locking and disintegrating lids.

2.2 TABLES AND SEATING

A. Chairs:

1. Semi-Upholstered Swivel Chairs: Recycled aluminum, hand welded w/ brushed anodized finish.
 - a. Basis of Design: Emeco 1022 SW chair or approved equal.
 - b. Quantity: (9) nine chairs.
2. Stacking Chair: Polyimide shell, w/ chrome base standard.
 - a. Basis of Design: Hightower Four Cast Line Stacker #FC13200A or approved equal.
 - b. Quantity: (8) eight chairs.
3. Lounge Chair: Fully upholstered w/ chrome post legs standard.
 - a. Basis of Design: Berliner Lounge #S3911 or approved equal.
 - b. Quantity: (6) six chairs.
4. 3-Seat Sofa: Fully upholstered w/ chrome post legs standard.
 - a. Basis of Design: Berliner Sofa- 3 Seat #S3918 or approved equal.
 - b. Quantity: (1) one sofa.
5. Ergonomic Task Chair: Upholstered flexogel seat with flexible, breathable mesh back, w/ 5- star castered base, height adjustable seat and arms.
 - a. Basis of Design: Liberty Chair by Humanscale or approved equal.
 - b. Quantity: (5) five chairs.

B. Tables:

1. Stainless Steel table with casters
 - a. Basis of Design: Quovis Table #1181 or approved equal
 - b. Quantity: (1) one.
2. Solid Surface 42" round table with #90230-28.5" flat bottom stainless steel pedestal base, with adjustable glides
 - a. Basis of Design: Beaufurn #1205-ST stainless steel base and 42" round Solid Surface top or approved equal
 - b. Quantity: (2) two tables.
3. Cast resin round occasional table, 20" diameter, 18" high.
 - a. Basis of Design: Hightower Martini round occasional table #HT9450B or approved equal
 - b. Quantity: (3) three tables.
4. 72" x 30" Desk with Single Box, box, file pedestal. Locking drawers. Steel frame, laminate top,

- a. Basis of Design: Desk by Steelcase, Knoll, or Herman Miller
- b. Quantity: (1) one desk.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. All items furnished under this Section shall be installed in strict accordance with the approved shop drawings and the manufacturer's printed instructions and recommendations.

PART 4 - MEASUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10290

BIRD CONTROL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Post-and-wire bird deterrent.
 - 2. Spike bird deterrent.
 - 3. Electrified tape bird deterrent systems at locations indicated.
 - 4. Area mesh system at locations indicated.

1.2 QUALITY ASSURANCE

- A. Source: Provide bird control systems that are the products of one manufacturer.
- B. Locations on Drawings indicate the intent of the design with the understanding that locations of equipment, adjustments in the spacing of the wires, and the dimensions that the wires are held off the protected surfaces may be adjusted or modified as necessary to provide guarantees.
- C. Installer Qualification Standard
 - 1. The installer must provide evidence of at least 3 similar projects in size and complexity which have been performed by the contractor.
 - 2. The installer must provide individual qualifications and past projects history of each installer who will work on this project.

1.3 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, certified performance data and finish specifications. Provide certifications stating that materials comply with requirements.
- B. Shop Drawings: Provide large scale shop drawings for fabrication, installation and erection of all parts of the work. Provide elevations and details of anchorages, connections and accessory items. Indicate joinery, fasteners and all other relevant information.
- C. Field Measurements: Take accurate field measurements before preparation of shop drawings and fabrication. Do not delay job progress.
- D. Samples: Submit representative samples of each material that is to be exposed in the finished work.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Deliver, store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from damage.
- B. Sequence deliveries to avoid delays, but minimize on-site storage.

1.5 WARRANTIES

- A. Provide a written warranty, signed by the manufacturer, installer, and Contractor, that birds will not perch or roost on the surfaces where anti-perching system is installed in locations indicated on Drawings.

1. Warranty period: 3 years from date of Final Acceptance.

PART 2 - PRODUCTS

2.1 PRODUCTS

- A. Post and Wire Anti-Roosting System

1. Basis of Design: Bird Wire and Post by Bird-X, BirdBGone, Bird Control Systems or equal.
- a. Stainless Steel Wire Cable: 1x7 nylon-coated, 0.7 mm diameter.
 - b. Posts: Stainless steel with flattened heads with hold for wire.
 - c. Accessories including weatherproof glue-on bases, railing clamps, springs and crimps as applicable.

- B. Electrified Tape Bird Deterrent System

1. Basis of Design: Provide BirdMaster Bird Control Systems, BirdMaster Voltape System, or approved equal, with the following:
- a. Clear acrylic tape with aluminum flat wire and pressure sensitive adhesive with peel off backing.
 - b. UL Approved 115VAC Line Chargers, Input Voltage: 115 VAC, 60mhz.
 - c. UL Approved Solar Line Chargers, Input Voltage: 6VDC, 4.5 amp rechargeable battery included- 2 year lifespan; Range: up to 1,000 feet (610 M).
 - d. Jumper Wire, Rating: 20KV
 - e. Aluminum Sleeves, use aluminum sleeves to make all wire and tape connections.

- C. Wire Mesh Area Bird Deterrent

1. Basis of Design: Provide Bird Control Systems, BirMaster, or approved equal.
- a. Mesh: Light gauge stainless steel mesh and anchors at locations indicated on the drawings.

- D. Spike Bird Deterrent

1. Basis of Design: Stainless Steel Spikes by Bird-X, BirdBGone, Bird Control Systems or equal
- a. Spikes: Bird-X Spikes, stainless steel with flexible base, width and height as required for application.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The Installer/Erector shall examine substrates, supports, and conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning of installation will be construed as installer accepting substrates and conditions.

3.2 INSTALLATION

- A. General Installation Requirements: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
- B. Holes to be drilled in mortar joints only where deemed necessary and be no more than 3/16" in diameter and 1" deep or as recommended by manufacturer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 MEASUREMENT AND PAYMENT

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10340

LIGHTWEIGHT TRENCH COVERS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies the following items:
1. Design, fabrication and installation of prefabricated lightweight trench covers made of Fiber Reinforced Plastic (FRP) for use on viaduct conduit enclosures.
 2. Field verification of as-built layout of constructed conditions prior to fabrication of covers.
 3. Installation of sealants and caulking of covers joints as indicated in this specification and or as required by design.
 4. Temporary protection of installed covers prior to full system operation.
- B. Related Work: The following items are not included in this Section and will be performed under the designated Sections:
1. PROTECTION OF WORK AND PROPERTY – Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements”.
 2. TEMPORARY CONTROLS – Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements”.
 3. SUSTAINABILITY REQUIREMENTS – Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements”.
 4. Section 03300 – CAST-IN-PLACE CONCRETE.
 5. Section 05041 – HOT DIP GALVANIZING.
 6. Section 05122 – STRUCTURAL STEEL FOR RAIL STRUCTURES.
 7. Section 05500 – MISCELLANEOUS METALS.
- C. Trench Covers:
1. Lightweight FRP covers shall be used as the standard type for viaduct conduit enclosure.
 2. The covers and associated hardware shall meet the structural and finish requirements as specified in this specification section.
 3. FRP covers shall be used in the spaces between ballast retainer stem walls and exterior viaduct parapet structure walls and at any other locations as required by design. The covers and associated hardware shall meet the specified structural and finish requirements and are intended to perform as a walkway surface. Conduit enclosures under the walkways will be used for all systemwide cables.
 4. Covers and associated hardware shall meet or exceed the following minimum design requirements:
 - a. Cover assemblies shall be designed to support a uniform live load of 100 pounds per square foot and a concentrated live load of 1,000 pounds over a 1 foot by 1 foot area

without damage to any trench components. Deflection at center of span under 100 pounds per square foot shall not be more than 1/16 inch.

- b. Stationary and hinged cover assemblies shall provide a walking surface. Abutting joint surfaces shall not produce a tripping hazard by misalignment of more than a 1/8 inch. Ends of each unit shall be configured and manufactured to interlock in such a manner that units will remain connected and aligned under the above specified live loads and normal environmental conditions.
- c. Walking surfaces of covers shall have a non-slip and non-skid surface.
- d. Covers shall be protected from ultraviolet deterioration. Plastic resins for cover manufacture shall be formulated to provide extremely low smoke (ELS) generation as specified in this specification section.

1.2 REFERENCES

- A. The publications listed below, latest revision applicable, form a part of this specification to the extent referenced herein. The publications are referred herein by the text designation only.
 - 1. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM), ASTM D 635 Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position.
 - 2. ASTM E 84 Surface Burning Characteristics of Building Materials.

1.3 SUBMITTALS

- A. Final approval for incorporation into the project will be made only after the review of shop drawings, specifications, and data as follows.
 - 1. Cover Manufacture qualifications as described in subsection 1.4.A.
 - 2. Shop drawings shall be complete with all As-Built field dimensions, anchor locations, details of connecting items and the size and locations of any required openings. In addition, setting drawings shall be submitted indicating each specific cover panel and its location on the viaduct structure.
 - 3. Specifications for all components shall be provided. Details of the major fabricated components showing the arrangement of components and labeled with component sizes and materials of construction shall be submitted.
 - 4. Structural design calculations, sealed and signed by a Professional Engineer registered in the Commonwealth of Massachusetts, engaged by the Design-Builder, for all components shall be submitted.
 - 5. Manufacturer's recommended procedures for job site storage of equipment, handling, and erection shall be submitted.
 - 6. Manufacturer's internal fabrication Quality Control and Quality Assurance program indicating how the fabricator evaluates and confirms the material usage and completed production cover panels.

- B. The Design-Builder shall submit sample pieces of each item specified herein for acceptance by the MBTA as to quality, finish and color. Sample pieces shall be manufactured by the method to be used in the work. Sample sizes shall have a minimum length and width of 12 inches, and thickness of the item being represented. Samples shall represent the final production units.
- C. The Design-Builder shall submit a reference List of prior projects of similar size, providing a description of the project, location of project, year and date of project start and completion, project owner address and contact and general contractor responsible for final installation. A minimum of 10 projects shall be listed.
- D. Design Calculations:
 - 1. As part of the shop drawings for the cover components, the fabricator shall supply any and all analyses pertinent to the composite design. The calculations shall include standard strength of materials approaches and computerized finite element analyses of sections where conventional methods do not apply. Furthermore, for the calculated loads, a complete laminate analysis shall be submitted identifying the various factors of safety for the proposed laminate schedule. Factors of safety shall be evaluated using criteria such as Tsai-Hill or equivalent theories.
 - 2. The evaluation of deflection and stresses on panel sections under uniform loading shall incorporate numerical analysis calculations.
 - 3. The calculations shall fully consider the access openings or access hatches within each cover panel.
 - 4. A written narrative that clearly states all of the basic design assumptions and parameters shall accompany the computerized calculations.
 - 5. Approval by the MBTA shall not relieve the manufacturer of responsibility for providing materials and designs conforming to the intent of these specifications.
 - 6. Complete structural design calculations and drawings shall be submitted as required herein.
 - 7. Design calculations and drawings shall be approved and stamped by a registered Professional Engineer registered in the Commonwealth of Massachusetts, engaged by the Design-Builder.

1.4 QUALITY ASSURANCE

- A. Qualifications: Cover manufacturer shall have a minimum of five (5) years history of successful fabrication and installations of similar size project and covers. Past job list with customer contact information will be required.
- B. Manufacturer's Quality Control: All fabrication shall be carefully inspected at the site of fabrication by factory inspectors who shall use whatever means necessary to assure the proper fit of all field connections and compliance with all material and fabrication requirements of the specifications.
- C. Warranty: A general warranty of the fabricated covers and associated hardware for materials and workmanship shall be for a minimum of five (5) year after installation.
- D. The Design-Builder and cover fabricator shall be responsible for verifying and coordinating all field dimensions to develop fabrication shop drawings. No fabrication shall take place until shop drawings are approved by the MBTA.

1.5 PRODUCT DELIVERY AND STORAGE

- A. Delivery of Materials: Manufactured materials shall be delivered in original, unbroken pallets, packages, containers, or bundles bearing the label of the manufacturer and location of manufacture.
- B. Storage of Products: All materials shall be carefully handled to prevent damage from abrasion, cracking, chipping, twisting, and other deformations, and other types of damage. Cover units and other materials for installation, shall be kept in an environmentally controlled enclosure until they are ready for final placement within the viaduct structure.

PART 2 - PRODUCTS

2.1 FIBERGLASS REINFORCED PLASTIC (FRP)

- A. FRP materials for covers shall be manufactured from a mineral-filled, continuous strand roving-mat reinforced, thermoset unsaturated polyester electrical insulating laminate, conforming to NEMA L1-1, Grade GPO-3, Polyester Glass Mat Sheet Laminates.
- B. Covers shall be manufactured from fiberglass-reinforced, extremely low smoke reinforced acrylic (ELSRA) resin that meets the requirements of these Specifications. The reinforcements and the resins used in the laminate shall provide the strength required in the longitudinal and transverse directions and the service conditions of chemical resistance and electrical insulating properties, as well as temperature, weather (ultraviolet light), and water resistance. All formulated resins shall have 0.2% to 0.3% ultraviolet absorber (UV 5411) added.
- C. FRP Cover Physical Requirements:
 - 1. Covers are a walking surface. They shall conform to design details and applicable requirements of Title 29 CFR 1910, Walking Working Surfaces, and shall be provided with a non-slip and non-skid surface. Smoke density and flame spread test shall be performed on covers after the non-slip and non-skid surface has been applied.
 - 2. Cover assemblies shall be capable of supporting a uniform live load of 100 pounds per square foot or a concentrated live load of 1,000 pounds over a 1 foot by 1 foot area. Deflection at center of span at 100 pounds per square foot loading shall not be more than 1/16 inch.
 - 3. Covers shall not exceed 30 pounds per unit.
 - 4. Fabrication:
 - a. FRP covers shall be produced by the cast/lay-up process with the cover, cast in the mold as one-piece finished product.
 - b. The color of the covers shall be light gray. The color shall be uniformly dispersed throughout the entire cover.
 - c. FRP covers shall consist of straight lateral load bearing bars extending in the direction of the span and perpendicular cross bars extending across the bearing bars with the surface cast-into-place at the same time to form a continuous one-piece construction. A skid-resistant surface shall be cast into the top of the cover at the time of manufacture while the cover is in the mold.

- d. Various selected additives shall be combined with the resin system to achieve ultra violet (weather) resistance. Fire retardant and smoke toxicity requirements in this specification section specified shall be achieved by using selected additives.
- e. Covers for conduit enclosure shall be capable of being hinged to sidewalls as required by design.
- f. Covers shall be one piece cast or molded unit with provision for lifting.
- g. Bolt or screws used to fasten covers to conduit enclosure shall be type 316 stainless steel.
- h. A minimum ½ inch diameter fastener size shall be used at a maximum spacing of 12 inches along each supporting side of cover.
- i. Depth: As required to accomplish strength and deflection requirements listed above. As a minimum, all supporting edges of cover shall be 2 inches thick. Depth dimension shall be submitted for review and approval of the MBTA. Tolerance on the approved depth dimension shall be plus or minus 1/32 inches.

D. FRP components shall exhibit the following properties when tested in accordance with specified test methods:

Property/Test Procedure	Value
Flexural Strength per ASTM D790	25,000 psi, minimum
Flexural Modulus per ASTM D790	1.0x10 ⁶ psi, minimum
Tensile Strength per ASTM D638	17,000 psi, minimum
Tensile Modulus per ASTM D638	9.0x10 ⁵ psi, minimum
Impact Strength per ASTM D256	25 ft-lb/in, minimum
Dielectric Strength per ASTM D149 (0.25 in.)	170 volts/mil, minimum
Arc Resistance per ASTM D495	180 seconds, minimum
Water Absorption per ASTM D570	0.2%, maximum
Thermal Expansion per ASTM D696	6 to 10 x 10 ⁶ in/in/°F, maximum
Flame Spread Index per ASTM E84	20 maximum
Flame Resistance per UL 94	UL 94 V-0, minimum
Tracking Resistance per ASTM D2303	600 minutes, minimum

Specific Optical Smoke Density per ASTM E662 (Flaming & Non-Flaming) 10 maximum within 4 minutes after start of test and 200 maximum at end of test.

- E. Smoke toxicity of gases emitted or produced from FRP components shall not exceed the following permissible values when tested in accordance with DDC Report No. AD297457:

Gases	Maximum Permissible Level (PPM)
Hydrogen Chloride	10
Hydrogen Bromide	10
Hydrogen Cyanide	10
Hydrogen Sulfide	10
Vinyl Chloride	10
Ammonia	500
Aldehydes	30
Oxides of Nitrogen	100
Carbon Dioxide	15,000
Carbon Monoxide	1,000

- F. Cover surfaces, shall be treated or coated with 1-1/2 mils of polyvinyl fluoride containing an ultraviolet ray inhibitor. The polyvinyl fluoride shall be integrally manufactured into the surface. Bonding of polyvinyl fluoride film on the cover surface using an adhesive is acceptable subject to the MBTA's approval. The cover fabricator shall submit proposed adhesive, bonding procedures, and test procedures to demonstrate long-term performance of the adhesion. Spraying or painting of a polyvinyl fluoride paint or coating material will not be acceptable.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Prior to any fabrication, manufacture and Design-Builder shall field measure supports, and shall coordinate final production fabrication with these field dimensions, making adjustments as needed in each cover unit.
- B. Manufacture shall inform the Design-Builder of any unacceptable field conditions prior to fabrication. Design-Builder shall promptly fix unacceptable conditions. Any additional costs associated with fixing unacceptable conditions will be borne by the Design-Builder.

3.2 PREPARATION

- A. Covers:
1. Shop Assembly: The manufacturer shall pre-assemble a minimum of three (3) equal cover segments to a full scale layout to insure proper fit and assembly.

2. Fiberglass cutouts from cover segments shall be identified and shipped with covers. Cutouts will be used by the MBTA to determine proper thickness, glass content and laminate sequence.
3. Assembly of panel segments will be such as to allow all bolting to be performed from the exterior of cover.
4. Anchor bolts, assembly hardware, rail nut plates, hinges and lock sets shall be type 316 stainless steel.
5. Accurately locate bolt anchoring for cover in the structure supports by using jigs, templates, or other standardized measuring devices. Location accuracy shall be sufficient to permit covers to be raised and lowered without binding or engaging adjacent covers.
6. Covers shall be placed into the designated location and temporarily supported in place to allow for installation of supports.
7. Hinged covers shall be installed as required by design, with two hinges per panel. Where covers meet, a gap and vertical offset no greater than 1/8 inch will be permitted.
8. Stationary covers shall be installed with overlapping adjacent units and without creating a tripping hazard.

3.3 PROTECTION

- A. Cover Protection: Provide temporary coating or wrap on covers to prevent damage from adjacent construction activities. Remove temporary coating or wrap only upon direction of the MBTA prior to the full operation of the system.

3.4 REPAIRS

- A. Promptly repair damage to covers or adjacent construction due to cover installation. If covers cannot be repaired, Design-Builder shall replace the damaged units at no additional cost.

3.5 CLEANING

- A. Clean covers after installation of dust, dirt, and debris caused by installation operations. Provide temporary wrap/cover over installed covers to prevent following construction activities from marring or damaging the surfaces. Remove temporary wrap/cover only when the MBTA confirms that all adjacent construction work is complete and system is ready for operations.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

NOISE PANELS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies pre-fabricated absorptive acoustic barrier panels and attachment system including transparent acrylic noise barrier panels.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS
 - 2. Section 03410 – PLANT-PRECAST STRUCTURAL CONCRETE
 - 3. Section 05120 – STRUCTURAL STEEL FOR STATIONS AND BUILDINGS, for steel supporting members.
 - 4. Section 09900 PAINTING
- C. Alternate: if the design Builder elects to use precast concrete panels for noise mitigation, the performance and quality of the precast concrete panels shall meet or exceed what is specified under articles herein. The appearance and aesthetic of the precast concrete panels shall be subject to MBTA’s approval, and in the case of the Cambridge Viaduct to local and state Authorities Having Jurisdiction.

1.2 QUALITY ASSURANCE

- A. The following Codes, Regulations, Referenced Standards and Specifications apply to work included in this Section:
 - 1. Codes and Standards:
 - a. ASTM E-90: Standard Test method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions.
 - b. ASTM C423: Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method.
 - c. ASTM E413: Classification for Rating Sound Insulation
 - 2. Acoustical Performance:
 - a. The acoustical panel manufacturer will be required to submit acoustical performance data in the form of up-to-date test reports from an independent testing laboratory indicating the panel system to be provided will have the required Sound Transmission Class Rating. Tests shall be performed in accordance with ASTM E90 and ASTM E413.
 - b. The acoustical panel manufacturer will be required to submit acoustical performance data in the form of up-to-date test reports from an independent testing laboratory indicating the panel system to be provided will have the required Sound Absorption Coefficients. Tests shall be performed in accordance with ASTM C423.

1.3 SUBMITTALS

- A. Submit the following for approval in compliance with Submittals, Section 01300 and with the additional requirements as specified for each.
 - 1. Product Data:
 - a. Submit the following:
 - 1) Material list of items provided under this section.
 - 2) Manufacturer's specifications and other data needed to prove compliance with these specifications. Include specifications, standard details, certified product test results, installation instructions and general recommendations as applicable to materials and finishes for each component and for the total panel system.
 - 2. Shop Drawings: Submit shop drawings showing layout, profiles and product components, including anchorage, accessories, finish colors, patterns and textures.
 - 3. Samples: Submit selection and verification samples for finishes, colors and textures. Sample materials minimum 12" x 12" x depth of panel. Include any panel accessories as required.
 - 4. Quality Assurance Submittals: Submit the following:
 - a. Certificates: Product certificates and literature signed by the manufacturer certifying materials comply with specified performance characteristics and criteria, and physical requirements.
 - b. Manufacturer's Instructions: Manufacturer's printed installation and handling instructions.
 - c. Field Reports: Manufacturer's field reports supporting specified application.
 - 5. Closeout Submittals: Submit the following:
 - a. Operation and Maintenance Data: Include methods for maintaining installed products and precautions against cleaning materials and methods detrimental to finishes and performance.
 - b. Warranty documents as further specified.

1.4 WARRANTY

- A. Warrant fabricated panels to be free from defective workmanship for one (1) year from date of Substantial Completion.
- B. Warrant factory applied finishes to be free from fading, chalking or cracking for ten (10) years from date of Substantial Completion.
- C. Warranty for acrylic panels, minimum 20 years against change in light transmission of more than 2-15 percent when tested in accordance with ASTM D 1003.

PART 2 - PRODUCTS

2.1 PRE-CAST CONCRETE BARRIER PANELS

- A. Panel Construction: Materials used in the fabrication of precast wall components shall be resistant to damage caused by insects and rodents. Panels shall be constructed of materials according to Section

03410 – PLANT-PRECAST STRUCTURAL CONCRETE.

- B. Concrete Coatings: Shall be an acrylic coating with silane in accordance with Section 09900 PAINTING for exterior concrete and masonry. Protective coatings shall be applied to all permanently exposed faces of concrete surfaces
- C. Absorptive Surface: Noise absorptive concrete should be considered a coating subject to other provisions in the specifications; the manufacturer's cited standards, or proprietary materials.

2.2 PRE-CAST CONCRETE BARRIER PANEL PERFORMANCE

- A. Acoustical Performance: Minimum NRC (noise reduction coefficient) rating of 0.7 or greater and Sound Transmission Class (STC) of 30 or greater after barrier installation. To aid in preventing the transmission of noise through the barrier, the payout should minimize or eliminate gaps or openings. Typically gaps should be less than 3% of the surface area of the barrier and fill materials should be used to seal all gaps.
- B. Durability: Panels should be resistant to freeze-thaw cycles. Test should be conducted in accordance with ASTM C666 Method B for 300 cycles. The product should experience a maximum weight loss of no more than of 7% and no physical distress (no cracking or breaking).

2.3 PRE-CAST CONCRETE BARRIER PANEL FABRICATION

- A. Components of the precast concrete noise barrier shall be fabricated to conform to the shape, size, texture and reinforcing details as shown on approved submittals.

2.4 PRE-CAST CONCRETE BARRIER PANEL FINISH

- A. Precast noise walls color will be in accordance with Section 09900 - PAINTING. Panel colors shall be uniform throughout the panel as well as across all panels. The concrete finish will be that of the concrete absorptive material.

2.5 STEEL ACOUSTIC BARRIER PANELS

- A. Panel Construction: Individual panels shall have a width of 12 inches and 3-3/4" thick, or as indicated on Drawings. Construct panels of galvanized steel manufactured in accordance with the requirements of ASTM A924, coated to ASTM A653 specification class G-90. Panel components shall meet the following structural requirements:
 - 1. Perforated face sheets shall be 22gauge cold formed ASTM A-653 steel and has 3/16 inch diameter perforations in a 3/8 inch staggered pattern.
 - 2. Solid face back panel sheet shall be 16 gauge cold formed ASTM A-653 steel.
 - 3. Caps shall be the same material and thickness as the metal panels.
 - 4. Panel back tray shall be filled with mineral wool.
- B. Acoustic Fill: Mineral rock wool conforming to Federal Specifications HH-I-558B and ASTM Standard E-136 with a density of 6 pounds per cubic foot and the following characteristics.
 - 1. Non-hygroscopic and absorbs less than 1% water.
 - 2. Melts about 2,000 degrees Fahrenheit, has a flame spread of 15 or less, and smoke

development of 0 when tested in accordance with ASTM E84.

2.6 STEEL ACOUSTIC BARRIER PANEL PERFORMANCE

- A. Acoustical Performance: Minimum NRC (noise reduction coefficient) rating of 0.7 or greater and Sound Transmission Class (STC) of 30 or greater after barrier installation. To aid in preventing the transmission of noise through the barrier, the payout should minimize or eliminate gaps or openings. Typically gaps should be less than 3% of the surface area of the barrier and fill materials should be used to seal all gaps.

2.7 STEEL ACOUSTIC BARRIER PANEL FABRICATION

- A. The perforated and solid sheet shall be roll-formed to lengths up to an including 16'-0". The panel shall be assembled forming a non-welded, free draining module. Spot welds or mechanical fasteners shall not be acceptable. Fabric 8 panels to be rigid, need in appearance and free from defects, warp or buckle.
- B. The panel assembly shall be such so as to compress and hold the fill materials in place under severe conditions of vibration such as encountered in shipment, installation and operation. Any voids in the panel will be unacceptable.
- C. Internal panel reinforcement shall not the required as the maximum unsupported height of the fill shall not exceed the 24 inches and the length of 16 feet.
- D. The panel manufacturer, where required, shall provide openings for any large known penetrations.
Pipe and conduit penetrations shall be located and cut in field and sealed in accordance with manufacturer's instructions.
- E. No field welding.

2.8 STEEL ACOUSTIC BARRIER PANEL FINISH

- A. Powder Coating: after the module is formed it shall be factory coated utilizing a polyester powder coating system that is applied through the use of an electrostatic charge to ensure complete panel and edge coverage. The coating shall be thermally bonded to the surface of the galvanized steel. Finish coating shall have a drive film thickness of three mils.
- B. Corrosion Testing: modules shall prove testing for corrosion resistance in accordance with ASTM B117. After 2400 hours of exposure the coating system shall not failed due to blistering, loss of adhesion, or corrosion along the score lines.
- C. Weathering Testing: modules shall prove testing for accelerated whether ring in accordance with ASTM G23. After 2400 hours of testing, module samples shall not exhibit chalking less than No.8 per ASTM D 4214 or a color change greater than 5 and NBS units per ASTMD2244.

2.9 TRANSPARENT ACRYLIC NOISE BARRIER PANELS

- A. Acrylic Panels: Colorless rigid monolithic sheet complying with the following. Sheet thickness and mounting details as indicated on the Drawings.
 - 1. Performance Requirements:

- a. Tensile Strength, ASTM D 638: Greater than 9,250 psi.
 - b. Flexural Modulus, ASTM D 790: Greater than 445,000 psi.
 - c. Rockwell Hardness, ASTM D 785: M-90.
 - d. STC, ASTM E 90 / ASTM D 413: Greater than 27.
2. Optical Requirements:
- a. Light Transmission, ASTM D 1003: Greater than 90 percent.
 - b. Haze, ASTM D 1003: less than 1.5 percent.
 - c. Yellowness Index, ASTM E 313: Less than 1.
 - d. Self Ignition, ASTM D 1929: Greater than 650 degrees F.
3. Weathering Requirements: Comply with values below after 10 years. Provide manufacturer's compliance documentation if requested.
- a. Light Transmission, ASTM D1003: Greater than 88 percent.
 - b. Haze, ASTM D 1003: Less than 10 percent.
 - c. Tensile Strength, ASTM D 638: Greater than 80 percent of initial value.
 - d. Flexural Strength, ASTM D 790: Greater than 80 percent of initial value
4. Flammability Requirements:
- a. Resistance to Brush Fire, EN 1794-2: Minimum, Class 3.
 - b. Horizontal Burn Rate, ASTM D 635: Less than 2.5 in/min.
 - c. Smoke Density, ASTM D 2843, less than 50 percent.
5. Impact Resistance:
- a. Comply with EN 1794-1, Appendix C.
 - b. Meet ANSI Z97.1 for a safety glazing material.
 - c. Pass large missile impact test, ASTM E 1996-97/02.
6. Resistance to Roadside Chemicals: Calcium chloride, magnesium chloride, potassium acetate, calcium/magnesium acetate and sodium acetate.
7. Resistance to Fungi, ASTM G21: Zero rating, no signs of fungi grown after standard 28 day test period.
8. Bird Deterrence: Manufacturer's standard pattern capable of preventing in excess of 90 percent bird impacts. Pattern shall be an integral part of the panel, capable of withstanding graffiti removal efforts. Application of films in a secondary post production process is not acceptable.
9. Fabrication Tolerances: Minus 0, plus 0.25 inches.
10. Bolts and Fasteners: Type 316/316L stainless steel conforming to ASTM A 276.
11. Mounting Gaskets: As detailed on the Drawings.
12. Graffiti Remover: Provide a list of manufacturer's approved graffiti removal products.

PART 3 - EXECUTION

3.1 MANUFACTURER'S INSTRUCTIONS

- A. Compliance: Comply with manufacturer's product data, including product technical bulletins, product catalog installation instructions and product carton instructions.

3.2 PREPARATION

- A. Adjacent Surfaces Protection: Protect adjacent work areas and finish surfaces from damage during product installation.
- B. Adjacent Construction: Coordinate steel frame details and details of approved Shop Adjacent Construction: Coordinate steel frame details and details of approved Shop

3.3 INSTALLATION

- A. Panels: Install work in accordance with reviewed shop drawings and these specifications using only factory-trained personnel as required by the manufacturer and approved by the project manager.
 - 1. Block bottom panels in accordance with approved shop drawings.
 - 2. Ensure that panels are placed properly toward noise source and right side up.
 - 3. Be sure panels are properly seated before installing next.
- B. Acrylic Panels: Install work in accordance with reviewed shop drawings and these specifications using only factory-trained personnel as required by the manufacturer and approved by the project manager.
 - 1. Installation tolerances shall be not more than 0.25 inch difference between the two diagonals for squareness, and plus or minus 0.25 inches for out of flat.
 - 2. Attachment bolts shall be fully engaged with no exposed threads, and bolts shall not be cross threaded. Bolts shall be tested to confirm a torque of at least 30 ft-lbs.
 - 3. Gaskets shall be installed the full length, less up to 1/4 inch at each end of the U-channel section in which the sheet edge resides.

3.4 FIELD QUALITY CONTROL

- A. Upon completion of this portion of work, and prior to its acceptance by the Authority, security visit to the job site by a qualified representative of the manufacturer of the acoustical barrier system to confirm the installation is in conformance with the manufacturer's recommendations.

3.5 DEMONSTRATION

- A. Instruct maintenance personnel regarding operation and maintenance of acoustic barrier

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10501

PLASTIC LOCKERS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies solid plastic lockers.

1.2 SUBMITTALS

- A. Product Data: For each type of locker.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each type of locker.
- B. Shop Drawings: For plastic HDPE lockers.
 - 1. Include plans, elevations, sections, details, and attachments to other work.
 - 2. Show details full size.
 - 3. Show locations and sizes of furring, blocking, and hanging strips, including concealed blocking and reinforcement specified in other Sections.
 - 4. Show locations and sizes of cutouts and holes for items installed in lockers.
 - 5. Show locker fillers, trim, base, sloping tops, and accessories.
 - 6. Show locker numbering sequence.
- C. Samples for Verification: Furnish a physical sample of the material in the selected color.
 - 1. Size: 6 by 6 inch (102 by 102mm) in the type of finish specified.
- D. Qualification Data: For qualified Installer.
- E. Sample Warranty: For special warranty.
- F. Maintenance Data: For adjusting, repairing, and replacing locker doors and latching mechanisms to include in maintenance manuals.

1.3 QUALITY ASSURANCE

- A. Manufacturer Qualifications: Approved manufacturer listed in this section, with minimum 5 years of experience in the manufacture of plastic lockers.
- B. Installers Qualifications: An experienced Installer regularly engaged in the installation of lockers for a minimum of 3 years.
- C. Source Limitations: Obtain plastic lockers from and trim accessories from single manufacturer.

- D. Accessibility Requirements: Comply with requirements of ADA/ABA and with requirements of authorities having jurisdiction.
- E. Surface Binding Characteristics: As determined by testing identical products according to ASTM E84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
 - 1. Flame-Spread Index: 100 or less.
 - 2. Smoke-Developed Index: 450 or less.

1.4 DELIVERY, STORAGE, AND HANDLING

- A. Do not deliver plastic lockers to the site until the building is enclosed and HVAC systems are in operation. Deliver plastic lockers in manufacturer's original packaging. Store in an upright condition. Protect plastic lockers from exposure to direct sunlight.
- B. Ship plastic lockers fully assembled.
- C. Lift and handle plastic lockers from the base not the sides.

1.5 FIELD CONDITIONS

- A. Environmental Limitations: Do not deliver or install lockers until building is enclosed, wet work is complete, and HVAC system is operating and maintaining temperature between 60 and 90 degrees F (16 and 32 degrees C) and relative humidity between 43 and 70 percent during the remainder of the construction period.
- B. Field Measurements: Where lockers are indicated to fit to other construction, verify dimensions of other construction by field measurements before fabrication, and indicate measurements on Shop Drawings. Coordinate fabrication schedule with construction progress to avoid delaying the Work.
- C. Locate concealed framing, blocking, and reinforcements that support lockers by field measurements before being enclosed, and indicate measurements on Shop Drawings.
- D. Established Dimensions: Where lockers are indicated to fit to other construction, establish dimensions for areas where lockers are to fit. Provide allowance for trimming at site, and coordinate construction to ensure that actual dimensions correspond to established dimensions.

1.6 COORDINATION

- A. Coordinate sizes and locations of framing, blocking, furring, reinforcements, and other related units of work specified in other Sections to ensure that lockers can be supported and installed as indicated.

1.7 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace components of lockers against rust, delamination or breakage of plastic parts under normal use within specified warranty period.
 - 1. Warranty Period: 20 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Accessibility Requirements: For lockers indicated to be accessible, comply with applicable provisions in the U.S. Architectural & Transportation Barriers Compliance Board's ADA-ABA Accessibility Guidelines and ICC A117.1.M

2.2 PLASTIC- LOCKERS

- A. Basis-of-Design Product: Lenox Z-Lockers by Bradley Corp., or equal by Lyons, Penco or equal.
- B. Locker Configurations: Multiple height double tier units with full-height garment and half-height accessory storage compartments.
- C. Locker Dimensions:
 - 1. Height, Nominal: 72 inches.
 - 2. Width: 18 inches.
 - 3. Depth: 15 inches.
- D. Sides, Tops, Bottoms, Dividers, and Shelves: 3/8 inch thick HDPE plastic with smooth finish.
- E. Locker Tops: Individual slope top.
- F. Doors: Fabricate from a single piece 1/2 inch HDPE plastic.
 - 1. Doors and Frame: 1/2 inch thick HDPE plastic with matte texture finish, with ventilation slots.
 - 2. Handle: ADA/ABA-compliant handle fabricated from injection molded plastic.
 - 3. Locks: Standard Hasp.
 - 4. Hinges: Continuous piano hinges, 0.05 inch thick type 304 stainless steel fabricated to wrap around edges of door and frame and attached with stainless steel tamper-resistant screws.
 - a. Finish: Powder coated to match color of locker.
 - 5. Latching Bar: Full-height latch bar constructed of 1/2 inch HDPE plastic secured to locker with stainless steel tamper-resistant screws.
- G. Color: Charcoal Gray.
- H. Accessories: End Panels: Match style, material, construction, and finish of plastic doors.
 - 1. Coat Hooks: Black polycarbonate double hook.
 - 2. End Panels: 3/8 inch thick, with color and finish matching locker body.
 - 3. Filler Panels: 1/2 inch HDPE filler panel, with color and finish matching locker body, attached with 3/8 inch thick HDPE solid plastic angle bracket.
 - 4. Number Plate: Black painted aluminum with silver numbers. Provide one per locker.
 - 5. Locker Base: 1 inch solid HDPE plastic, with color and finish matching locker body, 4 inch high.

2.3 MATERIALS

- A. High Density Polyethylene (HDPE): 100 percent pre-consumer or post-consumer recycled content polyethylene thermoplastic formed under high pressure into solid plastic components.
- B. Stainless-Steel Sheet: ASTM A666, Type 304
- C. Fasteners: Tamper-Resistant Fasteners: Stainless steel torx-head screws.
 - 1. Locker Connectors: No 10-24 sex bolts.
 - 2. Anchors: Type and size required for secure anchorage.
 - 3. Drilled-in-place Masonry Anchors: Minimum 1/4 by 1-3/4 inch screws.

2.4 LOCKER FABRICATION

- A. Fabricate locker box from a single sheet of HDPE solid plastic with corners fused together. Weld frames and shelves to box assembly. Provide all welded construction of locker parts without dovetail slots or metal fasteners.
- B. Center Dividers: Full-depth, vertical partitions between bottom and shelf; finished to match lockers.
- C. Hardware Attachment: All hinges, handles, hasps, hooks, latch bars, and locks attached with tamper-resistant screws.
- D. Provide ventilated panels where indicated.
- E. Continuous Base: Set toe clearance 3 inch from locker front. Notch end caps for ease of installation.
- F. Sloping Tops: Manufacturer's optional individual slope tops fabricated in lengths indicated, without visible fasteners at splice locations; and finished to match lockers.
- G. Filler Panels: Fabricated in unequal leg angle shape; finished to match lockers.
- H. Finished End Panels: Fabricated with 3/8 inch wide edge dimension, configured to conceal fasteners and holes at exposed ends of plastic lockers.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine walls, floors, and support bases, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Verify that furring is attached to concrete and masonry walls that are to receive lockers.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install lockers in climate controlled environment, shielded from direct sunlight.

- B. General: Install on floor or other firm support. Install level, plumb, and true.
 - 1. Position locker base per approved shop drawing. Using fasteners provided by manufacturer, anchor base sections to the floor.
 - 2. Attach filler pieces to lockers with male-female sex bolts.
 - 3. Position first locker according to submittal layout. Square and plumb the locker using concealed shims. Secure the locker to the wall at the top and bottom of the locker. Position second locker next to the first, square and plumb to align the tops and bottoms; and temporary clamp lockers together. Drill four holes through the sides of the lockers and connect lockers using sex bolts provided by the manufacturer.
- C. Accessories: Fit exposed connections of trim, fillers and closures together to form tight, hairline joints, with concealed fasteners and splice plates furnished by locker manufacturer. Install as indicated on approved shop drawings.

3.3 FINAL CLEANING

- A. Clean locker interior and exterior surfaces.
- B. Remove packaging and construction debris and legally dispose of off-site.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 10520

FIRE EXTINGUISHERS AND CABINETS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the following items.
 - 1. Hand carried fire extinguishers.
 - 2. Fire extinguisher cabinets
 - 3. Surface mounted extinguisher support brackets.

1.2 QUALITY ASSURANCE

- A. Source: For each type of product required for the work of this section, provide products which are the products of one manufacturer.
- B. Provide portable extinguishers which bear the UL listing mark.

1.3 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions and recommendations. For cabinets in rated wall assemblies, cabinet and installation shall meet or exceed rating of assembly.
- B. Verification Samples: Submit representative samples of each material that is to be exposed in the finished work, showing the full range of color and finish variations expected. Provide samples having minimum area of 144 square inches.

1.4 DELIVERY, STORAGE AND HANDLING

- A. Deliver products in unopened factory labeled packages. Store and handle in strict compliance with manufacturers' instructions and recommendations. Protect from damage.
- B. Sequence deliveries to avoid delays, but minimize on-site storage.

PART 2 - PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Provide products of one of the following manufacturers that meet or exceed the requirements of these specifications:
 - 1. Potter Roemer LLC.
 - 2. J.L. Industries, Embassy Series.
 - 3. Larsens Manufacturing Co.

2.2 FIRE EXTINGUISHERS

- A. Multipurpose Dry-Chemical Type in Steel Container: UL-rated 20-A:120-B:C, 20-lb (9.1-kg) nominal capacity, with monoammonium phosphate-based dry chemical in red enameled-steel container.
 - 1. Basis-of-Design Product: Subject to compliance with requirements, provide Potter Roemer LLC; #3020 or comparable product by one of the specified manufacturer.
- B. Brackets: Provide manufacturer's standard stainless steel wall bracket that permits easy removal, but not accidental dislodgment.

2.3 FIRE-PROTECTION CABINET

- A. Cabinet Type: Suitable for fire extinguisher.
 - 1. Basis-of-Design Product: Subject to compliance with requirements, provide Potter Roemer LLC; or comparable product by one of the specified manufacturer.
- B. Cabinet Construction: Nonrated.
 - 1. Fire-Rated Cabinets: Construct fire-rated cabinets with double walls fabricated from 0.043- inch- (1.09-mm-) thick cold-rolled steel sheet lined with minimum 5/8-inch- (16-mm-) thick fire-barrier material. Provide factory-drilled mounting holes.
- C. Cabinet Material: Cold-rolled steel sheet.
- D. Recessed Cabinet:
 - 1. Trimless with Concealed Flange: Surface of surrounding wall finishes flush with exterior finished surface of cabinet frame and door, without overlapping trim attached to cabinet. Provide recessed flange, of same material as box, attached to box to act as drywall bead.
 - 2. Basis-of-Design Product: Subject to compliance with requirements, provide Potter Roemer LLC; Model 1716 or comparable product by one of the specified manufacturer.
- E. Surface-Mounted Cabinet: Cabinet box fully exposed and mounted directly on wall with no trim.
 - 1. Basis-of-Design Product: Subject to compliance with requirements, provide Potter Roemer LLC; Model 1756 or comparable product by one of the specified manufacturer.
- F. Cabinet Trim Material: Same material and finish as door.
- G. Door Material: Stainless-steel sheet.
- H. Door Style: Fully glazed panel with frame.
- I. Door Glazing: Tempered break glass (clear).
- J. Door Hardware: Manufacturer's standard door-operating hardware of proper type for cabinet type, trim style, and door material and style indicated.
 - 1. Provide manufacturer's standard.
 - 2. Provide continuous hinge, of same material and finish as trim permitting door to open 180 degrees.

K. Accessories:

1. Mounting Bracket: Manufacturer's standard steel, designed to secure fire extinguisher to fire-protection cabinet, of sizes required for types and capacities of fire extinguishers indicated, with plated or baked-enamel finish.
2. Break-Glass Strike: Manufacturer's standard metal strike, complete with chain and mounting clip, secured to cabinet.
3. Door Lock: Cylinder lock, keyed alike to other cabinets.
4. Identification: Lettering complying with authorities having jurisdiction for letter style, size, spacing, and location.
 - a. Identify fire extinguisher in fire-protection cabinet with the words "**FIRE EXTINGUISHER.**"
 - 1) Location: Applied to cabinet door.
 - 2) Application Process: Pressure-sensitive vinyl letters.
 - 3) Lettering Color: Red.
 - 4) Orientation: Vertical.

L. Materials:

1. Cold-Rolled Steel: ASTM A 1008/A 1008M, Commercial Steel (CS), Type B.
 - a. Finish: Baked enamel or powder coat.
 - b. Color: White.
2. Stainless Steel: ASTM A 666, Type 304.
 - a. Finish: No. 4 directional satin finish.
3. Tempered Break Glass: ASTM C 1048, Kind FT, Condition A, Type I, Quality q3, 1.5 mm thick.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The Contractor shall examine substrates, supports, and conditions under which this work is to be performed and notify Engineer, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Contractor accepts substrates and conditions.

3.2 INSTALLATION

- A. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.
- B. Securely install at heights indicated or, if not indicated, at heights acceptable to authorities having jurisdiction and the Engineer. If exact locations are not indicated, locate where field directed by Engineer.
- C. Fire-Protection Cabinets: Fasten cabinets to structure, square and plumb.

- D. Coordinate with work in other sections to ensure proper sequence, position, height and clearances.

3.3 ADJUSTING, CLEANING AND PROTECTION

- A. Adjust operating parts to work easily, smoothly, and correctly.
- B. Repair minor damage to eliminate all evidence of repair. Remove and replace work which cannot be satisfactorily repaired.
- C. Clean exposed surfaces using materials and methods recommended by manufacturer of product being cleaned. Remove and replace work that cannot be successfully cleaned.
- D. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

END OF SECTION

SECTION 10670

STORAGE SHELVING

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the Design-Builder shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier.:
 - 1. Board, peg, tool (EQ ID: 1005)
 - 2. Rack, storage, 72 bin (EQ ID: 1270)
 - 3. Rack, bulk storage, 2x6x6 (EQ ID: 1295)
 - 4. Rack, pallet, 8' (EQ ID: 1325)
 - 5. Rack, pallet, 12', with deck (EQ ID: 1330)
 - 6. Rack, pallet, 10', with deck (EQ ID: 1340)
 - 7. Rack, pallet, 16' high bay (EQ ID: 1345)
 - 8. Shelving unit, 18", 36" W, 7' High (EQ ID: 1511)
 - 9. Shelving unit, 18", 7' high (EQ ID: 1516)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The Design-Builder shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 - Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Division 1 - General Requirements.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the Design-Builder.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by the MBTA .

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer’s containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer’s recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Division 1 - General Requirements.

PART 2 – PRODUCTS

2.1 BOARD, PEG, TOOL (EQ ID: 1005)

- A. Manufacturer's Reference:
1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Kennedy Manufacturing Company, Van Wert, OH - (800) 413-8665
 - 1) Model: 50004
 2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Modern Metal Products, Owatonna, MN - (507) 451-0882
 - b. Trion Industries, Inc., Wilkes-Barre, PA - (570) 824-1000
- B. Capacities/Dimensions:
1. Overall dimensions (nominal):
 - a. Width: 72"
 - b. Height: 36"
 - c. Depth: ½"
- C. Features/Performance/Construction:
1. The panels shall be steel reinforced with square holed perforations. Flanged panels shall be reinforced to support heavy loads.
 2. Panels shall be capable of being attached to any surface that can support the weight of heavy tools (fasteners not included).
 3. Panels shall be manufactured of chip resistant material that will withstand abuse over time.
 4. The tool board shall be a standard four-panel set, including a 60-piece tool holder set.
 5. Hooks, clips, and accessories shall be heavy-duty steel and capable of locking onto the panel.
- D. Finish:
1. Gray, durable chip-resistant baked on finish.

2.2 RACK, STORAGE, 72 BIN (EQ ID: 1270)

- A. Manufacturer's Reference:
1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Equipto, Tatamy, PA - (610) 253-2775
 - 1) Model: 30528 w/ accessories
 2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Akro-Mils, Akron OH – (800) 253-2467
 - b. Tri-Boro Shelving and Partition Corp., Farmville, VA – (434) 315-5600

- B. Capacities/Dimensions:
 - 1. No. of shelves: 9
 - 2. No. of drawers: 72
 - 3. Shelf capacity: 350 lbs. per shelf
 - 4. Overall structure dimensions:
 - a. Height: 60"
 - 5. Bin dimensions
 - a. Width: 4 ¼"
 - b. Depth: 11"
 - c. Height: 2"
- C. Features/Performance/Construction:
 - 1. System components shall be adjustable for reconfiguration.
 - 2. System shall accommodate high-rise and multi-level applications.
- D. Finish:
 - 1. Durable enamel paint finish
 - 2. Standard color – Office gray. For other colors refer to the manufacturer color chart.

2.3 RACK, BULK STORAGE (EQ ID: 1295)

- A. Manufacturer's Reference:
 - 1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Equipto, Tatamy, PA - (610) 253-2775
 - 1) Model: 1027D62S starter unit
 - 2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Lyon Metal Products, Inc., Aurora, IL - (708) 892-8941
 - b. Modern Equipment Company, Inc., Omaha, NE - (402) 341-4939
- B. Capacities/Dimensions:
 - 1. Overall dimensions (nominal):
 - a. Length: 72"
 - b. Depth: 24"
 - c. Height: 84"
 - 2. Steel Decking capacity: 2,778 lbs./level
- C. Features/Performance/Construction:
 - 1. Construction: Continuously welded heavy gauge steel.
 - 2. Unit shall have three (3) lugs on each beam connector that locks securely to the posts.
 - 3. Adjustments: Adjusts on 1½" centers.
 - 4. The unit shall have three shelves with solid decking.
 - 5. Seismic bracing and anchorage shall be provided to meet any local, state, and national codes and provisions.
 - 6. Floor anchors shall be provided to fasten racks to floor.
- D. Finish:
 - 1. Durable enamel using the MBTA's choice from the manufacturer's standard color office gray.

2.4 RACK, PALLET, VARIOUS DIMENSIONS

A. Manufacturer’s Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer’s name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Lyon Workspace Products, Montgomery, IL, (630) 892-8941
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Justrite Manufacturing Co., Des Plaines, IL - (847) 298-9250
 - b. Equipto, Tatamy, PA - (610) 253-2775

B. Capacities/Dimensions

1. Capacity: 8,000 lbs. per pair of beams
2. Provide dimensions below.

Equipment ID #	1325	1345	1340	1330
<u>Overall Dimensions (Nominal)</u>				
Length	8'	9'	10'	12'
Height of highest level	10'	10'	10'	10'
Height of second level	5'	5'	5'	5'
Depth	42"	42"	42"	42"
Upright frames, part number	42M120	42M120	42M120	42M120
Beams, part number	S96	S108	S120	S144
Wire Decking, part number	WD4642H	WD5242H	WD5842H	WD4642H
Decking quantity, per level	2	2	2	3

3. Verify beam heights with MBTA prior to installation.

C. Features/Performance/Construction:

1. Rack shall be roll formed upright
2. Unit shall have tapered keyhole slots on 2" centers for vertical adjustment of beams.
3. Racks shall be interchangeable with other traditional teardrop designs.
4. Beams shall be welded, step-type, heavy gauge steel box channel.
5. Provide integral safety catch that automatically snaps and locks into place when beam is properly seated.
6. Provide at least one front –to-back support (Part Number FBSUP42) on units with beams 120” or longer.
7. Install racks level, plumb, and anchor all column posts to floor.
8. Provide 4” wall ties and attach all pallet racks to adjacent walls per manufacturer’s instructions.
9. Provide seismic bracing and anchorage to meet any local, state, and national codes and provisions.

D. Finish:

1. The unit shall have a baked on, corrosion resistant, powder epoxy finish.

2.5 SHELVING UNIT, 18", 36" W, 7' HIGH (EQ ID: 1511)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Equipto, Tatamy, PA - (610) 253-2775
 - 1) Model: 773-7S, with 773-7A Add-ons where applicable.
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Lyon Workspace Products, Montgomery, IL, (630) 892-8941
 - b. Stanley Vidmar, Allentown, PA - (800) 523-9462

B. Capacities/Dimensions:

1. No. of shelves: Seven (7)
2. Shelf capacity: 1,170 lbs. per shelf
3. Overall dimensions, nominal:
 - a. Width: 36"
 - b. Depth: 18"
 - c. Height: 84"
 - d. Installed height from finished floor (nominal):
 - 1) Bottom shelf: 4 ½"
 - 2) Top shelf: 84"
 - 3) Space the remaining bottom six shelves evenly, approximately 12" center to center, and the top two shelves 10 ½" center to center.
4. Weight: 170 lbs.

C. Features/Performance/Construction:

1. Shelf construction shall be double flange 18 gauge steel and double flanged box-formed edges on all four sides.
2. Uprights shall be double flanged uprights with tapered bracket slots punched on 1 ½" centers for vertical shelf adjustment.
3. Shelf fastening shall consist of slip-in shelf brackets which reinforce and securely lock the shelf into place in all four corners.
4. Units shall share common end panels with adjoining units. Back-to-back units shall be joined with common upright joints.
5. Provide one stand-alone unit where indicated. Add-on units shall be used for adjacent units.
6. Provide seismic bracing and anchoring to meet any local, state, and national codes and provisions.
7. Accessories:
 - a. Anchors: Floor, for seismic bracing, Equipto No. 190317A. Four (4) per starter unit and two (2) per add-on unit.

D. Finish:

1. Durable enamel using the MBTA's choice from the manufacturer's standard colors

2.6 SHELVING Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.

- a. Lyon Workspace Products, Montgomery, IL, (630) 892-8941
 - 1) Model: 8464H
 - 2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Equipto, Tatamy, PA - (610) 253-2775
 - b. Stanley Vidmar, Allentown, PA - (800) 523-9462
- B. Capacities/Dimensions:
- 1. No. of shelves: Six (6)
 - 2. Overall dimensions, nominal:
 - a. Width: 48”
 - b. Depth: 18”
 - c. Height: 84”
 - d. Installed height from finished floor (nominal):
 - 1) Space shelves evenly throughout the unit.
- C. Features/Performance/Construction:
- 1. Shelf construction shall be 22 gauge steel.
 - 2. All posts shall be punched on 1 1/2" centers with pairs of parallel slots 1 1/16" long with 1 slot keyhole-shaped for bolting cross braces and other accessories to uprights.
 - 3. Shelf fastening shall consist of slip-in shelf brackets which reinforce and securely lock the shelf into place in all four corners.
 - 4. Provide seismic bracing and anchoring to meet any local, state, and national codes and provisions.
- D. Finish:
- 1. Durable enamel using the MBTA’s choice from the manufacturer’s standard colors. Coordinate with MBTA to select color.

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the Architect or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer’s instructions:
 - 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.

2. **Fitting:** Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. **Anchorage:** Attach equipment as directed by the Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the Architect or designated representative for acceptance inspection.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 10801

TOILET ACCESSORIES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies toilet accessories as shown on the Drawings and as scheduled herein.
- B. Related Work:
 - 1. Section 06100, CARPENTRY; blocking.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated. Include the following:
 - 1. Construction details and dimensions.
 - 2. Anchoring and mounting requirements, including requirements for cutouts in other work and substrate preparation.
 - 3. Material and finish descriptions.
 - 4. Features that will be included for Project.
 - 5. Manufacturer's warranty.
- B. Product Schedule: Indicating types, quantities, sizes, and installation locations by room of each accessory required.
 - 1. Identify locations using room designations indicated on Drawings.
 - 2. Identify products using designations indicated on Drawings.
- C. Maintenance Data: For toilet accessories to include in maintenance manuals.

1.4 QUALITY ASSURANCE

- A. Source Limitations: For products listed together in the same articles in Part 2, provide products of same manufacturer unless otherwise approved by Engineer.
- B. Comply with ADA/ADAAG and MAAB requirements for accessibility.

1.5 COORDINATION

- A. Coordinate accessory locations with other work to prevent interference with clearances required for access by people with disabilities, and for proper installation, adjustment, operation, cleaning, and servicing of accessories.
- B. Deliver inserts and anchoring devices set into concrete or masonry as required to prevent delaying the Work.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. A & J Washroom Accessories, Inc.
 - 2. American Specialties, Inc.
 - 3. Bobrick Washroom Equipment, Inc.
 - 4. Bradley Corporation.
 - 5. General Accessory Manufacturing Co. (GAMCO).

2.2 MATERIALS

- A. Stainless Steel: ASTM A 666, Type 304, 0.0312-inch minimum nominal thickness, unless otherwise indicated.
- B. Galvanized Steel Mounting Devices: ASTM A 153/A 153M, hot-dip galvanized after fabrication.
- C. Fasteners: Screws, bolts, and other devices of same material as accessory unit and tamper-and theft resistant where exposed, and of galvanized steel where concealed.

2.3 FABRICATION

- A. General: Fabricate units with tight seams and joints, and exposed edges rolled. Hang doors and access panels with full-length, continuous hinges. Equip units for concealed anchorage and with corrosion-resistant backing plates.
- B. Keys: Provide universal keys for internal access to accessories for servicing and resupplying. Provide minimum of six keys to the Engineer.

2.4 TOILET ACCESSORIES SCHEDULE

- A. Basis-Of-Design: The following schedule of items are Bobrick catalog designations which are specified to establish standards of quality for performance and materials and not to limit competition. Provide the specified toilet accessories, or equal from another manufacturer listed above.
 - 1. Recessed Combination Waste Receptacle/Paper Towel Dispenser: Bobrick B-3961.
 - 2. Surface Mounted Combination Waste Receptacle/Paper Towel Dispenser: B-43949.
 - 3. Recessed Feminine Napkin Disposal: Bobrick B-353.
 - 4. Surface Mounted Feminine Napkin Disposal: Bobrick B-254
 - 5. Soap Dispenser: Bobrick B-826.18.
 - 6. Grab Bar with Concealed Mounting: Bobrick B-5806 x 42 w/ complete anchor and fastener kit.
 - 7. Grab Bar – Custom: Bobrick B-5806 (similar) Custom grab bar as shown on drawings.

8. Toilet Tissue Dispenser: Bobrick B-4288.
9. Mirror: Bobrick B-290 2436.
10. Hook: Bobrick B-7671.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Before installation of toilet accessories, check openings and recesses to receive recessed units to assure they are of proper size and location, and are plumb and square. Check substrate materials, blockings, and built-in anchor plates for structural adequacy to support the accessories.
- B. Mount recessed accessories securely into wall openings and recesses, tightly anchored into place, and with trim fitted tightly and neatly against the wall surface. Mount surface mounted accessories plumb, level, and true, and securely anchored into place.
- C. After installation, adjust all accessories for proper operation, and clean and polish all exposed surfaces. Protect accessories from damage from all sources whatever.
- D. Deliver to Authority duplicate keys for each lockable accessory door or panel, properly tagged as to location.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 11170

SOLID WASTE HANDLING EQUIPMENT

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the Design-Builder shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Compactor, stationary, trash, 40 cubic yard (EQ ID: 2123)
 - 2. Baler, vertical, heavy-duty (EQ ID: 2129)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The Design-Builder shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 - Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements".

- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Division 1 - General Requirements.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the Design-Builder.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by the MBTA.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Division 1 - General Requirements.

PART 2 – PRODUCTS

2.1 COMPACTOR, STATIONARY, TRASH, 40 CY. (EQ ID: 2123)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Marathon Equipment Company, Vernon, AL – (800)269-7237
 - 1) RJ-225 with RJ-40 OC Container
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. Komar Industries, Groveport, OH – (614) 836-2366
 - b. SP Industries, Hopkins, MI – (800) 592-5959

B. General Description:

1. This compactor is built for reliable performance in commercial and medium industrial situations. It effectively reduces solid waste material to a fraction of its original size. It features 56 second cycle time and powerful 55,100 lbs. maximum compaction force.

C. Capacity/Dimensions

1. Charge box capacity:
 - a. Mfrs. Rating: 2.0 cy
 - b. WASTEC Rating: 1.55 cy
 - c. Clear top opening: 40.5”X60”
 - d. Capacity per hour: 100 cy
2. Performance Data:
 - a. Cycle time: 56 s
 - b. Total Normal Force: 46,700 lb
 - c. Total Maximum Force: 55,100 lb
 - d. Normal Ram Face Pressure: 26.8 psi
 - e. Maximum Ram Face Pressure: 31.7 psi
 - f. Ram Penetration: 14”
3. Electrical Equipment:
 - a. Electrical Motor 3/60-208/230/460: 10 hp/7.5 Kw
 - b. Electrical Control Voltage: 120 VAC
 - c. UL Labeled Panel Box: Type NEMA 3R, All Circuits Fused
 - d. Standard 2 Button Controls: Keylock Start/ Mushroom Stop Connected to 13' Sealtite

4. Hydraulic Equipment:
 - a. Hydraulic Pump Capacity: 13 gpm/49.2 L/min.
 - b. Normal Pressure: 1650 psi/11.4 mPa
 - c. Maximum Pressure: 1950 psi 13.4 mPa
 - d. Hydraulic Cylinder: 6" Bore x 2 1/2" Rod/152 mm x 64 mm
 - e. Weight 5150 lbs.: 2336 kg

D. Features/Performance/Construction:

1. Allen-Bradley Motor Starter
2. Heavier steel in key structural areas for heavy-duty construction: Floor & ram face made of 1/2" steel Ram top have 3/8" steel Sides have 1/4" steel
3. TEFC (totally enclosed fan cooled) motor
4. Quick Release Motor Mount for easy servicing and maintenance
5. TRICON Fullness Assurance System. This time shifting device eliminates all but one limit switch. It also produces better compaction ratios by making the ram dwell against the trash reducing the "memory" and springback. TRICON offers better cold weather performance and extends the life of the machine.
6. Ram Guide System
 - a. The packing ram is supported by specially formulated cast iron shoes which ride on replaceable wear strips. This exclusive design protects the charge box floor from the full force of the packing ram, extending its life and dramatically reducing compaction-robbing friction.
7. Side-Mount Power Unit
 - a. Side-Mounted Power Unit
8. Container:
 - a. Provide grease fittings on hinges, guide rollers, and ground rollers.
 - b. Provide door opening to match the RJ-225 Compactor.

2.2 BALER, VERTICAL, HEAVY-DUTY (EQ ID: 2129)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on equipment identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Marathon Equipment Company, Vernon, AL - (205) 695-7250
 - 1) Model: V-7230 HD
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, equipment produced by other manufacturers, including the following, may be considered as equal.
 - a. J.M. Hydraulics, Inc., Sun Valley, CA - (818) 771-0534
 - b. HJA International, Buffalo, NY - (716) 332-7061

B. Capacities/Dimensions:

1. Hydraulic cylinder:
 - a. Bore: 2.5”
 - b. Rod: 4”
 - c. Stroke: 48”

2. Hydraulic pump: 10.5 gallons per minute
3. Motor: 10 H.P.
4. System pressure: 2,000 PSI
5. RAM pressure: 62,200 lbs.
6. Platen pressure: 29 PSI
7. Cycle time: 58 seconds
8. Overall dimensions (nominal):
 - a. Width: 101”
 - b. Depth: 45”
 - c. Height: 11’-10”

9. Bale size:
 - a. Width: 72”
 - b. Depth: 30”
 - c. Height: 48”

10. Bale volume: 60 cu. ft.
11. Bale weight: 1,400 lbs.

C. Features/Performance/Construction:

1. Redundant interlock system works with gate latch for added safety redundancy.
2. Platen features replicable high density polyethylene guides to absorb side thrust and replaceable “no-lube” cast iron shoe guides. Cylinder rod locking collar with 1” plate.
3. Baler shall be constructed of heavy gauge steel plate and backed with structural steel channel.
4. Standard controls: Key lock, on/off auto cycle, emergency stop, platen raise/lower, and a baler “ready light.”
5. The panel box features a programmable “smart” relay control system which disables the baler if an attempt to override the interlocks is made.
6. Control system shall be UL listed and located in a weather proof NEMA 4 enclosure and a simple button operation. All electrical components shall be located outside of the baler.
7. Accessories:
 - a. Baler made light.
 - b. Automatic bale ejector.

D. Utility Requirements:

1. Electrical - 460 VAC, 3 phase, 10 H.P.

E. Finish:

1. Durable powder coat using the MBTA’s choice from the manufacturer’s standard colors

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the Architect or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 - 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 - 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 - 3. Anchorage: Attach equipment as directed by the Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the Architect or designated representative for acceptance inspection.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 11306

SUBMERSIBLE SOLIDS HANDLING PUMPS AND APPURTENANCES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Provide and test submersible solids handling pumps, motors, discharge base elbow, variable frequency motor controllers, and appurtenances as indicated and specified for installation at stormwater pumping stations.
- B. Construction of the Red Bridge and Washington Street pump stations (RPS and WSP, respectively) was initiated under IGMP-03, a previous GLX construction contract. That work was advanced to near completion of the basic structure. The pumps, variable frequency motor controllers, communication programmable logic controllers, and pump station controls were not (or may not have been) completed, however certain items of that equipment were procured by the Owner and will be provided to the Design-Builder. The Design-Builder shall complete the construction of these two pump stations in full compliance with the specifications. The Design-Builders shall complete all work within this Section and all related work, to provide complete operable pump station facilities.
- C. The specifications relative to the WPS and RPS pump stations, including all operating parameters, control logic and other parameters, shall not be modified in any way.
- D. The Design-Builder may elect to adapt these specifications, if appropriate, to any pump station it may propose at Gilman Square.
- E. Certain work under this Section was, or may have been, completed by the previous GLX contractor. The Design-Builder shall be responsible for making its own assessments and evaluations as to the exact scope and limits of the completed and the uncompleted work. The Design-Builder shall complete any and all work associated with this Section and all Related Sections, including any and all uncompleted and/or partially completed work. The Design-Builder shall coordinate all related work, to provide complete and operable stormwater pumping facilities.
- F. The terms and meaning of “Manufacturer’s Services Engineer”, “Startup/Testing Engineer”, “Factory Trained Service Engineer” and “Service Engineer” (collectively, “Startup, Testing and Service Engineers”) as used in this Section shall all remain unchanged and any remaining work required of these Startup, Testing and Service Engineers shall be the responsibility of the Design-Builder. Likewise, the services of a Structural Engineer as required herein shall be the responsibility of the Design-Builder unless that work was completed by the previous Contractor.
- G. The use of the word “Contractor” has been retained in this Section; however, it shall be interpreted to mean the Design-Builder for any and all work remaining to be completed. Likewise, the word “Engineer” has been retained; however, it shall be interpreted to mean the Owner for any and all work remaining to be completed.

1.2 REFERENCES

- A. American Society for Testing and Materials International (ASTM):
 - 1. A36: Standard Specification for Carbon Structural Steel.
 - 2. A48: Standard Specification for Gray Iron Castings.
 - 3. A576: Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality.
 - 4. A743: Standard Specification for Castings, Iron-Chromium, Iron-Chromium Nickel, Corrosion Resistant, for General Application.
 - 5. D2240: Standard Test Method for Rubber Property – Durometer Hardness.
- B. American National Standards Institute (ANSI):
 - 1. B16.1: Standard for Cast Iron Pipe Flanges and Flanged Fittings, 125 lb.
- C. Hydraulic Institute (HI):
 - 1. Current Standards.
 - 2. 11.6: Submersible Pump Tests
 - 3. 14.6: Rotodynamic Pumps for Hydraulic Performance Acceptance Tests
- D. National Electrical Manufacturers Association (NEMA):
 - 1. MG1: Motors and Generators.

1.3 SUBMITTALS

- A. Submit the following shop drawings in accordance with Section 01300 – SUBMITTALS:
 - 1. Data regarding pump and motor characteristics and performance:
 - a. Prior to fabrication and testing, provide manufacturer’s guaranteed performance curves based on actual shop tests of mechanically duplicate pumps, showing they meet indicated and specified requirements for head, capacity, horsepower, efficiency and NPSH₃.
 - 1) For units of same size and type, provide curves for a single unit only.
 - b. Provide catalog performance curves at maximum pump speed indicated and specified for each service showing maximum and minimum impeller diameters available, acceptable operating range (AOR) and preferred operating range (POR).
 - c. Results of shop performance tests as specified.
 - d. Submit curves for manufacturer’s guaranteed performance, and shop performance tests on 8-1/2-inch by 11-inch sheets, one curve per sheet.
 - 2. Characteristic curves for variable speed pumps for maximum pump speed and for speeds required to obtain minimum pump flow and head conditions specified and indicated. Identify curves by speed and provide all curves on one sheet. Provide NPSH₃ curve and wire to water efficiency for each speed.
 - 3. Shop drawing data for accessory items.

4. Certified setting plans, with tolerances, for anchor bolts.
5. Manufacturer's literature as needed to supplement certified data.
6. Operating and maintenance instructions and parts lists.
7. Listing of reference installations as specified with contact names and telephone numbers.
8. Certified results of hydrostatic testing.
9. Certified results of dynamic balancing.
10. List of recommended spare parts other than those specified.
11. Shop and field inspection reports.
12. Bearing Life: Certified by the pump manufacturer. Include design data.
13. Pump shop test results.
14. Motor shop test results.
15. Qualifications of field service engineer.
16. Recommendations for short and long-term storage.
17. Resonant frequency analysis.
18. Shop and field testing procedures, pump and piping set up, equipment to be used and ANSI/HI testing tolerances to be followed.
19. Special tools.
20. Number of service person-days provided and per diem field service rate.
21. Results of shop vibration test data for each pump and drive assembly.
22. Recommended location of discharge pressure gauges.
23. Manufacturer's product data, specifications, and color charts for shop painting.
24. Provide a listing of the materials recommended for each service specified and indicated.
Provide documentation showing compatibility with process fluid and service specified and indicated.
25. The latest ISO 9001 series certification.
26. Provide a scaled drawing for each pump service showing the pumps, motors, hoists and bridge cranes including equipment weights, lifting attachments, slings and clearances for equipment removal and maintenance.
27. Material Certification:
 - a. Provide certification from the equipment manufacturer that the materials of construction specified are recommended and suitable for the service conditions specified and indicated. If materials other than those specified are proposed based on incompatibility with the service conditions, provide technical data and certification that the proposed materials are recommended and suitable for the service conditions specified and indicated including an installation list of a minimum of five (5) installations in operation for a minimum of five (5) years. Provide proposed materials at no additional cost to the Owner.

- b. Where materials are not specified, provide technical data and certification that the proposed materials are recommended and suitable for the service conditions specified and indicated.
- B. A copy of the contract mechanical process, electrical and instrumentation drawings, with addenda that are applicable to the equipment specified in this section, marked to show all changes necessary for the equipment proposed for this specification section. If no changes are required, mark all drawings with “No changes required” or provide a statement that no changes are required.
 - 1. Failure to include all drawings or a statement applicable to the equipment specified in this section will result in submittal return without review until a complete package is submitted.
- C. A copy of this specification section with addenda and all referenced specification sections with addenda, with each paragraph check-marked to indicate specification compliance or marked and indexed to indicate requested deviations and clarifications from the specified requirements.
 - 1. If deviations and clarifications from the specifications are indicated, therefore requested by the Contractor, provide a detailed written justification for each deviation and clarification.
 - 2. Failure to include a copy of the marked-up specification sections and or the detailed justifications for any requested deviation or clarification will result in submittal return without review until marked up specifications and justifications are submitted in a complete package.

1.4 SPARE PARTS:

- A. Comply with the requirements specified in Section 01600 – MATERIALS AND EQUIPMENT.
- B. Provide spare parts that are identical to and interchangeable with similar parts installed.
 - 1. For each pump:
 - a. One complete set of gaskets and O-rings.
 - 2. For each set of pumps of the same size and performance.
 - a. One set of all special tools required.

1.5 QUALITY ASSURANCE:

- A. Comply with the requirements specified in Section 01400 – QUALITY ASSURANCE.
- B. Pumps shall be the product of one manufacturer.
- C. Pumps shall be manufacturer’s standard cataloged product and modified to provide compliance with the drawings, specifications and the service conditions specified and indicated.
- D. Welding: In accordance with latest applicable American Welding Society Code or equivalent.
- E. Shop tests as specified.
- F. The Contractor shall obtain the pumps, motors and appurtenances from the pump manufacturer, as a complete and integrated package to insure proper coordination and compatibility and operation of the system.

1. Variable frequency motor controllers can be supplied by the Contractor or the pump manufacturer at the Contractor's option. The pumping system must be a complete and integrated package to insure proper coordination and compatibility and operation of the system.
 - a. The Contractor shall coordinate the variable frequency motor controllers with the pump and motor manufacturer and submit as part of the shop drawings a written statement signed by the Contractor, pump manufacturer, motor manufacturer and variable frequency motor controller manufacturer that the variable frequency motor controller manufacturer has received the required information from the pump and motor manufacturers and that all parties have reviewed the system and coordinated the equipment selection. Also include all motor data and information that has been used for the coordination.
 - b. Provide variable frequency motor controllers in accordance with Section 16260 – VARIABLE FREQUENCY MOTOR CONTROLLERS FOR THE STORMWATER PUMP STATIONS.
 2. Guide cables or rails and hatches can be supplied by the Contractor or the pump manufacturer at the Contractor's option. The pumping system must be a complete and integrated package to insure proper coordination and compatibility and operation of the system.
 - a. The Contractor shall coordinate the hatch size with the pump manufacturer and submit as part of the shop drawings a written statement signed by the Contractor and pump manufacturer that the Contractor has received the required information from the pump manufacturer and that all parties have reviewed the hatch size and coordinated the hatch size, bridge crane and equipment removal.
 - b. The Contractor shall coordinate the cable or rail size with the pump manufacturer and submit as part of the shop drawings a written statement signed by the contractor and pump manufacturer that the Contractor has received the required information from the pump manufacturer and that all parties have reviewed the cable or rail size and coordinated the size and equipment removal.
- G. Services of Manufacturer's Representative as stated in Section 01400 - QUALITY ASSURANCE and as specified herein.
- H. Provide services of factory-trained Service Technician, specifically trained on type of equipment specified:
1. Service Technician must be present on site for all items listed below. Person-day requirements listed are exclusive of travel time, and do not relieve Contractor of the obligation to place equipment in operation as specified.
 2. Installation: Inspect grouting, location of anchor bolts; setting, leveling, alignment, field erection; coordination of piping and electrical:
 - a. 2 person-days.
 3. Functional Testing: Calibrate, check alignment and perform a functional test with water. Tests to include all items specified.
 - a. 2 person-days.
 4. Performance Testing: Field performance test equipment specified.
 - a. 3 person-days.

5. Vendor Training: Provide classroom and field operation and maintenance instruction including all materials, slides, videos, handouts, and preparation to lead and teach classroom sessions.
 - a. 2 person-days.
 6. Credit to the Owner, all unused service person-days specified above, at the manufacturer's published field service rate.
 7. Any additional time required of the factory trained service technician to assist in placing the equipment in operation or testing, or to correct deficiencies in installation, equipment, or material shall be provided at no additional cost to the Owner.
- I. Manufacturer of pumps shall have a minimum of five (5) operating installations with pumps of the size specified and in a similar service as specified operating for not less than five (5) years.
 - J. If equipment proposed is heavier or taller, different rotation, or discharge arrangement than specified and indicated; provide all structural, architectural, mechanical, electrical and plumbing revisions at no additional cost to the Owner.
 1. If equipment is heavier than specified, the Contractor shall provide all hoisting equipment sized to maintain the minimum safety factor between the specified maximum equipment weight and the lifting capacity of the hoisting equipment indicated and specified.
 - K. For variable speed pump systems the pump manufacturer must perform an analysis of the combined motor and pump assembly for resonant frequency or their harmonics independent of a structure.
 1. Submit a copy of these calculations for the record.
 2. Should calculations indicate the probability of encountering such frequencies within the speed range required, provide all additional supporting devices necessary to affect the unit mass, and raise or lower resonant point to be within the speed range required.
 3. Provide and install such additional devices at no additional cost to the Owner.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Comply with the requirements specified in Section 01600 - MATERIALS AND EQUIPMENT.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Pump capacities and operating data are indicated in the Process Pump Schedule.

2.2 MANUFACTURERS

- A. Submersible Solids Handling Pumps
 1. KSB
 2. Flowserve

2.3 SEISMIC DESIGN REQUIREMENTS

- A. Conform to the requirements indicated on the structural drawings and as specified.
- B. The Contractor shall conform to the seismic design requirements for this project and for the work of this specification section.
- C. Provide all equipment bases, anchorage, supports and foundations designed in accordance with the seismic requirements indicated and specified.
- D. Additionally, provide with the Certificate of Unit Responsibility, certification for all equipment signed by a registered structural engineer stating that computations were performed and that all components have been sized for the seismic forces specified and indicated.

2.4 PUMP CONSTRUCTION

- A. Pumps: Solids handling radial and mixed flow single-stage, centrifugal pumps. Driven as indicated in the Process Pump Schedule.
- B. Design and proportion all parts of pump specially adapted for the service specified and indicated.
- C. Pump Mounting: Provide type as indicated and specified.
 - 1. Mount each pump on a discharge elbow discharging vertically.
- D. Pump Casing, Fronthead, Backhead and Lower Housing:
 - 1. Cast iron ASTM A48 Class 30 or 35.
 - 2. Provide lifting devices on pump/motor assembly for handling.
 - a. Type 316 stainless steel.
 - 3. Provide ribs or reinforcing if required to withstand the specified hydrostatic test pressure, to prevent deflection caused by hydraulic thrust and to support the motor.
 - 4. Face and drill flanges of discharge connections in accordance with 125-lb. ANSI B16.1 Standard.
 - 5. Provide components with machined registered concentric shoulder fits for precision alignment.
Equipment without registered fits is not acceptable.
 - 6. Pumps with splitter vanes in casing are not acceptable unless specifically indicated in the Process Pump Schedule.
 - 7. Lining
 - a. Manufacturer:
 - 1) Belzona Supermetalglide
 - 2) Devcon Brushable Ceramic BlueType: Ceramic filled epoxy
 - b. Percent Solids by Volume: 100 percent
 - c. Provide two coats 8 to 15 mils thick with total minimum DFT of 20 mils
 - d. Cured Hardness: 90D in accordance with ASTM D2240

- e. Surface preparation, mixing and application and safety requirements shall be in accordance with the lining manufacturer's printed instructions and as specified.

E. Impellers:

1. Type: Enclosed radial, solids handling single suction.
2. Provide vanes having wide suction and waterways that will pass solids and stringy without clogging.
3. Provide pumps capable of passing a solid sphere size as indicated in the Process Pump Schedule.
 - a. Pumps capable of only passing a deformable sphere are not acceptable.
4. Provide impellers not greater than 95 percent or the percentage indicated in the Process Pump Schedule, of the maximum diameter impeller available.
5. Do not design hub with ports for reduction of thrust on impeller.
6. Key-seat and hold impeller to shaft by a streamlined bolt or locknut capable of holding in event of motor reversal under full torque.
 - a. Impeller Fasteners: Type 416 stainless steel or Type 316Ti stainless steel
7. Statically and dynamically balance each impeller.
8. Enclosed Impellers:
 - a. Material:
 - 1) Provide Stainless Steel:
 - a) ASTM A743 Grade CA-6NM (13 percent Cr, 4 percent Ni-Mo)
 - b) CD4MCu duplex stainless steel
 - b. Wearing Rings:
 - 1) Provide on impeller and in pump casing at suction side.
 - 2) Impeller and Casing Wearing Rings:
 - a) Impeller: Stainless Steel ASTM A743 Grade CA-40 with a 300 to 350 BHN.
 - b) Casing Wearing Rings: Stainless Steel ASTM A743 Grade CA-40 with a 450 to 480 BHN.
 - c) Impeller and casing wearing rings of VG434 duplex stainless steel 350 BHN.

2.5 MOTORS

- A. Provide in accordance with Section 01600 – MATERIALS AND EQUIPMENT and as specified and indicated.
- B. Horsepower rating of motors: Not less than maximum brake horsepower requirements of pumps under any condition of operation specified and indicated without operating in the motor service factor.
- C. Maximum motor speed: As indicated in the Process Pump Schedule.

- D. Enclosure: Explosion proof, Class I, Division 1, Group D; UL or FM certified.
- E. In addition to the requirements for bearings specified under Electric Motors in Section 01600, provide pump motors with ball or roller bearings. Provide vertical motors with at least one bearing designed for thrust with bearings. Provide bearing with a minimum B-10 life of 100,000 hours.
- F. Operate without overheating at the speeds specified and indicated.
- G. Service Factor: 1.15, with 1.0 inverter duty rating for pumps equipped with variable frequency motor controllers.
- H. Rating: 460V, 3 PH, 60 Hz.
- I. Insulation: Class H with Class B temperature rise, 40 degrees C ambient.
- J. Site Altitude: Less than 3,300 feet above sea level.
- K. Motors:
 1. Provide complete sealed electric submersible squirrel cage induction motors in accordance with the above and as specified herein.
 2. Provide all components housed in an air or oil filled cast-iron watertight electric submersible squirrel cage induction motor in accordance with the above and as specified herein.
 3. Provide a closed loop cooling system which circulates a non-toxic oil or glycol-water mixture through a cooling jacket surrounding the motor, and through an integrated heat exchanger to transfer the motor heat to the process fluid. Insulate stator-winding and lead with moisture resistant Class H insulation for continuous duty in 40 degrees C rise liquids.
 4. Provide motor capable of ten (10) starts per hour at maximum speed.
 5. Motor shaft: Type 416 or Type 420 stainless steel or ASTM A576 Cr 1040 with Type 420 stainless steel sleeve.
 - a. One piece internal pump/motor shaft.
 - b. Provide shaft of sufficient diameter that the ratio of the shaft overhand, distance from lowest bearing to the impeller hub, to the shaft diameter through the seal area not to exceed 2.5.
 6. Dynamically balance rotor to within NEMA vibration limits.
 7. All hardware: Type 316 stainless steel.
 8. Provide all cables of multi-conductor SOW-A, G-GC or W of sufficient length to extend from pump motor to the control panel. Cable size shall be in accordance with NEC specifications.
 9. Cable Entry:
 - a. Provide all power and control lead wires double sealed entering the motor in a method that prevents cable wicking.
 - b. Provide the sealing system consisting of a rubber grommet to seal the cable exterior followed by interior epoxy seal.

- c. Provide each cable wire with a section of insulation removed to establish a window area of bare wire and each wire surrounded by epoxy potting material.
 - d. Provide a cable strain relief mechanism as an integral part of this sealing system.
 - e. Provide the cable sealing system capable of withstanding an external pressure test of 1,200 psi as well as a cable assembly pull test as required by UL or FM.
 - f. Provide the cable entry rated by UL or FM for submerged operating depths to 85 feet.
 - g. Singular grommet or other similar sealing systems are not acceptable.
10. Seals:
- a. Provide two separate tandem-mounted mechanical seals with the upper and lower seals mounted to rotate in the same direction.
 - b. Upper Seals:
 - 1) Provide seal completely immersed in an oil or glycol bath sealing the oil chamber and motor housing.
 - 2) Materials: Silicon carbide rotating and stationary faces.
 - c. Lower Seals:
 - 1) Provide lower seal with mating faces immersed in the oil or glycol bath sealing the pump volute and oil chamber.
 - 2) Materials: Silicon carbide rotating and stationary faces.
 - 3) Provide a cover extending completely over the lower seal spring.
 - d. Springs: Type 316 stainless steel.
 - e. Elastomers: Viton.
11. Moisture and Temperature Probes:
- a. Provide two moisture detection probes to detect moisture in the seal and stator cavity measuring conductivity.
 - b. Provide moisture detection panel and one piece cable from pump to panel; see electrical drawings for panel location. Contractor to provide conduit and cable from pump to control panel.
 - c. Provide sufficient length of cable to extend from the pump assembly to a junction box above top of wet well as stated in Part 6.
 - d. Provide O-ring sealed plugged fill and drain inspection ports.
 - e. Provide winding over temperature protection.
 - f. Moisture detection to alarm, over temperature to shut down pumps, indicates condition and alarm.
 - g. Provide NEMA 4X Type 316L stainless steel panel with moisture detection system.
12. Bearings:
- a. Provide a minimum of two bearings permanently lubricated but capable of being regreased.
 - b. Minimum B-10 bearing life of 100,000 hours.
 - c. Provide RTD for thrust bearing for pumps 100 hp and larger.

13. Provide all mating surfaces machined and fitted with O-rings. All fittings shall be metal to metal contact between each machine surface.
14. Provide a Type 316 lifting attachment capable of lifting the entire pump and motor assembly.
15. Motors shall conform to UL or FM quality assurance specifications and be manufactured by an ISO-9001 company.
16. Provide a motor resistance monitor.

2.6 DISCHARGE BASE

- A. Provide an ASTM A48 Class 30 or Class 35 cast iron discharge base assembly including a 90 degree elbow and base to support the entire weight of the pump and motor and to secure the lower end of the guide rails.
- B. Provide base machined to receive sliding bracket of pump discharge.
- C. Provide seat constructed of bronze or non-metallic O-ring that is self-cleaning, non-clogging and non-sparking UL or FM certified explosionproof.
- D. Bolt to floor with Type 316 stainless steel anchors.

2.7 GUIDE ASSEMBLY

- A. Provide Schedule 40 Type 316L stainless steel guide rails or Type 316 cables for each pump discharge assembly.
 1. Guide Rail: Pump manufacturer's standard size but not less than 2-inch diameter.
- B. Provide Type 316L stainless steel intermediate supports for guide rails with a maximum spacing of 10 feet between supports.
- C. Provide Type 316L stainless steel top guide rail retainer brackets to support the guide rails or cables. Bracket to be attached to top slab of wet well.
- D. Provide Type 316 stainless steel chain of sufficient length, to reach from pump to top of wet well plus 10 feet and of strength for lifting pump and motor. Provide chain designed for attachment to lifting bail provided on motor and to the guide rail retainer bracket.

2.8 PUMP LIFTING/DOCKING DEVICE

- A. Provide a chain and latch mechanism to allow the pumps and motors to be removed in one pull without re-rigging the system. Provide a device that is lowered along the guide cables or rails and can be remotely latched to the pump lifting bail without the need to enter the wet well.
- B. Materials:
 1. Lifting Bail: ASTM A248 B
 2. Hook, Shackle, Counterweight and Chain: ASTM A322
 3. Guide Ropes: Stainless Steel
 4. Latch Operating Rope: Polyamid
- C. Mechanism Lifting Capacity to be suitable for equipment provided.

- D. Provide one (1) device for each size pump

2.9 HARDWARE

- A. Type 316 stainless steel.

2.10 GAUGES

- A. Provide gauges assemblies for discharge of each pump in accordance with Section 15101 – PROCESS VALVES AND APPURTENANCES and as indicated.
- B. Discharge Gauges: Compound type with operating range with top limit above pump shutoff head at maximum pump speed.
 - 1. Scale: Inches Hg to psi.

2.11 SHOP PAINTING

- A. Primer and Finish Paint: Shop-apply to all exterior ferrous surfaces, high solids epoxy in accordance with Section 09900 - PAINTING.
- B. Ferrous surfaces which are not to be painted shall be given a shop applied coat of grease or rust resistant coating.
- C. Provide additional shop paint coating for touch-up to all surfaces after installation and testing is completed and equipment accepted.

2.12 SHOP TESTING

- A. Provide motor shop testing in accordance with Section 01600 – MATERIALS AND EQUIPMENT and as specified.
 - 1. Provide the following motor tests in accordance with ANSI/HI 11.6
 - a. Test motor integrity in a submerged condition.
 - b. Dry run no load test.
 - c. Motor electrical integrity test.
 - d. Moisture and temperature sensors integrity test.
- B. Pump Tests:
 - 1. Test pump casings under a hydrostatic head of at least 75 psi or 150 percent of rated shutoff head, whichever is greater. Test casing with pump assembled.
 - 2. Provide witnessed performance tests as specified herein for all pumps.
 - 3. Witnessed performance testing.
 - a. Testing of submersible pumps dry is not acceptable.
 - b. Run pump at full speed rating point for 60 minutes prior to start of any testing or until temperature has stabilized.
 - c. Full speed tests:
 - 1) Test pumps at the conditions specified and indicated and take not less than seven operating points between shut-off and run out. Test points must be at the conditions specified and indicated.
 - 2) Take readings to determine flow, differential pressure, rpm, horsepower, and wire to water efficiency.
 - 3) Operate each pump for not less than one hour and take readings to determine that the pump will operate as specified and indicated without cavitation at the

specified minimum head condition with not more than the specified NPSH available.

- d. Variable speed tests:
 - 1) Conduct tests as specified above for full speed at reduced speeds except that tests for cavitation at run out are not required.
 - 2) Run one speed test at speed required to discharge the minimum rating point specified and indicated with one point of test at the minimum rating point.
 - 3) Run a second test at a speed approximately midway between full and minimum speed.
 - 4) Run addition tests for each reduced speed operating condition specified and indicated.
 - e. Conduct additional tests as follows:
 - 1) Run each pump at the minimum speed rating point for 4 hours and continuously record motor temperature. Pumps must be run submerged at LWL submergence as indicated.
 - f. Factory tests on pumps:
 - 1) Use tested job motors and one (1) job variable frequency motor controller shipped to the pump testing facility for use in these pump tests for all pumps 100 hp and larger.
 - 2) Use factory calibrated test drives for all pumps less than 100 hp.
 - g. Provide a minimum of 30 days written notice to the Engineer prior to shop testing.
- 4. Run all tests in accordance with the latest standards of the Hydraulic Institute and as specified.
 - 5. Testing Acceptance Grade and Tolerances:
 - a. ANSI/HI 14.6 Acceptance Grade: 1U.
 - b. Wire to Water Efficiency Tolerance: -0 percent.
 - c. If pumps do not meet the tolerances specified, trim the impeller or modify the pump and retest until the specified results are obtained.
 - 6. Tests of variable frequency motor controllers specified in Section 16260 - VARIABLE FREQUENCY MOTOR CONTROLLERS FOR THE STORMWATER PUMP STATIONS.
 - 7. In the event that specified tests indicate that pump, motor, or variable frequency drive will not meet specifications, the Engineer has the right to require additional complete witnessed tests for all pumps, motors, and variable frequency drives at no additional cost to the Owner.
 - 8. Repeat tests until specified results are obtained.
 - 9. Correct or replace promptly all defects or defective equipment revealed by or noted during tests at no additional cost to the Owner.
 - 10. When pump witness performance testing is specified, provide roundtrip airfare\\, all transportation and lodging for witness testing for two (2) people. If air travel is more than 6 hours provide business class airfare.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install items in accordance with shop drawings, and manufacturer's printed instructions.
- B. Install pumping units and align.
 - 1. Set base on metal shims placed directly under the part of the base carrying the greatest weight and spaced close enough to provide uniform support.
- C. After alignment is correct, grout using high grade non-shrink grout.
 - 1. Do not imbed leveling nuts in grout.

3.2 FIELD TESTING

- A. Field testing will not be conducted without an accepted procedure, calibration certificates for all testing equipment, gauges and flow meters and a completed and signed pretesting check list.
- B. After installation of pumping equipment, and after inspection, operation, testing and adjustment have been completed by the manufacturer's field service technician, conduct running test for each pump in presence of the Engineer to determine its ability to operate within the vibration and temperature limits specified, and to deliver its rated capacity under specified conditions.
 - 1. During tests, observe and record head, capacity, and motor inputs.
 - a. Test Duration: Determined by the Engineer but not less than three hours of continuous operation at each condition specified and indicated.
 - 2. Immediately correct or replace all defects or defective equipment revealed by or noted during tests at no additional cost to the Owner.
 - 3. Repeat tests until specified results are obtained.
 - 4. Contractor to provide all water labor, piping, testing equipment, equipment, flow meters and test gauges for conducting tests.
 - a. Contractor shall provide calibrated test gauges for all permanently installed gauges and portable calibrated flow meters for all pumping systems even in those cases where permanent flow meters are installed.
 - b. All calibrations must be within 30 days of the field testing.
 - c. The testing will not be started and will not be accepted until the calibrated testing equipment stated above is operational and all certifications have been submitted.
- C. Make all adjustments necessary to place equipment in specified working order at time of above tests.
- D. Test pump on product only. If product is not available, test with water. Water for testing furnished by Contractor.
- E. Remove all replace equipment at no additional cost to the Owner with equipment that will meet all requirements specified and indicated if unable to demonstrate to the satisfaction of the Engineer that equipment will perform the service specified, indicated and as submitted and accepted.

3.3 FIELD TOUCH-UP PAINTING

- A. After installation and accepted testing by the Engineer, apply touch-up paint to all scratched, abraided and damaged shop painted surfaces. Coating type and color shall match shop painting.

3.4 CONTRACT CLOSEOUT

- A. Provide in accordance with Section 01700 – CONTRACT CLOSEOUT.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 11450

APPLIANCES

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies appliances including refrigerators, microwave ovens and flat screen televisions.
- B. Related Work:
 - 1. Section 01800 – SUSTAINABILITY REQUIREMENTS.
 - 2. Division 16 - ELECTRICAL for services and connections to appliances.

1.2 SUBMITTALS

- A. Product Data: For each type of product indicated. Include operating characteristics, dimensions of individual appliances, and finishes for each appliance.
- B. Appliance Schedule: For appliances; use same designations indicated on Drawings.
- C. Maintenance Data: For each product to include in maintenance manuals.
- D. Warranties: Special warranties specified in this Section.

1.3 QUALITY ASSURANCE

- A. Installer Qualifications: An employer of workers trained and approved by manufacturer for installation and maintenance of units required for this Project.
- B. Source Limitations: Provide products from same manufacturer for each type of appliance required.
- C. Regulatory Requirements: Comply with provisions of the following product certifications:
 - 1. NFPA: Provide electrical appliances listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
 - 2. UL and NEMA: Provide electrical components required as part of residential appliances that are listed and labeled by UL and that comply with applicable NEMA standards.
 - 3. ANSI: Provide gas-burning appliances that comply with ANSI Z21 Series standards.
- D. Regulatory Requirements, Accessibility: Where residential appliances are indicated to comply with accessibility requirements, comply with Massachusetts Architectural Access Board requirements and the U.S. Architectural & Transportation Barriers Compliance Board's "Americans with Disabilities Act (ADA), Accessibility Guidelines for Buildings and Facilities (ADAAG)."

- E. Energy Ratings: Provide residential appliances that carry labels indicating energy-cost analysis (estimated annual operating costs) and efficiency information as required by the FTC Appliance Labeling Rule.
 - 1. Provide appliances that qualify for the EPA/DOE ENERGY STAR product labeling program.
- F. Switches: Provide mercury-free switches in appliances.
- G. Preinstallation Conference: Conduct conference at Project site to comply with requirements in Division 01.

1.4 WARRANTY

- A. Special Warranties: Manufacturer's standard form in which manufacturer of each appliance specified agrees to repair or replace residential appliances or components that fail in materials or workmanship within manufacturer's standard warranty period.

PART 2 - PRODUCTS

2.1 APPLIANCES

- A. Refrigerators: 4.1 cu.ft, 32 inch stainless steel undercounter refrigerator, Basis of Design: FF511LB17ADA Series or approved equal.
- B. Microwave Ovens: 1200-watt stainless steel countertop microwave oven with baking dish, Architect Series II by KitchenAid or equal by General Electric or Jenn-Air.
- C. Flat Screen Televisions: 60 inch screen class diagonal flat-panel plasma HDTV by Samsung, or equal by Sony or LG.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of work.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before equipment installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

- A. General: Comply with manufacturer's written instructions.

- B. Built-in Equipment: Securely anchor units to supporting cabinets or countertops with concealed fasteners. Verify that clearances are adequate for proper functioning and rough openings are completely concealed.
- C. Freestanding Equipment: Place units in final locations after finishes have been completed in each area. Verify that clearances are adequate to properly operate equipment, including ventilation clearances.
- D. Utilities: Refer to Division 16 - ELECTRICAL for electrical requirements.

3.3 CLEANING AND PROTECTION

- A. Test each item to verify proper operation. Make necessary adjustments.
- B. Verify that accessories required have been furnished and installed.
- C. Remove packing material from appliances and leave units in clean condition, ready for operation.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to train the Owner's maintenance personnel to adjust, operate, and maintain appliances.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 12490

WINDOW TREATMENTS

PART 1 - GENERAL

1.1 SUMMARY

- A. Section Includes:
 - 1. Motor-operated roller shades with single rollers.
- B. Related Requirements:
 - 1. Section 06100 "Carpentry" for wood blocking and grounds for mounting roller shades and accessories.
 - 2. Section 08520 Aluminum Windows
 - 3. Section 07920 "Joint Sealants" for sealing the perimeters of installation accessories for light-blocking shades with a sealant.

1.2 SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include styles, material descriptions, construction details, dimensions of individual components and profiles, features, finishes, and operating instructions for roller shades.
- B. Shop Drawings: Show fabrication and installation details for roller shades, including shadeband materials, their orientation to rollers, and their seam and batten locations.
 - 1. Motor-Operated Shades: Include details of installation and diagrams for power, signal, and control wiring.
- C. Samples: For each exposed product and for each color and texture specified, 10 inches (250 mm) long.
- D. Qualification Data: For Installer.
- E. Product Certificates: For each type of shadeband material, signed by product manufacturer.
- F. Product Test Reports: For each type of shadeband material, for tests performed by a qualified testing agency.
- G. Maintenance Data: For roller shades to include in maintenance manuals.

1.3 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Roller Shades: Full-size units equal to 5 percent of quantity installed for each size, color, and shadeband material indicated, but no fewer than two units.

1.4 QUALITY ASSURANCE

- A. Installer Qualifications: Fabricator of products.

1.5 DELIVERY, STORAGE, AND HANDLING

- A. Deliver roller shades in factory packages, marked with manufacturer, product name, and location of installation using same designations indicated on Drawings.

1.6 FIELD CONDITIONS

- A. Environmental Limitations: Do not install roller shades until construction and finish work in spaces, including painting, is complete and dry and ambient temperature and humidity conditions are maintained at the levels indicated for Project when occupied for its intended use.
- B. Field Measurements: Where roller shades are indicated to fit to other construction, verify dimensions of other construction by field measurements before fabrication and indicate measurements on Shop Drawings. Allow clearances for operating hardware of operable glazed units through entire operating range. Notify Architect of installation conditions that vary from Drawings. Coordinate fabrication schedule with construction progress to avoid delaying the Work.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Roller shades shall: be flame-retardant treated 100% polyester; also treated to resist dust, dirt, static, and stains; single cell construction; aluminum alloy 6063 rails width to fit finished openings; spring for un-motorized operation by cord; concealed mounting hardware of stainless steel.
- B. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. BTX Window Automation, Inc.
 2. Draper Inc.
 3. Hunter Douglas Contract.
 4. Lutron Electronics Co., Inc.
 5. MechoShade Systems, Inc.
 6. Shade Techniques, LLC.
 7. Silent Gliss USA, Inc.
- C. Source Limitations: Obtain roller shades from single source from single manufacturer.

2.2 SHADEBAND MATERIALS

- A. Shadeband Material Flame-Resistance Rating: Comply with NFPA 701. Testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
- B. Light-Blocking Fabric: Opaque fabric, stain and fade resistant.
 - 1. Source: Roller-shade manufacturer.
 - 2. Type: PVC free fiberglass with acrylic backing.
 - 3. Openness: 0 percent
 - 4. Orientation on Shadeband: Up the bolt.
 - 5. Color: As selected by Architect from manufacturer's full range.

2.3 ROLLER-SHADE FABRICATION

- A. Product Safety Standard: Fabricate roller shades to comply with WCMA A 100.1, including requirements for flexible, chain-loop devices; lead content of components; and warning labels.
- B. Unit Sizes: Fabricate units in sizes to fill window and other openings, measured at 74 deg F (23 deg C).
- C. Shadeband Fabrication: Fabricate shadebands without battens or seams to extent possible except as follows:
 - 1. Vertical Shades: Where width-to-length ratio of shadeband is equal to or greater than 1:4, provide battens and seams at uniform spacings along shadeband length to ensure shadeband tracking and alignment through its full range of movement without distortion of the material.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances, operational clearances, accurate locations of connections to building electrical system, and other conditions affecting performance of the Work.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 ROLLER-SHADE INSTALLATION

- A. Install roller shades level, plumb, and aligned with adjacent units according to manufacturer's written instructions.
 - 1. Opaque Shadebands: Located so shadeband is not closer than 2 inches (51 mm) to interior face of glass. Allow clearances for window operation hardware.
- B. Electrical Connections: Connect motor-operated roller shades to building electrical system.

3.3 ADJUSTING

- A. Adjust and balance roller shades to operate smoothly, easily, safely, and free from binding or malfunction throughout entire operational range.

3.4 CLEANING AND PROTECTION

- A. Clean roller-shade surfaces after installation, according to manufacturer's written instructions.
- B. Provide final protection and maintain conditions, in a manner acceptable to manufacturer and Installer, that ensure that roller shades are without damage or deterioration at time of Substantial Completion.
- C. Replace damaged roller shades that cannot be repaired, in a manner approved by Architect, before time of Substantial Completion.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain motor-operated roller shades.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 12570

INDUSTRIAL FURNITURE

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the Design-Builder shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Workbench, severe duty, 6' x 32" (EQ ID: 8117)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The Design-Builder shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 – Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Division 1 - General Requirements.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the Design-Builder.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by the MBTA .

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Division 1 - General Requirements.

PART 2 – PRODUCTS

2.1 WORKBENCH, SEVERE DUTY, 6' X 32" (EQ ID: 8117)

- A. Manufacturer's Reference: Fabricated Item
- B. Capacities/Dimensions:

1. Load capacity: 2,500 lbs.
2. Work surface thickness: 3/8"
3. Overall dimensions (nominal):
 - a. Length: 72"
 - b. Depth: 32"
 - c. Height: 34"

C. Features/Performance/Construction:

1. Legs: Workbench legs shall be fabricated of 3" x 3" x 3/16" steel tube.
2. Leg braces: Leg braces shall be 3" x 1/4" steel plate continuously welded to tubing.
3. Top braces: Top braces shall be 3" x 3" x 1/4" steel angle with continuous electrical welds to tubing.
4. Top: Top shall be 3/8" steel plate with 50% minimum electrical welds to top braces. The corners of the top shall have a 2" radius for protection of personnel. All edges shall be ground smooth.
5. Skid plate: Skid plate shall be 4" x 4" x 1/4" steel plate with continuous welds to tubing.
6. Welds: All welds shall conform to American Welding Society standards.

D. Finish:

1. Cover all exposed steel surfaces, including both sides of the top, braces and legs, with one (1) coat of zinc chromate primer and two (2) coats of epoxy, using the MBTA's choice color

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the Architect or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. Anchorage: Attach equipment as directed by the Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the Architect or designated representative for acceptance inspection.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 12690

ENTRANCE MATS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Work Included: This Section specifies recessed entrance mats and frames of the following types:
 - 1. Aluminum entrance mat with carpet inserts.
 - 2. Polypropylene entrance mats.
- B. Related Work:
 - 1. Section 03300- CAST-IN-PLACE CONCRETE.

1.2 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, and maintenance recommendations for each material used. Provide certifications stating that materials comply with requirements.
- B. Shop Drawings: Provide large scale shop drawings for fabrication and installation of all parts of the work. Provide large scale plans and details of anchorages, connections and accessory items. Provide installation templates for frames installed in coordination with concrete work.
- C. Field Measurements: Where possible, take accurate field measurements before preparation of shop drawings and fabrication. Do not delay job progress; allow for field cutting and fitting where taking field measurements before fabrication is not possible.
- D. Verification Samples: Submit representative samples of each material that is to be exposed in the finished work, showing the full range of finish variations expected. Provide samples having minimum area of 144 square inches.

1.3 DELIVERY, STORAGE AND HANDLING

- A. Deliver materials and products in unopened factory labeled packages. Store and handle in strict compliance with manufacturers' instructions and recommendations. Protect from damage.
- B. Sequence deliveries to avoid delays, but minimize on-site storage.

1.4 SEQUENCING AND SCHEDULING

- A. Conference: Convene a pre-installation conference to establish procedures to coordinate this work with related and adjacent work.
- B. Provide oversized recess in concrete subfloors and delay actual installation of recessed mat frame until near time of Substantial Completion of Project. Do not install mats until immediately before Authority's Final Acceptance of the Project.

PART 2 - PRODUCTS

2.1 ENTRANCE MATS

- A. Basis-of-Design: Advanced Track by Mats Inc., or equal by Construction Specialties, Kadee Industries or equal Provide aluminum entrance grate and frame as follows:
 - 1. Type: Cross-bolted heavy gauge 6061-T6 aluminum with aluminum alloy 6063-T5 scraping rails and 100 percent nylon fiber drying inserts. Panel thickness 1-1/2 inches for recessed mounting. Blade spacing not to exceed 3/16 inch. Manufacturer's standard 10 year warranty. Insert color as selected by Engineer from manufacturer's standard colors
- B. Basis-of-Design: Berber Vinylback by Mats Inc., or equal by Construction Specialties, Kadee Industries or equal Provide aluminum entrance grate and frame as follows:
 - 1. Type: 100% solution-dyed UV stabilized polypropylene fibers with Premium SureTac Vinyl backing. Mat thickness 3/8 inches. Face weight 37 ounces per square yard; loose lay installation. Manufacturer's standard 1 year warranty. Color as selected by Engineer from manufacturer's standard colors.

2.2 FABRICATION

- A. Fabricate frame to be truly straight, level and square. Provide frame pieces in longest available lengths to minimize joints. Space unavoidable joints evenly about centerline of mat and spline butt-joints with connecting pins. Form corners with tightly mitered joints or use prefabricated jointless corners.
- B. Shop fabricate framework to the greatest extent possible.

PART 3 - EXECUTION

3.1 INSPECTION

- A. The Installer shall examine substrates, supports, and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.

3.2 INSTALLATION

- A. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.
- B. Coordinate top of grid elevation with frame and floor elevations to provide proper foot cleaning and to avoid all possibility of tripping hazard. Coordinate installation with door bottom clearances of doors that swing across grids.
 - 1. Entrance grates shall be fabricated full length in not less than two (2) equal width sections, unless otherwise indicated. For mats over 5 ft. in width, provide equal width sections not less than 214 in. or more than 36 in. in width. Length shall be measured perpendicular to path of travel. Width of section shall be measured parallel to path of travel.

- C. Install frame near time of Substantial Completion of Project. Shim and grout frame into oversize recess. Provide temporary filler of plywood or other suitable material to protect frame until installation of grid at time of final acceptance of Project.

3.3 CLEANING

- A. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully cleaned.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 13200

STORAGE TANKS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the Design-Builder shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Tank, Waste Oil, w/Transfer Pump, 250 gallons (EQ ID: 7937)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The Design-Builder shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 - Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Division 1 - General Requirements.
- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the Design-Builder.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by the MBTA.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer’s containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer’s recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Division 1 - General Requirements.

PART 2 – PRODUCTS

2.1 TANK, WASTE OIL, W/TRANSFER PUMP, 250 GALLONS (EQ ID: 7937)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on furniture identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Containment Solutions, (877) CSI-TANK
 - 1) Model: Safewaste SW250
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, furniture produced by other manufacturers, including the following, may be considered as equal.
 - a. XXXX
 - b. YYYY

B. General Tank Description:

1. Capacity: 250 gallons.
2. The Aboveground Used Oil Collection and Storage System is to be constructed in accordance with National, State, and Locally recognized Aboveground Storage Tank Standards, such as: Underwriters Laboratory Standard 142 for the primary tank, National Fire Protection Association Sections 30 & 30A, and Uniform Fire Code.
3. The system is to provide a minimum of 110% secondary containment for the primary tank, and 360° radius containment for the primary tank and control assemblies.
4. The control assemblies shall be new, and installed on top of the primary tank at the factory.
5. The anchoring tie downs shall be an integral part of the exterior support feet and shall be welded to the bottom of the Environmental Tank Enclosure.
6. The system must be off-loaded on site with a large forklift or crane.
7. All openings in the primary tank shall be from the top, with threaded NPT fittings.
8. The system shall include a one (1) year warranty for the tanks and accessories.
9. The manufacturer shall provide proof of a minimum 5 years of manufacturing hazardous liquid storage systems.

C. Primary Storage Tank:

1. The primary storage tank shall be rectangular in design and constructed of UL specified steel thickness, with continuous welds.
2. The primary storage tank shall be constructed and listed in accordance with UL 142 standards.

3. The primary tank shall be fitted with a minimum of: a 3/4" product inlet, a 2" overfill prevention valve, a 2" suction tube for product withdrawal, a 2" primary working vent, either a 4" or 6" emergency vent, a 2" product level gauge, and a 1" sampling port.
4. The primary tank shall be pressure tested to UL 142 Standard (minimum 3 to maximum 5 psi) at the factory.
5. The primary tank shall be mounted within the secondary containment cabinet by means of at least four (4) stabilizing brackets to prevent the primary tank from shifting.
6. The primary tank shall be placed within the secondary containment cabinet with a minimum of 3" visual clearance around all sides to allow for 100% visual inspection.
7. The exterior of the primary tank shall be cleansed of foreign material, and coated with a corrosion resistant industrial paint (3 to 5 mils dry film thickness).

D. Environmental Tank Enclosure:

1. The Environmental Enclosure (secondary leak containment tank) shall be rectangular in design and constructed with a minimum 12 ga. steel. All welds shall be full penetration.
2. The Environmental Enclosure shall be separate from the primary tank, and shall not be welded or attached to the primary tank in any fashion.
3. The secondary leak containment tank shall completely enclose the primary tank and all operating equipment (360° radius), providing secondary containment to the primary tank and operating equipment. It shall be sized to contain 110% of the primary tank storage capacity.
4. The inside bottom of the secondary tank shall be fitted with a minimum of two (2) raised steel channels (a minimum of 2" in height), to support the primary tank above the secondary tank floor.
5. The secondary tank shall be supported by two (2) 4" high steel support feet channels with integral anchoring holes to maintain ground clearance for better anchoring to concrete foundation.
6. The secondary tank shall contain a removable, locking roof that provides at least 30" of clearance from the top of the primary tank to the bottom of the roof.
7. The secondary containment cabinet shall contain louvered vents on the cabinet, which is above the level of the primary tank. These vents shall provide a minimum of 20" of venting capacity.
8. The secondary containment cabinet shall contain a knock-out hole above the primary tank level to provide for the working vent installation. Internally threaded couplers for air supply hose (1/2") and product suction (3/4") shall be welded into the side of the cabinet above the top of the primary tank, so that the respective hoses are easily installed, and contractors do not have to create any hole in the side of the cabinet. The cabinet shall not be drilled or penetrated, or in any way destroy the integrity of its containment capacity.
9. The secondary containment cabinet shall include a hinged, locking security door with viewport for the product level gauge and OPTIONAL annular space leak detection gauge, and shall be mounted on a removable door frame, at or above the level of the primary tank. This will provide access to the components for service or extraction operations. The removable door frame shall allow for easy replacement of the door and frame if they are damaged during operating procedures.
10. The interior surface of the secondary containment cabinet shall be cleansed of foreign material, and coated with a corrosion resistant industrial paint (3 to 5 mils dry film thickness). The exterior

surface of the secondary containment cabinet shall be cleansed of foreign material, and coated with a corrosion resistant industrial paint (3 to 5 mils dry film thickness).

11. The primary tank shall be stabilized from lateral movement within the enclosure by placement of four (4) lateral supports, one at each corner of the primary tank, welded to the base plate of the enclosure.

E. Control Assemblies:

1. The control assemblies shall be installed on top of the primary tank, enclosed totally within the environmental containment cabinet and tested at the factory before shipment.
2. PUMP ASSEMBLY: The pump assembly consists of a 1" UL Listed air operated double diaphragm suction pump with a capacity of 10-15 gpm at 50 psi.
3. AUTOMATIC OVERFILL VALVE ASSEMBLY: The automatic overfill valve assembly consists of air operated valve that is preset at the factory to stop the air flow to the suction pump when the liquid level in the storage tank reaches 95% of its capacity. This assembly also includes an air filter/regulator, pressure gauge, and flexible air supply hose to connect the valve to the 1/2" coupler and air pump.
4. AUDIBLE ALARM: The audible alarm is incorporated within the automatic overfill valve assembly, and engages at the 95% capacity level.
5. PRODUCT INTAKE LINE: The product intake line consists of a UL Listed 3/4" by 8' hardwall suction hose with in-line strainer, one each 3/4" female quick coupler and 3/4" male quick coupler, and hose hanger bracket.
6. PRODUCT REMOVAL: The product contained inside the primary tank shall be removed through a 2" cam and groove fitting with locking cap assembly and 2" suction tube.
7. NORMAL VENTING: The working vent consists of a 2" mushroom vent cap and rubber grommet for sealing penetration through the secondary tank.
8. EMERGENCY VENT: The emergency vent consists of a 4" or 6" emergency relief device.
9. PRODUCT LEVEL GAUGE: The sight level gauge is mechanical, reading in inches. A tank conversion chart shall be provided to convert the inch readings into gallons.
10. ANNULAR SPACE LEAK DETECTOR: An OPTIONAL leak gauge can be installed.

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the Architect or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 - 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 - 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 - 3. Anchorage: Attach equipment as directed by the Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Notify the Architect or designated representative for acceptance inspection.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 14100

DUMBWAITERS

PART 1 – GENERAL

1.1 DESCRIPTION OF WORK

- A. The provisions of Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions apply to the Work in this Section.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the Design-Builder shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Lift, Parts, Two stops, 3,000 lbs. (EQ ID: 9705)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- F. Carefully examine all of the contract documents for requirements which affect the work of this section.
- G. The Design-Builder shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 – Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 “Design Submittal Review Management” and Subsection 2.8 “Construction Submittal Requirements”.
- B. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Division 1 - General Requirements.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the Design-Builder.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by the Owner and Architect.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer’s containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect,

misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.

- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Division 1 - General Requirements.

PART 2 – PRODUCTS

2.1 LIFT, PARTS, TWO STOPS, 3,000 LBS. (EQ ID: 9705)

A. Manufacturer's Reference:

1. Prime Manufacturer: Specifications are based on furniture identified herein by the manufacturer's name and model in order to establish minimal acceptable standards of quality, features, performance, and construction.
 - a. Pflow Industries, (414) 352-9000
 - 1) Model: Series D VRC
2. Alternate manufacturers: Contingent upon compliance with these specifications, and the documentation requirements set forth in Division 1 - Submittals, furniture produced by other manufacturers, including the following, may be considered as equal.
 - a. XXXX
 - b. YYYY

B. General Description

1. The parts lift purpose is to provide the capability to roll a pallet into the lift with a pallet jack, lower the pallet to the pit floor, then roll off the pallet from the other side to allow transport of parts and equipment to and from the pit.

C. Capacities/Dimensions:

1. Capacity: The VRC shall be rated at a live load capacity of 3000 lbs..
2. Speed: The VRC shall have a lifting speed of 17 feet per minute when loaded to capacity.
3. Vertical Travel: The VRC shall have a total of 2 operating levels.
4. Lift Platform: The VRC platform shall be a minimum of 60 inches wide x 60 inches long x 84" load height with a steel deck plate and minimum 48" high welded handrails and kickplates on non-operating ends and safety chains with snaphooks on operating ends.

5. Support Columns: The VRC shall have a minimum of two (2) 6” wide, roll formed or wide flange support columns.
6. Deflection Under Load: When loaded to rated capacity, no portion of the VRC shall exhibit permanent deformations.
7. Hydraulic Power Unit:
 - a. A pressure compensated flow control valve shall be included to provide for safe lowering of the load.
 - b. A velocity sensing check valve is required to prevent uncontrolled carriage descent in case of a failure in the hydraulic pressure line.
 - c. A pressure relief valve shall be provided to protect the hydraulic system from excessive pressure due to overloading or jam situations.
8. Lifting Means:
 - a. Raising and lowering of the carriage shall be provided by dual 2” ram direct-acting hydraulic cylinders. Sheaves, wire ropes, or chains are not to be incorporated in the lifting means.
 - b. An adjustable mechanical stop and pressure switch act to limit the upward travel of the lift platform to a height flush and level with the upper floor. The pressure switch shall be designed and set to allow full build up of hydraulic pressure to secure the lift platform in place and prevent bounce during loading or unloading.
9. Safety Enclosure: Guarding on all non-operating sides of the VRC shall be by safety enclosures a minimum of 8’ high consisting of material which will reject a ball 1/2” in diameter.
10. Floor Level Gates: Gates are required on all operating sides of the VRC at each level of operation.
 - a. The gates shall be (vertical acting) (swing) (slide) type.
 - b. Each gate shall be equipped with an electro-mechanical interlock to prevent opening of the gate unless the carriage is present, and to prevent operation of the VRC unless all gates are closed.
11. Signs: “NO RIDER” signs shall be provided. Lettering shall be a minimum of 2” high for visibility.
12. Approach Ramp: If a pit is not specified, the manufacturer shall supply or option a steel fabricated approach ramp to be installed within 1” of the VRC platform at the ground level.

VRC ELECTRICAL SPECIFICATION

13. Motor:
 - a. Motor horsepower shall be sized for the rated live load and specified speed.

- b. All motors are three phase and shall be designed for continuous duty at ambient temperatures from 32° to 102° Fahrenheit.

14. Controls:

- a. Each operating floor level shall be equipped with a momentary contact push button control station with call, send, and mushroom style E-stop operators for manual control of lift operation.
- b. An internally pre-wired main control panel shall be provided with step-down transformer and field wiring terminal block.
- c. The motor/pump unit shall be pre-wired to the main control panel.
- d. Provide quick-connect type cables and connectors for field connection of push button control stations and gate interlocks to the main control panel.

15. Power Source: Owner shall terminate high voltage operating power within 10' of the location designated for installation of the VRC.

FINISHES

- 16. All carbon steel surfaces shall be coated with an industrial enamel finish over primer.
- 17. Prior to painting, all dirt, mill scale, oil, and grease shall be removed from carbon steel surfaces by a combination of brushing, wiping, and use of solvents.

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the Architect or designated representative.
- B. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:

1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 3. Anchorage: Attach equipment as directed by the Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- C. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.
- B. Operating Load Test: The owner will provide a 3000 pound test load and load the VRC at the ground level. The loaded VRC platform shall be conveyed to an upper floor level and returned to the ground level to assure proper operation. If the VRC conveyor cannot lift or lower the load, the VRC shall fail the test.
- C. Performance Test: This Test is to be performed in conjunction with Test 1 above. During the demonstration of the lifting and lowering test, the owner shall measure the time required to lift and lower the capacity load. The owner will average times for lifting and lowering the load and calculate the average lifting and lowering speed. If the VRC does not lift the load within 10% of the specified speed, or if the lowering speed exceeds the lifting speed by more than 10%, the VRC shall fail the test.
- D. Stationary Load Test: This Test is to be performed in conjunction with Test 1 above. The loaded VRC platform shall remain stationary at an upper level for a minimum of one (1) hour. After the one (1) hour period, the VRC will be inspected for deflection of the components or drift of the platform. If deformation or downward drift is evident, the VRC shall fail the test.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.
- D. Verify that equipment is properly installed and guarded per ANSI/ASME B20.1
- E. Notify the Architect or designated representative for acceptance inspection.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 15050

BASIC MATERIALS AND METHODS FOR HVAC WORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes the following:

1. Piping materials and installation instructions common to most piping systems.
2. Ductwork materials and installation instructions common to most air systems.
3. Transition fittings.
4. Dielectric fittings.
5. Mechanical sleeve seals.
6. Sleeves.
7. Escutcheons.
8. Grout.
9. Equipment installation requirements common to equipment sections.
10. Painting and finishing.
11. Concrete bases.
12. Supports and anchorages.

- B. Related Sections:

1. Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements” – SUSTAINABILITY REQUIREMENTS
2. Section 03300 - CAST IN PLACE CONCRETE
3. Section 07840 - FIRE STOPPING
4. Section 07920 - JOINT SEALANTS
5. Section 08139 – ACCESS DOORS
6. Section 09900 – PAINTING
7. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
8. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
9. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
10. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
11. Section 15086 – DUCT INSULATION
12. Section 15088 – HVAC PIPING INSULATION
13. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
14. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
15. Section 15127 – METERS AND GAGES FOR PIPING

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations, installations below overhangs.
- D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.
- E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
- F. The following are industry abbreviations for National and International Standards organizations:
 - 1. ASME: American Society of Mechanical Engineers
 - 2. ASTM: American Society for Testing and Materials.
 - 3. AWS: American Welding Society
 - 4. SMACNA: Sheet Metal and Air Conditioning Contractors' National Association.
- G. The following are industry abbreviations for plastic materials:
 - 1. ABS: Acrylonitrile-butadiene-styrene plastic.
 - 2. CPVC: Chlorinated polyvinyl chloride plastic.
 - 3. PE: Polyethylene plastic.
 - 4. PVC: Polyvinyl chloride plastic.
 - 5. PP-R: Polypropylene pipe
 - 6. PEX: Crosslinked Polyethylene Plastic
- H. The following are industry abbreviations for rubber materials:
 - 1. EPDM: Ethylene-propylene-diene terpolymer rubber.
 - 2. NBR: Acrylonitrile-butadiene rubber.

1.4 SUBMITTALS

- A. Product Data: For the following:
 - 1. Transition fittings.
 - 2. Dielectric fittings.
 - 3. Mechanical sleeve seals.
 - 4. Escutcheons.

5. Painting

B. Welding certificates.

1.5 QUALITY ASSURANCE.

A. System Life Expectancy:

1. All HVAC piping and ductwork distribution systems shall be designed and installed with materials and practices to meet a minimum 50-year median useful life in their respective environments. This includes the selection of appropriate corrosion resistant materials, compatible joining methods, provisions for moisture shedding, access for inspection, cleaning and service and isolation from incompatible materials, protection from wildlife and moisture.
2. All HVAC system equipment including but not limited to fans, refrigerant-based air conditioning equipment and electric fan-forced heaters shall be selected, designed and installed to meet a minimum median 15 year operating useful life in their respective environments. Design and installation shall take into account access for regular service and replacement. This shall include the ability to disconnect, make safe and remove a piece of equipment and replace in-kind, restored to function, without disrupting other services.
3. For specific equipment not listed, the median useful life shall conform to "Table 4 Comparison of Service Life Estimates, 2015 ASHRAE Handbook, HVAC Applications".
4. Useful life shall include consideration of the expected design duty including hours of use, frequency of start-stop cycles, availability of common or specific parts and consumables including attic stock spare parts to limit down-time.
5. Where rotating equipment uses selectable bearings, the bearings shall have a minimum duty life of L10 - 200,000 Hours.

B. Steel Support Welding: Qualify processes and operators according to AWS D1.1, "Structural Welding Code--Steel."

C. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."
2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

D. Electrical Characteristics for Mechanical Equipment: Equipment that requires different voltages, amperages or additional, electrical services, devices or equipment may be furnished provided such proposed equipment is approved in writing, connecting electrical services, circuit breakers, and conduit sizes are appropriately modified, and required additional services, devices and equipment are provided. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements. Variations approved under this subparagraph shall be at no additional cost to the MBTA.

E. Ductwork Materials and Configurations: Ductwork installed in interior locations at a minimum shall be fabricated per standard SMACNA figures of minimum G90 galvanized sheet steel of not less than

24 gauge. Default minimum pressure class shall be 2.0 inches. Seal and leakage class shall be Seal Class A/Leakage Class 3. Ductwork conveying moist air, including locker-shower areas, vehicle wash areas, shall be aluminum. Sheet metal exposed to the weather shall be 304 or 316 Stainless Steel. Higher pressure classes and materials of construction for corrosion resistance shall be specified, furnished and installed according to their system requirements, including process exhaust, material handling and locations of exposure. Other duct categories shall be designed for specific processes and applications, including exposed ductwork for architectural aesthetic requirements.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver pipes and tubes with factory-applied end caps and ductwork ends sealed with self-adhering plastic wrap. Maintain end caps and sealing means through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture into piping and ductwork.
- B. Maintain all crating and shrink-wrapping in factory condition except where inspection is required. All protection shall be restored to factory condition after inspections.

1.7 COORDINATION

- A. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for mechanical installations.
- B. Coordinate installation of required supporting devices in form work and set sleeves in poured-in-place concrete and other structural components as they are constructed.
- C. Coordinate requirements for access panels and doors for mechanical items requiring access that are concealed behind finished surfaces. Access panels and doors are specified in Division 8 Section "Access Doors and Frames."
- D. Coordinate requirements for concrete pads and foundations with the providing subcontractor. In general, all concrete pads shall be of sufficient height to promote drainage from the equipment but not less than four (4) inches high and shall extend beyond the supporting footprint of the equipment by not less than six (6) inches in all directions. Concrete work is specified in DIVISION 3.

Special Coordination at the VMF: The Vehicle Maintenance Facility is intended to have a light-weight insulated panel skin system which will be replaceable over time. No connections of services, piping, conduits, clips controls, equipment and the like, shall be attached directly to this panel system. All attachments of such services to the exterior walls shall be made only to permanent structure, girts or secondary steel strut systems, independent of the exterior panel skin system.

1.8 MANUFACTURERS

- A. There is no intention of requiring proprietary products for products and systems under this section. Any reference to a particular manufacturer is to indicate the level of quality and commercial availability of the product or system in a competitive market.
- B. The final Design-Builder design specifications shall indicate at least three manufacturer's names for the proposed equipment, product or system. This requirement does not apply to common sundry

materials such as piping and sheet metal available from numerous suppliers, subject to meeting the specifications.

PART 2 - PRODUCTS

2.1 PIPE, TUBE, AND FITTINGS

Refer to individual Division 15 piping Sections for pipe, tube, and fitting materials and joining methods.

2.2 JOINING MATERIALS

A. Refer to individual Division 15 piping Sections for special joining materials for specific systems.

2.3 DIELECTRIC SEPARATION

A. Description: Separate connections of dis-similar metals with electrically insulated devices. Refer to individual Division 15 piping Sections for dielectric separation for specific systems.

2.4 SLEEVES

A. Refer to Section 15093- "SLEEVES AND SLEEVE SEALS FOR PIPING".

2.5 ESCUTCHEONS

A. Refer to Section 15098 "ESCUTCHEONS FOR HVAC PIPING."

2.6 GROUT

A. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.

1. Characteristics: Post-hardening, volume-adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
2. Design Mix: (5000-psi), 28-day compressive strength.
3. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 PIPING SYSTEMS - COMMON REQUIREMENTS

A. Install piping according to the following requirements and Division 15 Sections for specific piping systems.

- B. All piping installations shall be installed with provisions to allow thermal expansion in runs over 25 feet and where piping passes across building expansion joints. Expansion shall be accommodated by means of offsets, passive loops, applied expansion joints, anchors and guides.
- C. Verify final equipment locations for roughing-in.
- D. Refer to equipment specifications in other Sections of these Specifications for roughing-in requirements.

3.2 PIPING JOINT CONSTRUCTION

- A. Join pipe and fittings according to the Division 15 Sections for specific piping systems.

3.3 PIPING CONNECTIONS

- A. Make connections according to the Division 15 Sections for specific piping systems.

3.4 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

- A. Install equipment to allow maximum possible headroom unless specific mounting heights are indicated.
- B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.
- C. Install mechanical equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.
- D. Install equipment to allow right of way for piping installed at required slope.

3.5 PAINTING

- A. Painting of mechanical systems, equipment, and components is specified in Division 9 Section 09900 "PAINTING."
- B. Damage and Touchup: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

3.6 CONCRETE BASES

- A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project. All concrete bases shall be furnished and installed as specified under DIVISION 3.
 - 1. Coordinate concrete bases of dimensions indicated, but not less than (4 inches) larger in both directions than supported unit.

2. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

3.7 ERECTION OF WOOD SUPPORTS AND ANCHORAGES

- A. Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor mechanical materials and equipment.
- B. Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.
- C. Attach to substrates as required to support applied loads.

3.8 GROUTING

- A. Mix and install grout for mechanical equipment base bearing surfaces, pump and other equipment base plates, and anchors.
- B. Clean surfaces that will come into contact with grout.
- C. Provide forms as required for placement of grout.
- D. Avoid air entrapment during placement of grout.
- E. Place grout, completely filling equipment bases.
- F. Place grout on concrete bases and provide smooth bearing surface for equipment.
- G. Place grout around anchors.
- H. Cure placed grout

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15051

BASIC MATERIALS AND METHODS FOR PLUMBING WORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes the following:

1. Piping materials and installation instructions common to most piping systems.
2. Transition fittings.
3. Dielectric fittings.
4. Mechanical sleeve seals.
5. Sleeves.
6. Escutcheons.
7. Grout.
8. Equipment installation requirements common to equipment sections.
9. Painting and finishing.
10. Concrete bases.
11. Supports and anchorages.

- B. Related Section:

1. Volume 2 Technical Provisions Exhibit 2I "Additional Project Requirements"
2. Section 03300 - CAST IN PLACE CONCRETE
3. Section 07840 - FIRESTOPPING
4. Section 07600 - FLASHING AND SHEET METAL
5. Section 07920 - JOINT SEALANTS
6. Section 09900 - PAINTING
7. Section 05500 - MISCELLANEOUS METALS
8. Section 15058 - COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
9. Section 15062 - HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
10. Section 15074 - VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
11. Section 15084 - PLUMBING EQUIPMENT INSULATION
12. Section 15085 - PLUMBING PIPING INSULATION
13. Section 15093 - SLEEVES AND SLEEVE SEALS FOR PIPING
14. Section 15112 - GENERAL-DUTY VALVES FOR PIPING
15. Section 15127 - METERS AND GAGES FOR PIPING
16. Section 15140 - DOMESTIC WATER PIPING
17. Section 15145 - DOMESTIC WATER PIPING SPECIALTIES
18. Section 15150 - SANITARY WASTE AND VENT PIPING
19. Section 15155 - SANITARY WASTE PIPING SPECIALTIES
20. Section 15160 - STORM DRAINAGE PIPING
21. Section 15165 - STORM DRAINAGE PIPING SPECIALTIES

22. Section 15182 – HIGH PRESSURE PIPING
23. Section 15195 - FACILITY NATURAL-GAS PIPING

C. Product Conformance

1. All plumbing and gas-related equipment, products and appliances shall be approved by the Commonwealth of Massachusetts Board of State Examiners of Plumbers and Gas Fitters, for the appropriate category of Plumbing, Gas or Plumbing/Gas Combination and the approval number furnished with the submittals.

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations, installations below overhangs.
- D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.
- E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
- F. The following are industry abbreviations for National and International Standards organizations:
 1. ASME: American Society of Mechanical Engineers.
 2. ASPE: American Society of Plumbing Engineers.
 3. ASTM: American Society for Testing and Materials.
 4. AWS: American Welding Society.
 5. AWWA: American Water Works Association.
- G. The following are industry abbreviations for plastic materials:
 1. ABS: Acrylonitrile-butadiene-styrene plastic.
 2. CPVC: Chlorinated polyvinyl chloride plastic.
 3. PE: Polyethylene plastic.
 4. PVC: Polyvinyl chloride plastic.
- H. The following are industry abbreviations for rubber materials:
 1. EPDM: Ethylene-propylene-diene terpolymer rubber.
 2. NBR: Acrylonitrile-butadiene rubber.

1.4 SUBMITTALS

- A. Product Data: For the following:
 - 1. Transition fittings.
 - 2. Dielectric fittings.
 - 3. Mechanical sleeve seals.
 - 4. Escutcheons.
 - 5. Painting
- B. Welding certificates.

1.5 QUALITY ASSURANCE.

- A. System Life Expectancy:
 - 1. All plumbing piping distribution systems shall be designed and installed with materials and practices to meet a minimum 50-year median useful life in their respective environments. This includes the selection of appropriate corrosion resistant materials, permanent coatings, compatible joining methods, provisions for moisture shedding, access for inspection, cleaning and service and isolation from incompatible materials, protection from wildlife and moisture.
 - 2. Design and installation shall take into account access for regular service and replacement. This shall include the ability to disconnect, make safe and remove a piece of equipment and replace in-kind, restored to function, without disrupting other services.
 - 3. All plumbing system fixtures including but not limited to water closets, lavatories, service sinks, eyewash and emergency shower stations shall be selected, designed and installed to meet a minimum median 30 year operating useful life in their respective environments, with faucets, flush valves, exposed connections and associated trim to meet a minimum median 15 year operating useful life.
 - 4. Domestic Hot Water Heaters shall be selected for the following: Fuel Fired; Gas: 10-year minimum warranty; 10-year median useful life. Electric Resistance: 10-year minimum warranty; 12-year median useful life. Electric Heat Pump: 10-year minimum warranty; 8-year median useful life.
 - 5. Useful life shall include consideration of the expected design duty including hours of use, frequency of start-stop cycles, availability of common or specific parts and consumables including attic stock spare parts to limit down-time.
- B. Steel Support Welding: Qualify processes and operators according to AWS D1.1, "Structural Welding Code--Steel."
- C. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
 - 1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."

2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.
- D. Electrical Characteristics for Mechanical Equipment: Equipment that requires different voltages, amperages or additional, electrical services, devices or equipment may be furnished provided such proposed equipment is approved in writing, connecting electrical services, circuit breakers, and conduit sizes are appropriately modified, and required additional services, devices, and equipment are provided. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements. Variations approved under this subparagraph shall be at no additional cost to the MBTA.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Deliver all materials, fixtures, pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- B. Maintain all crating and shrink-wrapping in factory condition except where inspection is required. All protection shall be restored to factory condition after inspections.
- C. Store plastic pipes protected from direct sunlight. Properly support plastic pipes to prevent sagging and bending.

1.7 COORDINATION

- A. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for mechanical installations.
- B. Coordinate installation of required supporting devices in form work and set sleeves in poured-in-place concrete and other structural components as they are constructed.
- C. Coordinate requirements for access panels and doors for mechanical items requiring access that are concealed behind finished surfaces. Access panel and doors shall be flush mounted, paintable and use concealed hinges and latches.
- D. Coordinate requirements for concrete pads and foundations with the providing subcontractor. In general, all concrete pads shall be of sufficient height to promote drainage from the equipment but not less than four (4) inches high and shall extend beyond the supporting footprint of the equipment by not less than six (6) inches in all directions. Concrete work is specified in DIVISION 3.
- E. Special Coordination at the VMF: The Vehicle Maintenance Facility is intended to have a light-weight insulated panel skin system which will be replaceable over time. No connections of services, piping, conduits, clips controls, equipment and the like, shall be attached directly to this panel system. All attachments of such services to the exterior walls shall be made only to permanent structure, girts or secondary steel strut systems, independent of the exterior panel skin system.

1.8 MANUFACTURERS

- A. There is no intention of requiring proprietary products for products and systems under this section. Any reference to a particular manufacturer is to indicate the level of quality and commercial availability of the product or system in a competitive market.
- B. The final Design-Builder design specifications shall indicate at least three manufacturer's names for the proposed equipment, product or system. This requirement does not apply to common sundry materials such as piping and joining materials available from numerous suppliers, subject to meeting the specifications.

PART 2 - PRODUCTS

2.1 PIPE, TUBE, AND FITTINGS

- A. Refer to individual Division 15 piping Sections for pipe, tube, and fitting materials and joining methods. For specific systems with additional joining requirements.
- B. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

2.2 JOINING MATERIALS

- A. Refer to individual Division 15 piping Sections for specific systems for special joining materials not listed below.
- B. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of the fluids within the piping system
 - 1. ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.
 - a. Full-Face Type: For flat-face, Class 125, and Class 250 cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, steel flanges.
 - 2. AWWA C110, rubber, flat face, 1/8 inch thick, unless otherwise indicated; and full-face or ring type, unless otherwise indicated.
- C. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- D. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated. Full face gaskets required.
- E. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.
- F. Brazing Filler Metals: AWS A5.8, BCuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated; and AWS A5.8, BAgl, silver alloy for refrigerant piping and copper tubing run below slabs or below grade outside the building lines, unless otherwise indicated.

- G. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.3 TRANSITION FITTINGS

- A. AWWA Transition Couplings: Same size as, and with pressure rating at least equal to and with ends compatible with, piping to be joined.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cascade Waterworks Mfg. Co.
 - b. Dresser Industries, Inc.; DMD Div.
 - c. Ford Meter Box Company, Incorporated (The); Pipe Products Div.
 - d. JCM Industries.
 - e. Smith-Blair, Inc.
 - f. Viking Johnson.
 2. Underground Piping NPS 1-1/2 and Smaller: Manufactured fitting or coupling.
 3. Underground Piping NPS 2 and Larger: AWWA C219, metal sleeve-type coupling.
 4. Aboveground Pressure Piping: Pipe fitting.
- B. Plastic-to-Metal Transition Fittings: PVC one-piece fitting with manufacturer's Schedule 80 equivalent dimensions; one end with threaded brass insert, and one solvent-cement-joint end.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eslon Thermoplastics.
- C. Plastic-to-Metal Transition Adaptors: One-piece fitting with manufacturer's SDR 11 equivalent dimensions; one end with threaded brass insert, and one solvent-cement-joint end.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Thompson Plastics, Inc.
- D. Plastic-to-Metal Transition Unions: MSS SP-107, PVC four-part union. Include brass end, solvent-cement-joint end, rubber O-ring, and union nut.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. NIBCO INC.
 - b. NIBCO, Inc.; Chemtrol Div.
- E. Flexible Transition Couplings for Underground Nonpressure Drainage Piping: ASTM C 1173 with elastomeric sleeve, ends same size as piping to be joined, and corrosion-resistant metal band on each end.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cascade Waterworks Mfg. Co.
 - b. Fernco, Inc.
 - c. Mission Rubber Company.
 - d. Plastic Oddities, Inc.

2.4 DIELECTRIC FITTINGS

- A. Description: Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.
- B. Insulating Material: Suitable for system fluid, pressure, and temperature.
- C. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 deg F.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Capitol Manufacturing Co.
 - b. Central Plastics Company.
 - c. Eclipse, Inc.
 - d. EpcO Sales, Inc.
 - e. Hart Industries, International, Inc.
 - f. Watts Industries, Inc.; Water Products Div.
 - g. Zurn Industries, Inc.; Wilkins Div.
- D. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig minimum working pressure as required to suit system pressures.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Capitol Manufacturing Co.
 - b. Central Plastics Company.
 - c. EpcO Sales, Inc.
 - d. Watts Industries, Inc.; Water Products Div.
- E. Dielectric-Flange Kits: Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advance Products & Systems, Inc.
 - b. Calpico, Inc.
 - c. Central Plastics Company.
 - d. Pipeline Seal and Insulator, Inc.

2. Separate companion flanges and steel bolts and nuts shall have 150- or 300-psig minimum working pressure where required to suit system pressures.
- F. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 deg F.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Calpico, Inc.
 - b. Lochinvar Corp.
- G. Dielectric Nipples: Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225 deg F.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Perfection Corp.
 - b. Precision Plumbing Products, Inc.
 - c. Sioux Chief Manufacturing Co., Inc.
 - d. Victaulic Co. of America.

2.5 MECHANICAL SLEEVE SEALS

- A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advance Products & Systems, Inc.
 - b. Calpico, Inc.
 - c. Metraflex Co.
 - d. Pipeline Seal and Insulator, Inc.
 2. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
 3. Pressure Plates: Stainless steel. Include two for each sealing element.
 4. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.6 SLEEVES

- A. Refer to Section 15093- "Sleeves and Sleeve Seals for Piping".

2.7 ESCUTCHEONS

- A. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.
- B. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.
- C. One-Piece, Cast-Brass Type: With set screw.
 - 1. Finish: Polished chrome-plated.
- D. One-Piece, Stamped-Steel Type: With set screw or spring clips and chrome-plated finish.
- E. One-Piece, Floor-Plate Type: Cast-iron floor plate.

2.8 GROUT

- A. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
 - 1. Characteristics: Post-hardening, volume-adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
 - 2. Design Mix: 5000-psi, 28-day compressive strength.
 - 3. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 PIPING SYSTEMS - COMMON REQUIREMENTS

- A. Install piping according to the following requirements and Division 15 Sections specifying piping systems.
- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- C. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- F. Install piping to permit valve servicing, installation of insulation and tightening of flange bolts.
- G. Install piping at indicated slopes.
- H. Install piping free of sags and bends.

- I. Install fittings for changes in direction and branch connections.
- J. Install piping to allow application of insulation.
- K. Select system components with pressure rating equal to or greater than system operating pressure.
- L. Install escutcheons for penetrations of walls, ceilings, and floors according to the following:
 - 1. New Piping:
 - a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
 - b. Chrome-Plated Piping: One-piece, cast-brass type with polished chrome-plated finish.
 - c. Insulated Piping: One-piece, stamped-steel type with spring clips.
 - d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
 - e. Bare Piping in Unfinished Service Spaces: One-piece, stamped-steel type with concealed hinge and set screw or spring clips.
 - f. Bare Piping in Equipment Rooms: Two-piece, cast-brass type.
 - g. Bare Piping at Floor Penetrations in Equipment Rooms: Two-piece, floor-plate type.
- M. Sleeves are not required for core-drilled holes.
- N. Permanent sleeves are not required for holes formed by removable PE sleeves.
- O. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs.
 - 1. Cut sleeves to length for mounting flush with both surfaces.
 - a. Exception: Extend sleeves installed in floors of mechanical equipment areas, fire sprinklered areas, or other wet areas 2 inches above finished floor level. Extend cast-iron sleeve fittings below floor slab as required.
 - 2. Install sleeves in new walls and slabs as new walls and slabs are constructed.
 - 3. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation. Use the following sleeve materials:
 - a. Steel Pipe Sleeves.
 - 4. Except for underground wall penetrations, seal annular space between sleeve and pipe or pipe insulation, using joint sealants appropriate for size, depth, and location of joint. Refer to Division 7 Section 07920 "JOINT SEALANTS" for materials and installation.
- P. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
 - 1. Install steel pipe for sleeves smaller than 6 inches in diameter.
 - 2. Install steel pipe for sleeves 6 inches and larger in diameter.
 - 3. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and

install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

- Q. Underground, Exterior-Wall Pipe Penetrations: Install steel pipe for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
 - 1. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
- R. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Refer to Division 7 Section 07840 "FIRESTOPPING" for materials.
- S. Verify final equipment locations for roughing-in.
- T. Refer to equipment specifications in other Sections of these Specifications for roughing-in requirements.

3.2 PIPING JOINT CONSTRUCTION

- A. Join pipe and fittings according to the following requirements and Division 15 Sections specifying piping systems. For specific systems
- B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe to be welded.
- C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
- E. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.
- F. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- G. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.
- H. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.3 PIPING CONNECTIONS

- A. Make connections according to the following, unless otherwise indicated:
1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
 2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.
 3. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
 4. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.
 5. Locate unions and flanges so that equipment and appurtenances are easily removable without removing additional piping.

3.4 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

- A. Install equipment to allow maximum possible headroom unless specific mounting heights are indicated.
- B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.
- C. Install mechanical equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.
- D. Install equipment to allow right of way for piping installed at required slope.

3.5 PAINTING

- A. Painting of mechanical systems, equipment, and components is specified in Division 9 Section 09900 "PAINTING."
- B. Damage and Touchup: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

3.6 CONCRETE BASES

- A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project. All concrete bases shall be furnished and installed as specified under DIVISION 3.
1. Coordinate concrete bases of dimensions indicated, but not less than 4 inches larger in both directions than supported unit.
 2. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.

3. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

3.7 ERECTION OF METAL SUPPORTS AND ANCHORAGES

- A. Refer to Division 5 Section 05500 "MISCELLANEOUS METALS" for structural steel.
- B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.
- C. Field Welding: Comply with AWS D1.1.

3.8 GROUTING

- A. Mix and install grout for mechanical equipment base bearing surfaces, pump and other equipment base plates, and anchors.
- B. Clean surfaces that will come into contact with grout.
- C. Provide forms as required for placement of grout.
- D. Avoid air entrapment during placement of grout.
- E. Place grout, completely filling equipment bases.
- F. Place grout on concrete bases and provide smooth bearing surface for equipment.
- G. Place grout around anchors.
- H. Cure placed grout

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15052

BASIC MATERIALS AND METHODS FOR FIRE PROTECTION WORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes the following:

1. Piping materials and installation instructions common to most piping systems.
2. Joining Materials
3. Transition fittings.
4. Dielectric fittings.
5. Mechanical sleeve seals.
6. Sleeves.
7. Escutcheons.
8. Grout.
9. Equipment installation requirements common to equipment sections.
10. Painting and finishing.
11. Concrete bases.
12. Supports and anchorages.

- B. Related Section:

1. Section 03300 - CAST IN PLACE CONCRETE
2. Section 07840 - FIRESTOPPING
3. Section 07920 - JOINT SELANTS
4. Section 09900 - PAINTING
5. Section 05500 - MISCELLANEOUS METALS
6. Section 15058 - COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
7. Section 15062 - HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
8. Section 15074 - VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
9. Section 15093 - SLEEVES AND SLEEVE SEALS FOR PIPING
10. Section 15112 - GENERAL-DUTY VALVES FOR PIPING
11. Section 15127 - METERS AND GAGES FOR PIPING
12. Section 15160 - STORM DRAINAGE PIPING
13. Section 15165 - STORM DRAINAGE PIPING SPECIALTIES

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
- D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.
- E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
- F. The following are industry abbreviations for rubber materials:
 - 1. EPDM: Ethylene-propylene-diene terpolymer rubber.
 - 2. NBR: Acrylonitrile-butadiene rubber.

1.4 SUBMITTALS

- A. Product Data: For the following:
 - 1. Piping materials and installation instructions common to most piping systems.
 - 2. Joining Materials
 - 3. Transition fittings.
 - 4. Dielectric fittings.
 - 5. Mechanical sleeve seals.
 - 6. Sleeves.
 - 7. Escutcheons.
 - 8. Grout.
 - 9. Equipment installation requirements common to equipment sections.
 - 10. Painting and finishing.
 - 11. Concrete bases.
 - 12. Supports and anchorages.
- B. Welding certificates.

1.5 QUALITY ASSURANCE.

- A. System Life Expectancy:
 - 1. All Fire Protection piping and distribution systems shall be designed and installed with materials and practices to meet a minimum 50-year median useful life in their respective environments. This includes the selection of appropriate corrosion resistant materials, compatible joining methods, provisions for moisture shedding, access for inspection, cleaning and service and isolation from incompatible materials, protection from wildlife and moisture.
 - 2. All Fire Protection system design and installation shall take into account access for regular service and replacement. This shall include the ability to disconnect, make safe and remove a piece of equipment and replace in-kind, restored to function, without disrupting other services.

3. Useful life shall include consideration of the expected design duty including hours of use, frequency of start-stop cycles, availability of common or specific parts and consumables including attic stock spare parts to limit down-time.
- B. Steel Support Welding: Qualify processes and operators according to AWS D1.1, "Structural Welding Code--Steel."
 - C. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
 1. Comply with provisions in ASME B31 Series, "Code for Pressure Piping."
 2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.
 - D. Electrical Characteristics for Mechanical Equipment: Equipment that requires different voltages, amperages or additional, electrical services, devices or equipment may be furnished provided such proposed equipment is approved in writing, connecting electrical services, circuit breakers and conduit sizes are appropriately modified, and required additional services, devices, and equipment are provided. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements. Variations approved under this subparagraph shall be at no additional cost to the MBTA.

1.2 DELIVERY, STORAGE, AND HANDLING

- A. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

1.3 COORDINATION

- A. Arrange for pipe spaces, chases, slots, and openings in building structure during progress of construction, to allow for mechanical installations.
- B. Coordinate installation of required supporting devices in form work and set sleeves in poured-in-place concrete and other structural components as they are constructed.
- C. Coordinate requirements for access panels and doors for mechanical items requiring access that are concealed behind finished surfaces.
- D. Special Coordination at the VMF: The Vehicle Maintenance Facility is intended to have a light-weight insulated panel skin system which will be replaceable over time. No connections of services, piping, conduits, clips controls, equipment and the like, shall be attached directly to this panel system. All attachments of such services to the exterior walls shall be made only to permanent structure, girts or secondary steel strut systems, independent of the exterior panel skin system.

PART 2 - PRODUCTS

2.1 PIPE, TUBE, AND FITTINGS

- A. Refer to individual Division 15 piping Sections for pipe, tube, and fitting materials and joining methods.
- B. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

2.2 JOINING MATERIALS

- A. Refer to individual Division 15 piping Sections for special joining materials not listed below.
- B. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of the fluids within the piping system
 - 1. ASME B16.21, nonmetallic, flat, asbestos-free, (1/8-inch) maximum thickness unless thickness or specific material is indicated.
 - a. Full-Face Type: For flat-face, Class 125, and Class 250 cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, steel flanges.
 - 2. AWWA C110, rubber, flat face, (1/8 inch) thick, unless otherwise indicated; and full-face or ring type, unless otherwise indicated.
- C. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.
- E. Brazing Filler Metals: AWS A5.8, BCuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated; and AWS A5.8, BAg1, silver alloy for refrigerant piping and copper tubing run below slabs or below grade outside the building lines, unless otherwise indicated.
- F. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.3 TRANSITION FITTINGS

- A. AWWA Transition Couplings: Same size as, and with pressure rating at least equal to and with ends compatible with, piping to be joined.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cascade Waterworks Mfg. Co.
 - b. Dresser Industries, Inc.; DMD Div.
 - c. Ford Meter Box Company, Incorporated (The); Pipe Products Div.
 - d. JCM Industries.
 - e. Smith-Blair, Inc.
 - f. Viking Johnson.

2. Underground Piping (NPS 1-1/2) and Smaller: Manufactured fitting or coupling.
 3. Underground Piping (NPS 2) and Larger: AWWA C219, metal sleeve-type coupling.
 4. Aboveground Pressure Piping: Pipe fitting.
- B. Flexible Transition Couplings for Underground Nonpressure Drainage Piping: ASTM C 1173 with elastomeric sleeve, ends same size as piping to be joined, and corrosion-resistant metal band on each end.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cascade Waterworks Mfg. Co.
 - b. Fernco, Inc.
 - c. Mission Rubber Company.
 - d. Plastic Oddities, Inc.

2.2 DIELECTRIC FITTINGS

- A. Description: Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.
- B. Insulating Material: Suitable for system fluid, pressure, and temperature.
- C. Dielectric Unions: Factory-fabricated, union assembly, for (250-psig) minimum working pressure at (180 deg F).following:
- a. Capitol Manufacturing Co.
 - b. Central Plastics Company.
 - c. Eclipse, Inc.
 - d. Epco Sales, Inc.
 - e. Hart Industries, International, Inc.
 - f. Watts Industries, Inc.; Water Products Div.
 - g. Zurn Industries, Inc.; Wilkins Div.
- D. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig minimum working pressure as required to suit system pressures.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Capitol Manufacturing Co.
 - b. Central Plastics Company.
 - c. Epco Sales, Inc.
 - d. Watts Industries, Inc.; Water Products Div.
- E. Dielectric-Flange Kits: Companion-flange assembly for field assembly. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Advance Products & Systems, Inc.
 - b. Calpico, Inc.
 - c. Central Plastics Company.
 - d. Pipeline Seal and Insulator, Inc.
2. Separate companion flanges and steel bolts and nuts shall have 150- or 300-psig minimum working pressure where required to suit system pressures.
- F. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and (300-psig) minimum working pressure at (225 deg F).
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Calpico, Inc.
 - b. Lochinvar Corp.
- G. Dielectric Nipples: Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and (300-psig) minimum working pressure at (225 deg F). Following:
- a. Perfection Corp.
 - b. Precision Plumbing Products, Inc.
 - c. Sioux Chief Manufacturing Co., Inc.
 - d. Victaulic Co. of America.

2.2 MECHANICAL SLEEVE SEALS

- A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advance Products & Systems, Inc.
 - b. Calpico, Inc.
 - c. Metraflex Co.
 - d. Pipeline Seal and Insulator, Inc.
 - 2. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
 - 3. Pressure Plates: Stainless steel. Include two for each sealing element.
 - 4. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.3 SLEEVES

- A. Steel Pipe: ASTM A 53, Type E, Grade B, Schedule 40, galvanized, plain ends.

2.4 ESCUTCHEONS

- A. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.
- B. One-Piece, Cast-Brass Type: With set screw.
 - 1. Finish: Polished chrome-plated.
- C. One-Piece, Stamped-Steel Type: With set screw or spring clips and chrome-plated finish.
- D. One-Piece, Floor-Plate Type: Cast-iron floor plate.

2.5 GROUT

- A. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
 - 1. Characteristics: Post-hardening, volume-adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
 - 2. Design Mix: (5000-psi), 28-day compressive strength.
 - 3. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 PIPING SYSTEMS - COMMON REQUIREMENTS

- A. Install piping according to the following requirements and Division 15 Sections specifying piping systems.
- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems.

Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- C. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- F. Install piping to permit valve servicing, installation of insulation and tightening of flange bolts.
- G. Install piping at indicated slopes.

- H. Install piping free of sags and bends.
- I. Install fittings for changes in direction and branch connections.
- J. Install piping to allow application of insulation.
- K. Select system components with pressure rating equal to or greater than system operating pressure.
- L. Install escutcheons for penetrations of walls, ceilings, and floors according to the following:
 - 1. New Piping:
 - a. Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
 - b. Chrome-Plated Piping: One-piece, cast-brass type with polished chrome-plated finish.
 - c. Insulated Piping: One-piece, stamped-steel type with spring clips.
 - d. Bare Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
 - e. Bare Piping in Unfinished Service Spaces: One-piece, stamped-steel type with concealed hinge and set screw or spring clips.
 - f. Bare Piping in Equipment Rooms: One-piece, cast-brass type.
 - g. Bare Piping at Floor Penetrations in Equipment Rooms: One-piece, floor-plate type.
- M. Sleeves are not required for core-drilled holes.
- N. Permanent sleeves are not required for holes formed by removable PE sleeves.
- O. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs.
 - 1. Cut sleeves to length for mounting flush with both surfaces.
 - a. Exception: Extend sleeves installed in floors of mechanical equipment areas, fire sprinklered areas, or other wet areas (2 inches) above finished floor level. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
 - 2. Install sleeves in new walls and slabs as new walls and slabs are constructed.
 - 3. Install sleeves that are large enough to provide (1 inch) annular clear space between sleeve and pipe or pipe insulation. Use the following sleeve materials:
 - a. Steel Pipe Sleeves: For pipes smaller than (NPS 6).
 - b. Steel Sheet Sleeves: For pipes (NPS 6) and larger, penetrating gypsum-board partitions.
 - c. Stack Sleeve Fittings: For pipes penetrating floors with membrane waterproofing.
 - d. Secure flashing between clamping flanges. Install section of cast-iron soil pipe to extend sleeve to (2 inches) above finished floor level.

- 1) Seal space outside of sleeve fittings with grout.

4. Except for underground wall penetrations, seal annular space between sleeve and pipe or pipe insulation, using joint sealants appropriate for size, depth, and location of joint.
- P. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for (1-inch) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
1. Install steel pipe for sleeves smaller than (6 inches) in diameter.
 2. Install steel pipe for sleeves (6 inches) and larger in diameter.
 3. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
- Q. Underground, Exterior-Wall Pipe Penetrations: Install steel pipe for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for (1-inch) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
1. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
- R. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.
- S. Verify final equipment locations for roughing-in.
- T. Refer to equipment specifications in other Sections of these Specifications for roughing-in requirements.

3.2 PIPING JOINT CONSTRUCTION

- A. Join pipe and fittings according to the following requirements and Division 15 Sections specifying piping systems.
- B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe to be welded.
- C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end.
- E. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
- F. Brazed Joints: Construct joints according to AWS's "Braze Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.

- G. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
- H. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
- I. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.
- J. Do not use pipe sections that have cracked or open welds.
- K. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.
- L. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application.
- M. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.
- N. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
 - 1. Plain-End Pipe and Fittings: Use butt fusion.
 - 2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.3 PIPING CONNECTIONS

- A. Make connections according to the following, unless otherwise indicated:
 - 1. Install unions, in piping (NPS 2) and smaller, adjacent to each valve and at final connection to each piece of equipment.
 - 2. Install flanges or couplings, in piping (NPS 2-1/2) and larger, adjacent to flanged or grooved valves and at final connection to each piece of equipment.
 - 3. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
 - 4. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.
 - 5. Locate unions and flanges so that equipment and appurtenances are easily removable without removing additional piping.

3.4 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS

- A. Install equipment in accordance with applicable codes and standards to allow maximum possible headroom unless specific mounting heights are indicated.
- B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

- C. Install mechanical equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.
- D. Install equipment to allow right of way for piping installed at required slope.

3.5 PAINTING

- A. Painting of mechanical systems, equipment, and components is specified in Division 09 Section 09900 "Painting."
- B. Damage and Touchup: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

3.6 CONCRETE BASES

- A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project. All concrete bases shall be furnished and installed under DIVISION 3.
 - 1. Coordinate concrete bases of dimensions indicated, but not less than (4 inches) larger in both directions than supported unit.
 - 2. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
 - 5. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

3.7 ERECTION OF METAL SUPPORTS AND ANCHORAGES

- A. Refer to Division 05 Section "Miscellaneous Metal" for structural steel.
- B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.
- C. Field Welding: Comply with AWS D1.1.

3.8 ERECTION OF WOOD SUPPORTS AND ANCHORAGES

- A. Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor mechanical materials and equipment.

- B. Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.
- C. Attach to substrates as required to support applied loads.

3.9 GROUTING

- A. Mix and install grout for mechanical equipment base bearing surfaces, pump and other equipment base plates, and anchors.
- B. Clean surfaces that will come into contact with grout.
- C. Provide forms as required for placement of grout.
- D. Avoid air entrapment during placement of grout.
- E. Place grout, completely filling equipment bases.
- F. Place grout on concrete bases and provide smooth bearing surface for equipment.
- G. Place grout around anchors.
- H. Cure placed grout

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15053

COORDINATION AMONG MECHANICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes the following:

1. Coordination of Work
2. Coordination Drawings
3. Record Drawings.
4. Giving Information
5. Mechanical-Electrical Coordination

- B. Related Section:

1. Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements”
2. Section 03300 - CAST IN PLACE CONCRETE
3. Section 07840 - FIRESTOPPING
4. Section 07600 - FLASHING AND SHEET METAL
5. Section 07920 - JOINT SEALANTS
6. Section 09900 - PAINTING
7. Section 05500 - MISCELLANEOUS METALS
8. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
9. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
10. Section 15052 – BASIC MATERIALS AND METHODS FOR FIRE PROTECTION
11. Section 15058 - COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
12. Section 15062 - HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
13. Section 15074 - VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
14. Section 15084 - PLUMBING EQUIPMENT INSULATION
15. Section 15085 - PLUMBING PIPING INSULATION
16. Section 15086 – DUCT INSULATION
17. Section 15093 - SLEEVES AND SLEEVE SEALS FOR PIPING
18. Section 15112 - GENERAL-DUTY VALVES FOR PIPING
19. Section 15127 - METERS AND GAGES FOR PIPING
20. Section 15140 - DOMESTIC WATER PIPING
21. Section 15145 - DOMESTIC WATER PIPING SPECIALTIES
22. Section 15150 – SANITARY WASTE AND VENT PIPING
23. Section 15155 - SANITARY WASTE PIPING SPECIALTIES
24. Section 15160 - STORM DRAINAGE PIPING
25. Section 15165 - STORM DRAINAGE PIPING SPECIALTIES
26. Section 15183 – REFRIGERANT PIPING
27. Section 15195 - FACILITY NATURAL-GAS PIPING
28. Section 15815 – METAL DUCTS

29. Section 15900 – HVAC INSTRUMENTATION AND CONTROLS
30. Section 15940 – SEQUENCE OF OPERATION FOR HVAC SYSTEMS
31. Section 15950 – TESTING, ADJUSTING and BALANCING
32. Specific Sections Used On This Project Not Listed Here
33. DIVISION 16 – ELECTRICAL

1.3 COORDINATION OF WORK

- A. All work shall be coordinated by the Design-Builder.
- B. Work shall be performed in full harmony in cooperation with other trades on the project and so scheduled as to allow speedy and efficient completion of the work.
- C. In all spaces, prior to installation of visible material and equipment, including access panels, review Architectural Drawings for exact locations and where not definitely indicated, request information from Architect. Where the HVAC work shall interfere with the work of other trades, assist in working out the space conditions to make satisfactory adjustments before installation. Maintain maximum headroom at all locations. All piping, duct, conduit, and associated components to be as tight to underside of structure as possible.
- D. If any HVAC work has been installed before coordination with other trades so as to cause interference with the work of such trades, all necessary adjustments and corrections shall be made by the trades involved without extra cost to MBTA.
- E. Where conflicts or potential conflicts exist and engineering guidance is desired, submit sketch of proposed resolution to Architect for review and approval.
- F. Protect all materials and work of other trades from damage which may be caused by the HVAC work, and repair all damages without extra cost to MBTA.
- G. Base all required measurements, both horizontal and vertical, on reference and datum points established by the Design-Builder and be responsible for the correct laying out of the trade work. In the event of a discrepancy between actual measurements and those indicated, notify the General Contractor in writing, and do not proceed with the work required until written instructions have been issued by the General Contractor.
- H. Special Coordination at the VMF: The Vehicle Maintenance Facility is intended to have a light-weight insulated panel skin system which will be replaceable over time. No connections of services, piping, conduits, clips controls, equipment and the like, shall be attached directly to this panel system. All attachments of such services to the exterior walls shall be made only to permanent structure, girts or secondary steel strut systems, independent of the exterior panel skin system.

1.4 COORDINATION DRAWINGS

- A. Conform to the requirements of DIVISION 01. The Design-Builder shall comply with provisions of documentation including drawing format, electronic 3-D and Building Information Modeling (BIM) processes, specified elsewhere. For the purposes of this specification, the term, “coordination drawings” and, “drawings” will be used to indicate documentation in any number of forms for the purposes of this project.

- B. In general, the larger system elements including structures shall lead the coordination effort, followed by smaller systems and elements. Services and systems that must pitch shall have right-of-way over systems that may change elevation. Architectural elements including finishes, reflected ceiling plans, fixtures and construction, shall have first order precedence. Systems serving the building shall have a first duty to conform, prior to changing the architectural or structural elements. Nothing in this paragraph shall prohibit parallel work-flow by separate parties if it is in the best interests of the project schedule.
- C. Produce composite All-Trade systems Coordination Drawings showing how HVAC, Plumbing, Fire Protection and Electrical systems are to be installed where conflicts with the work of other trades may occur. The Design-Builder, before transmittal of the Shop Drawings for approval, may require the HVAC and Sheet Metal Subcontractors to revise the composite systems and Shop Drawings and to make reasonable modifications in the layout of the HVAC work, so that the HVAC work may be properly accommodated without the interference with work of other trades. The HVAC and Sheet Metal Subcontractors shall make such revisions to composite systems coordination drawings, when requested, without extra charge.
- D. The Design-Builder shall be responsible for the cost of changes in their respective systems and adjoining work where an approved substitution of the any trade equipment requires such changes in the work or in the adjoining work of any other trade. Coordination Drawings shall show all changes.
- E. In no case shall the work of any trade and their systems be used to support the ceiling construction.
- F. No trade contractor shall install their systems in any portion which interferes with access to any element requiring access by any trade's work.
- G. Access Panel Coordination: Show locations and sizes of all access panels for all trades on Coordination Drawings. The Testing Adjusting and Balancing Sub-subcontractor (TAB) shall review the Coordination Drawings and verify that all balancing devices are shown and all required access has been addressed. The Design-Builder shall sign-off on the Coordination Drawings prior to submittal.
- H. The Design-Builder shall produce a set of Rooftop-Level Equipment Coordination Drawings; complete with air intakes, boiler stacks, emergency generator exhaust and air systems exhausts shown and identifying the appropriate clearances between discharge and intake points and illustrating that minimum clearances are identified, dimensioned and maintained, including elevations.

1.5 RECORD DRAWINGS

- A. Comply with Volume 1 DB Contract Terms and Conditions.
- B. This trade shall submit the record set for approval by the fire and building departments in a form acceptable to the departments, when required by the jurisdiction.
- C. Drawings shall show record condition of details, sections, riser diagrams, control changes and corrections to schedules. Schedules shall show actual manufacturer and make and model numbers of final equipment installation.

1.6 GIVING INFORMATION

- A. The Design-Builder shall keep themselves and others continuously informed of the progress of their respective work. This shall include scheduling of pending work, coordination of related work by other contractors, cutting, patching, operations affecting schedule and progress of others.
- B. Furnish to other trades advance information on locations and sizes of all frames, boxes, sleeves and openings needed for their work, and also furnish information and shop drawings necessary to permit trades affected by the work to install same properly and without delay.

1.7 MECHANICAL-ELECTRICAL COORDINATION

- A. Each Mechanical (HVAC, Plumbing and Fire Protection) Contractor shall furnish and install various electrical items relating to the HVAC equipment and control apparatus. The Electrical Contractor shall be required to connect power wiring to this equipment unless noted otherwise.
- B. For this project in general, HVAC equipment with motors up to 1/2 HP shall be 120 volt single-phase. Motors $\frac{3}{4}$ HP and above shall be 480 volt three-phase. It shall be understood that equipment manufacturer's increments, motor ratings and commercial availability may differ from the above core voltages. All shall be coordinated and accommodated.
- C. Single-phase variable speed motor driven equipment shall be furnished with speed controllers. These speed controllers shall be furnished to the DIV 16 Subcontractor for installation and wiring in the power train to the equipment served.
- D. Variable Frequency Drives VFD for 3-phase motors under this Division shall be furnished and installed under this Division and wired from source to VFD and from VFD to load, by the DIV 16 Subcontractor. This shall include but not be limited to pumps, fans and loose equipment that does not have packaged VFDs. Packaged VFDs shall be wired to source by the DIV 16 Subcontractor.
- E. The Mechanical and Electrical Contractors shall coordinate their respective portions of the work, as well as the electrical characteristics of the powered equipment and maintain a common shared schedule for reference prior to commencing work.
- F. All power wiring and local disconnect switches will be provided by the Electrical Contractor for the line voltage power. All low-voltage control and interlocking wiring shall be the responsibility of the HVAC contractor's ATC Subcontractor.
- G. 120V and above power wiring sources extended and connected to HVAC control panels, transformers and switches shall be the responsibility of the Electrical Contractor. All low voltage thermostats, zone valve and any switch wiring shall be the responsibility of the HVAC contractor's ATC/DDC Subcontractor.
- H. DDC System control and equipment wiring shall be installed by the ATC/DDC Sub-subcontractor. This work shall include connection to 120 Volt source as provided under Division 16, transformers, power supplies and power conditioners. All such wiring shall conform to wiring standards and practices in accordance with applicable Division 16 specifications.

PART 2 - PRODUCTS

2.1 Not Used.

PART 3 - EXECUTION

3.1 Not Used

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment"

END OF SECTION

SECTION 15054

ELECTRICAL REQUIREMENT FOR MECHANICAL WORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT

1.2 SUMMARY

- A. Section Includes:
 - 1. This section defines the extent of electrical equipment and wiring for mechanical equipment and systems that shall be provided under Division 15 – MECHANICAL and Division 16 – ELECTRICAL.
 - 2. Motors provided with mechanical equipment shall meet the requirements of Section 15058- COMMON MOTOR REQUIREMENTS FOR EQUIPMENT.
 - 3. Motor starting equipment provided by Division 15 for mechanical units shall meet the requirements of Section 15058- COMMON MOTOR REQUIREMENTS FOR EQUIPMENT. Drawings and general provisions of the Contract.

1.3 DEFINITIONS

- A. “Power wiring” is defined as wiring (120V and higher) from the power source, e.g., panelboard, motor control center, or switchboards, to the equipment disconnect switch or disconnect switch and starter, including wiring from the switches to the equipment.
- B. “Control wiring” is defined as wiring and conduit not defined as power wiring, whether line (120V) voltage or low voltage, to provide for the operation of the equipment, equipment-motorized dampers and ATC control devices.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Wiring Diagrams: For power, signal, and control wiring.

PART 2 - PRODUCTS

2.1 MOTOR STARTING EQUIPMENT

A. General:

1. The Division 15 Contractor, in accordance with this section, shall furnish all magnetic motor starters and combination starters, which serve the mechanical equipment.
2. Motor control centers, starters, disconnect switches, and combination starters and disconnect switches shall be installed by the Division 16 Contractor, except for packaged equipment which contains integral control panels.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Siemens
2. Square-D
3. Allen Bradley
4. Cutler Hammer

C. Motor starters shall be three pole, 60 Hertz, full-voltage magnetic across the line type with NEMA 1A gasketed enclosures. For exterior, damp, or wet locations, enclosures shall be NEMA 4 stainless steel, or NEMA 3R rain tight.

1. Minimum size starter shall be NEMA size 0.

D. Starters shall be of the combination thermal/magnetic circuit breaker type.

1. The short circuit interrupting rating of the protective device provided shall be higher than the available system short circuit capacity at the point of connection, and match the bus bracing withstand rating.

E. Starter shall be furnished complete with "hand-off-automatic" selector switches, pilot indicating lights, a minimum of four auxiliary convertible contacts and fuses unless otherwise noted. Include other equipment as required and as necessary for proper power operation including but not limited to the following:

1. Green pilot light for starter contacts "OPEN" or motor not running.
2. Red pilot light for starter contacts "CLOSED" or motor running.

F. Each magnetic starter shall have a 120 volt coil and a fuse for protection of control wiring. Each starter shall have an individual control power transformer with primary and secondary fuses. Control power transformer shall have a VA rating sufficient to provide power for devices to be operated from transformer.

G. Class K-5 shall provide dual element current limiting fuses for fused starters circuit protection.

H. Each starter shall be furnished complete with the proper quantity of ambient compensated thermal overload relays rated for the motor amperes. Overload relays, used with power factor corrected motors, shall be selected to compensate for the reduced line current due to the capacitor.

I. Motor starters for two-speed, two winding motors shall be three pole, non-reversing type with three position "hand-off-automatic" selector switch and two position "high-low" selector switch. Starters

for three or four speed motors shall be of the same type with the number of contactors and wiring as required for the application.

- J. All magnetic starters shall be electrically held, and equipped with two (2) normally opened and two (2) normally closed auxiliary contacts.

2.2 MOTOR CIRCUIT FUSES

- A. Individual motor circuit fuses, rated 480 volts or less, shall be rated approximately 125 percent of motor full load current except where high ambient temperatures prevail or where the motor drives a heavy revolving part which cannot be brought up to full speed quickly, such as large fans. Under such conditions, the fuse should be 150 to 200 percent of motor full load current.

2.3 THERMAL MANUAL MOTOR STARTING SWITCHES

- A. Thermal manual motor starting switches, for single phase motors, shall be manually operated toggle switches equipped with a melting alloy type thermal overload relay.
 - 1. Thermal unit shall be interchangeable and starter shall be inoperative if thermal overload unit is removed.
 - 2. Toggle switch shall be quick make and break type with self-indicating trip free handle.
- B. Single phase motors, which are controlled by devices not rated for control of the motor, shall be provided with magnetic starter and accessories as specified in paragraph 2.1.
- C. Enclosures to be NEMA 1 for interior use and NEMA 4 stainless steel or NEMA 3R rain tight for exterior, damp, or wet locations. Provide handle guard having locking provisions on enclosures. Provide flush mounted enclosures for units located in finished areas.
- D. Starting switches shall be combined with a three-position "hand-off-automatic" selector switch horsepower rated and a red pilot light mounted in the same enclosure.
- E. For two speed single phase motors, furnish two-speed starters combined with at three position "hand-off-automatic" selector switch and a two position "high-low" selector switch.

2.4 VARIABLE FREQUENCY CONTROLLERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. ABB Power Distribution, Inc.; ABB Control, Inc. Subsidiary.
 - 2. Eaton Corporation; Cutler-Hammer Products.
 - 3. General Electric Company; GE Industrial Systems.
 - 4. Rockwell Automation; Allen-Bradley Co.; Industrial Control Group.
 - 5. Siemens Energy and Automation; Industrial Products Division.
 - 6. Square D.
- B. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.

1. Provide unit suitable for operation of premium-efficiency motor as defined by NEMA MG 1.
- C. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.
- D. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.
- E. Unit Operating Requirements:
1. Input ac voltage tolerance of 480 V plus or minus 10 percent.
 2. Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
 3. Minimum Efficiency: 96 percent at 60 Hz, full load.
 4. Minimum Displacement Primary-Side Power Factor: 98 percent.
 5. Overload Capability: 1.1 times the base load current for 60 seconds; 1.5 times the base load current for 3 seconds.
 6. Starting Torque: 100 percent of rated torque or as indicated.
 7. Speed Regulation: Plus or minus 1 percent.
- F. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
1. Electrical Signal: 4 to 20 mA at 24 V.
- G. Internal Adjustability Capabilities:
1. Minimum Speed: 5 to 25 percent of maximum rpm.
 2. Maximum Speed: 80 to 100 percent of maximum rpm.
 3. Acceleration: 2 to a minimum of 22 seconds.
 4. Deceleration: 2 to a minimum of 22 seconds.
 5. Current Limit: 50 to a minimum of 110 percent of maximum rating.
- H. Self-Protection and Reliability Features:
1. Input transient protection by means of surge suppressors.
 2. Under- and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
 3. Motor Overload Relay: Adjustable and capable of NEMA ICS 2, Class 20 performance.
 4. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
 5. BACnet® card
 6. Instantaneous line-to-line and line-to-ground overcurrent trips.
 7. Loss-of-phase protection.
 8. Reverse-phase protection.
 9. Short-circuit protection.
 10. Motor overtemperature fault.
- I. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.
1. Provide power loss ride through of 2 seconds.
- J. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.

- K. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
- L. Input Line Conditioning 3% Line Reactor
- M. Status Lights: Door-mounted LED indicators shall indicate the following conditions:
 - 1. Power on.
 - 2. Run.
 - 3. Overvoltage.
 - 4. Line fault.
 - 5. Overcurrent.
 - 6. External fault.
- N. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual speed control potentiometer and elapsed time meter.
- O. Indicating Devices: Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
 - 1. Output frequency (Hz).
 - 2. Motor speed (rpm).
 - 3. Motor status (running, stop, fault).
 - 4. Motor current (amperes).
 - 5. Motor torque (percent).
 - 6. Fault or alarming status (code).
 - 7. PID feedback signal (percent).
 - 8. DC-link voltage (VDC).
 - 9. Set-point frequency (Hz).
 - 10. Motor output voltage (V).
- P. Control Signal Interface:
 - 1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
 - 2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BMS or other control systems:
 - a. 0 to 10-V dc.
 - b. 0-20 or 4-20 mA.
 - c. Potentiometer using up/down digital inputs.
 - d. Fixed frequencies using digital inputs.
 - e. BACnet® interface.
 - f. Keypad display for local hand operation.
 - 3. Output Signal Interface:
 - a. A minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
 - 1) Output frequency (Hz).
 - 2) Output current (load).
 - 3) DC-link voltage (VDC).

- 4) Motor torque (percent).
 - 5) Motor speed (rpm).
 - 6) Set-point frequency (Hz).
4. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
- a. Motor running.
 - b. Set-point speed reached.
 - c. Fault and warning indication (overtemperature or overcurrent).
 - d. PID high- or low-speed limits reached.
- Q. Communications: Provide a BACnet® interface allowing VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.
- R. Integral Disconnecting Means: NEMA KS 1 non-fusible switch with lockable handle.
- S. Enclosures shall be NEMA 1.
- T. Accessories:
- 1. Devices shall be factory installed in controller enclosure, unless otherwise indicated.
 - 2. Control Relays: Auxiliary and adjustable time-delay relays.
 - 3. Standard Displays:
 - a. Output frequency (Hz).
 - b. Set-point frequency (Hz).
 - c. Motor current (amperes).
 - d. DC-link voltage (VDC).
 - e. Motor torque (percent).
 - f. Motor speed (rpm).
 - g. Motor output voltage (V).
- U. Historical Logging Information and Displays:
- 1. Real-time clock with current time and date.
 - 2. Running log of total power versus time.
 - 3. Total run time.
 - 4. Fault log, maintaining last four faults with time and date stamp for each.
- V. Factory finishes: Manufacturer's standard paint applied to factory-assembled and -tested VFCs before shipping.

PART 3 - EXECUTION

3.1 GENERAL

- A. All electric wiring, motors and motor starting equipment provided under Division 15 shall be installed in accordance with the requirements of Division 16 Specifications.

- B. Control panels provided as a part of mechanical equipment shall include circuit protection for each motor, electric heater, control circuit and other circuits requiring protection. Where remote manual controls are required, they shall operate at 120 volts maximum. A control power transformer shall be provided for these remote manual controls.
- C. All outdoor equipment shall be wired in weatherproof, seal tight cast boxes with rigid steel conduit. Provide flexible, seal tight conduit final connection to equipment.
- D. All panels, relays, terminal boxes, junction boxes, contactors, circuit breakers, safety switches, motor starters and similar items, shall be identified by name, function and/or control. See Specification Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT" for further identification requirements

3.2 DIVISION 15 – REQUIREMENTS

- A. The Division 15 Control Subcontractor shall provide all controls, control devices, and mountings for controls and all other electrical devices as specified and necessary for the complete installation and satisfactory operation of all electrically operated controls furnished under the mechanical contract. Control wiring throughout the project, including wiring to controls installed on equipment, piping and in ductwork, shall be provided by the Division 15 Contractor.
- B. Control wiring under Division 15 shall include all connections to control devices, interlock wiring, control relays, alarm wiring, and minor power wiring to auxiliary components for major pieces of equipment. Minor power wiring, 120 volts and below, shall include requirements for such equipment as damper motors, speed controllers, control switches, VAV boxes, solenoid valves, water treatment equipment, electrically operated filters, control panels, controllers, other ATC devices and interconnecting wiring on equipment that has not been factory installed. In general, all control wiring that is not shown on Electrical Drawings shall be provided under Division 15.
- C. Provide power sources for all control wiring from spare breakers in building electrical panels. Coordinate spare breaker usage with Division 16 Contractor. Provide additional breakers in panels or addition electrical panels if required, to obtain power sources. Provide transformers to reduce voltage as required.
- D. All internal wiring in equipment shall be completely factory installed. Where internal wiring cannot be factory installed, it shall be field installed under Division 15.
- E. Internal wiring in equipment shall be brought to terminal facilities at one location, for connection of field wiring. For individual motors, a larger wiring chamber of conduit entry shall be provided. For equipment with a control panel, barrier type terminal strips shall be provided in an enclosure arranged for conduit entry.
- F. The Division 15 Contractor shall coordinate with the Division 16 Contractor the exact location of disconnects, smoke detectors and combination disconnects and starter when not indicated.
- G. It shall be the responsibility of the Division 15 Contractor to insure that the voltage and current characteristics of the electrical equipment provided under Division 15 shall be suitable for the electrical services provided.

- H. The Division 15 Contractor shall receive smoke detectors from Division 16. The Division 15 Contractor shall mount detectors in ductwork, but Division 16 shall wire detectors as specified in Division 16 requirements below.

3.3 DIVISION 16 – REQUIREMENTS

- A. All starters and combination starters/ disconnect switches shall be furnished by the Division 15 Contractor, and installed by the Division 16 Contractor. Disconnect Switches not noted in the Division 15 Equipment Schedules shall be provided by the Division 16 Contractor. Power wiring from the power source to the above noted devices, from these devices to the equipment, and final connection to the equipment and devices, shall be by the Division 16 Contractor.
- B. Power wiring under Division 16 shall include power feeders to major pieces of equipment. From the source of building power, the feeder shall be extended to wiring terminals on the equipment as following noted:
 - 1. At individual motors, such as those used for fans and pumps, power wiring shall be extended to the wiring chamber on the motor.
 - 2. At factory assemblies of components, such as duplex pumps, power wiring shall be extended to the assembly. Where control panels include motor starters, power wiring under Division 16 will terminate at the control panel terminal strip or starter, but shall be extended to each motor under Division 15. Where control panels do not include motor starters, power wiring under Division 16, shall be extended through motor starters and terminate at the wiring chamber on each motor.
 - 3. At factory assembled manufactured equipment with control panels having starters, power wiring under Division 16 shall terminate at the control panel terminal strip or starter, and shall be extended to each motor by the equipment manufacturer, if control panel is mounted on equipment, or by the Division 15 Contractor if the control panel is remote from equipment.

PART 4 - PAYMENTS AND MEASUREMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 15058

COMMON MOTOR REQUIREMENTS FOR EQUIPMENT

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING
 - 3. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 4. Division 15 Sections for specific motorized equipment.

1.2 SUMMARY

- A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation. Section also includes single-phase and poly-phase variable-speed brushless DC Electronically Commutating Motors (ECM) and associated controls, installed at equipment manufacturer's factory.

1.3 COORDINATION

- A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:
 - 1. Motor speed controllers.
 - 2. Torque, speed, and horsepower requirements of the load.
 - 3. Ratings and characteristics of supply circuit and required control sequence.
 - 4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

- A. Comply with NEMA MG 1 unless otherwise indicated.

2.2 MOTOR CHARACTERISTICS

- A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.

- B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.3 POLYPHASE MOTORS

- A. Description: NEMA MG 1, Design B, medium induction motor.
- B. Efficiency: Energy efficient, as defined in NEMA MG 1.
- C. Service Factor: 1.15.
- D. Multispeed Motors: Variable torque.
 - 1. For motors with 2:1 speed ratio, consequent pole, single winding.
 - 2. For motors with other than 2:1 speed ratio, separate winding for each speed.
- E. Multispeed Motors: Separate winding for each speed.
- F. Rotor: Random-wound, squirrel cage.
- G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.
- H. Temperature Rise: Match insulation rating.
- I. Insulation: Class F.
- J. Code Letter Designation:
 - 1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
 - 2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.
- K. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.4 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS

- A. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
 - 1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
 - 2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
 - 3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
 - 4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

2.5 SINGLE-PHASE AND CERTAIN POLYPHASE MOTORS

- A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:
 - 1. Electronically Commutating (EC) Motors; Default for all variable and constant torque applications including fans and circulators. Applications and controls specific to equipment in which installed.
 - 2. Permanent-split capacitor (PSC): Use limited to constant speed motors not exceeding ¼ HP and where EC motors are not specified.
 - 3. Capacitor start, inductor run.
- B. EC Motor Controls: Integral 0-10 VDC potentiometer dial switches for manual adjustment at a minimum. Automatic controllers for applications requiring external input signals; switchable values including 0-10 VDC, 4-10 VDC, 4-20 mA and 0-135 Ohm, to suit available control inputs.
- C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.
- D. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION

Not Applicable.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15062

HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:

1. Metal pipe hangers and supports.
2. Trapeze pipe hangers.
3. Metal framing systems.
4. Fastener systems.
5. Pipe stands.
6. Equipment supports.
7. Miscellaneous materials

- B. Related Sections:

1. Section 05500 - MISCELLANEOUS METALS for structural-steel shapes and plates for trapeze hangers for equipment supports.
2. Section 07720 – ROOF ACCESSORIES
3. Section 15074 - VIBRATION AND SEISMIC CONTROLS" for vibration isolation devices.
4. Section 15815 - METAL DUCTS" for duct hangers and supports.
5. Section 07720 - ROOF ACCESSORIES
6. Section 15085 - PLUMBING PIPING INSULATION
7. Section 15088 - HVAC PIPING INSULATION
8. Section 15093 - SLEEVES AND SLEEVE SEALS FOR PIPING
9. Section 15140 - DOMESTIC WATER PIPING
10. Section 15150 - SANITARY WASTE AND VENT PIPING
11. Section 15160 - STORM DRAINAGE PIPING
12. Section 15183 - REFRIGERANT PIPING
13. Section 15195 - FACILITY NATURAL-GAS PIPING

1.3 DEFINITIONS

- A. MSS: Manufacturers Standardization Society of The Valve and Fittings Industry Inc.

1.4 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design trapeze pipe hangers and equipment supports, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: Signed and sealed by a qualified professional engineer, registered in MA. Show fabrication and installation details and include calculations for the following; include Product Data for components:
 - 1. Metal framing systems.
 - 2. Pipe stands.
 - 3. Equipment supports.
- C. Delegated-Design Submittal: For trapeze hangers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 - 1. Detail fabrication and assembly of trapeze hangers.
 - 2. Design Calculations: Calculate requirements for designing trapeze hangers.

1.6 INFORMATIONAL SUBMITTALS

- A. Welding certificates.

1.7 QUALITY ASSURANCE

- A. Structural Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

PART 2 - PRODUCTS

2.1 METAL PIPE HANGERS AND SUPPORTS

- A. Carbon-Steel Pipe Hangers and Supports:
 - 1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
 - 2. Galvanized Metallic Coatings: Pregalvanized or hot dipped.
 - 3. Nonmetallic Coatings: Plastic coating, jacket, or liner.
 - 4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
 - 5. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.
- B. Stainless-Steel Pipe Hangers and Supports:
 - 1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
 - 2. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
 - 3. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.

C. Copper Pipe Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.
2. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.

2.2 TRAPEZE PIPE HANGERS

- A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

2.3 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Allied Tube & Conduit.
 - b. Cooper B-Line, Inc.
 - c. Flex-Strut Inc.
 - d. GS Metals Corp.
 - e. Thomas & Betts Corporation.
 - f. Unistrut Corporation; Tyco International, Ltd.
2. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
3. Standard: MFMA-4.
4. Channels: Continuous slotted steel channel with inturned lips.
5. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
6. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.
7. Metallic Coating: Electroplated zinc.

2.4 FASTENER SYSTEMS

- A. Mechanical-Expansion Anchors: Insert-wedge-type, stainless- steel anchors, for use in hardened Portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

2.5 PIPE STANDS

- A. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.
- B. Compact Pipe Stand: One-piece plastic unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.

- C. Low-Type, Single-Pipe Stand: One-piece stainless-steel base unit with plastic roller, for roof installation without membrane penetration.
- D. High-Type, Single-Pipe Stand:
 - 1. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
 - 2. Base: Stainless steel.
 - 3. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
 - 4. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.
- E. Curb-Mounted-Type Pipe Stands: Shop- or field-fabricated pipe supports made from structural-steel shapes, continuous-thread rods, and rollers, for mounting on permanent stationary roof curb.

2.6 EQUIPMENT SUPPORTS

- A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

2.7 MISCELLANEOUS MATERIALS

- A. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; black and galvanized.
- B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
 - 1. Properties: Nonstaining, noncorrosive, and nongaseous.
 - 2. Design Mix: 5000-psi, 28-day compressive strength.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

- A. Metal Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.
 - 1. Trapeze pipe hanger in first paragraph below requires calculating and detailing at each use.
 - 2. Metal framing system in first paragraph below requires calculating and detailing at each use.
- B. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.
- C. Fastener System Installation:
 - 1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.

2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.
- D. Pipe Stand Installation:
1. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Section 07720 "ROOF ACCESSORIES" for curbs.
- E. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.
- F. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
- G. Install lateral bracing with pipe hangers and supports to prevent swaying.
- H. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.
- I. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
- J. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

3.2 EQUIPMENT SUPPORTS

- A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.
- B. Grouting: Place grout under supports for equipment and make bearing surface smooth.
- C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.3 METAL FABRICATIONS

- A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.
- B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
- C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
 1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
 2. Obtain fusion without undercut or overlap.

3. Remove welding flux immediately.
4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.4 ADJUSTING

- A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.
- B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches.

3.5 PAINTING

- A. Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Section 09900 "PAINTING"
- B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

3.6 HANGER AND SUPPORT SCHEDULE

- A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
- B. Comply with MSS SP-69 for pipe-hanger selections and applications that are not specified in piping system Sections.
- C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish and where stainless steel materials are not specified. All support systems including hardware, brackets, hangers, rods and isolators shall be of compatible materials for each application.
- D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.
- E. Use carbon-steel pipe hangers and supports metal trapeze pipe hangers and metal framing systems and attachments for general interior service applications.
- F. Use stainless-steel pipe hangers and supports metal trapeze pipe hangers and metal framing systems and attachments for general exterior service applications. All exterior-applied support systems shall be manufactured specifically for exterior applications.
- G. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
 1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
 2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
 3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
 4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
 5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.

H. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joint construction, to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
 - a. Light (MSS Type 31): 750 lb.
 - b. Medium (MSS Type 32): 1500 lb.
 - c. Heavy (MSS Type 33): 3000 lb.
13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

I. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.

J. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15074

VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15051 - BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15084 – PLUMBING EQUIPMENT INSULATION
 - 6. Section 15085 – PLUMBING PIPING INSULATION
 - 7. Section 15086 – DUCT INSULASTION
 - 8. Section 15088 – HVAC PIPING INSULATION
 - 9. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 10. Section 15140 – DOMESTIC WATER PIPING
 - 11. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 12. Section 15160 – STORM DRAINAGE PIPING
 - 13. Section 15182 – HIGH PRESSURE PIPING
 - 14. Section 15183 – REFRIGERANT PIPING
 - 15. Section 15195 – FACILITY NATURAL-GAS PIPING
 - 16. Section 15815 – METAL DUCTS

1.2 SUMMARY

- A. Section Includes:
 - 1. Elastomeric isolation pads.
 - 2. Elastomeric isolation mounts.
 - 3. Open-spring isolators.
 - 4. Housed-spring isolators.
 - 5. Pipe-riser resilient supports.
 - 6. Resilient pipe guides.
 - 7. Elastomeric hangers.
 - 8. Spring hangers.
 - 9. Snubbers.
 - 10. Restraint channel bracings.
 - 11. Restraint cables.
 - 12. Seismic-restraint accessories.
 - 13. Mechanical anchor bolts.
 - 14. Adhesive anchor bolts.

1.3 DEFINITIONS

- A. IBC: International Building Code.
- B. ICC-ES: ICC-Evaluation Service.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
 - 2. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device and seismic-restraint component required.
 - a. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by an agency acceptable to authorities having jurisdiction.
 - b. Annotate to indicate application of each product submitted and compliance with requirements.
 - 3. Interlocking Snubbers: Include ratings for horizontal, vertical, and combined loads.
- B. Shop Drawings:
 - 1. Detail fabrication and assembly of equipment bases. Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 - 2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
- C. Delegated-Design Submittal: For each vibration isolation and seismic-restraint device.
 - 1. Include design calculations and details for selecting vibration isolators, seismic restraints, and vibration isolation bases complying with performance requirements, design criteria, and analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 - 2. Design Calculations: Calculate static and dynamic loading due to equipment weight, operation, and seismic and wind forces required to select vibration isolators and seismic and wind restraints and for designing vibration isolation bases.
 - a. Coordinate design calculations with wind load calculations required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.
 - 3. Riser Supports: Include riser diagrams and calculations showing anticipated expansion and contraction at each support point, initial and final loads on building structure, spring deflection changes, and seismic loads. Include certification that riser system was examined for excessive stress and that none exists.
 - 4. Seismic- and Wind-Restraint Details:
 - a. Design Analysis: To support selection and arrangement of seismic and wind restraints. Include calculations of combined tensile and shear loads.
 - b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values

of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.

- c. Coordinate seismic-restraint and vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.
- d. Preapproval and Evaluation Documentation: By an agency acceptable to authorities having jurisdiction, showing maximum ratings of restraint items and the basis for approval (tests or calculations).

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Show coordination of vibration isolation device installation and seismic bracing for HVAC piping and equipment with other systems and equipment in the vicinity, including other supports and restraints, if any.
- B. Qualification Data: For professional engineer and testing agency.
- C. Welding certificates.
- D. Field quality-control reports.

1.6 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910.7 and that is acceptable to authorities having jurisdiction.
- B. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.
- C. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- D. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are unavailable, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

PART 2 - PRODUCTS

2.1 ELASTOMERIC ISOLATION PADS

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.

- b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.
2. Fabrication: Single or multiple layers of sufficient durometer stiffness for uniform loading over pad area.
 3. Size: Factory or field cut to match requirements of supported equipment.
 4. Pad Material: Oil and water resistant with elastomeric properties.
 5. Surface Pattern: Waffle pattern.
 6. Infused nonwoven cotton or synthetic fibers.
 7. Load-bearing metal plates adhered to pads.
 - a. Surface Pattern: Waffle pattern.
 - b. Infused nonwoven cotton or synthetic fibers.

2.2 ELASTOMERIC ISOLATION MOUNTS

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.
2. Mounting Plates:
 - a. Top Plate: Encapsulated steel load transfer top plates, factory drilled and threaded with threaded studs or bolts.
 - b. Baseplate: Encapsulated steel bottom plates with holes provided for anchoring to support structure.
3. Elastomeric Material: Molded, oil-resistant rubber, neoprene, or other elastomeric material.

2.3 OPEN-SPRING ISOLATORS

- A. Freestanding, Laterally Stable, Open-Spring Isolators: .
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Baseplates: Factory-drilled steel plate for bolting to structure with an elastomeric isolator pad attached to the underside. Baseplates shall limit floor load to 500 psig.
7. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

2.4 HOUSED-SPRING ISOLATORS

A. Freestanding, Laterally Stable, Open-Spring Isolators in Two-Part Telescoping Housing:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Isolation.
 - h. Vibration Mountings & Controls, Inc.
2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Two-Part Telescoping Housing: A steel top and bottom frame separated by an elastomeric material and enclosing the spring isolators.
 - a. Drilled base housing for bolting to structure with an elastomeric isolator pad attached to the underside. Bases shall limit floor load to 500 psig.
 - b. Top housing with elastomeric pad.

2.5 PIPE-RISER RESILIENT SUPPORT

1. Vertical-Limit Stops: Steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions.
2. Maximum Load Per Support: 500 psig on isolation material providing equal isolation in all directions.

2.6 RESILIENT PIPE GUIDES

1. Factory-Set Height Guide with Shear Pin: Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.7 ELASTOMERIC HANGERS

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Isolation Technology, Inc.
 - d. Kinetics Noise Control, Inc.
 - e. Mason Industries, Inc.
 - f. Vibration Eliminator Co., Inc.
 - g. Vibration Mountings & Controls, Inc.
2. Frame: Steel, fabricated with a connection for an upper threaded hanger rod and an opening on the underside to allow for a maximum of 30 degrees of angular lower hanger-rod misalignment without binding or reducing isolation efficiency.
3. Dampening Element: Molded, oil-resistant rubber, neoprene, or other elastomeric material with a projecting bushing for the underside opening preventing steel to steel contact.

2.8 SPRING HANGERS

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ace Mountings Co., Inc.
 - b. California Dynamics Corporation.
 - c. Kinetics Noise Control, Inc.
 - d. Mason Industries, Inc.
 - e. Vibration Eliminator Co., Inc.
 - f. Vibration Isolation.
 - g. Vibration Mountings & Controls, Inc.
2. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
4. Minimum Additional Travel: 50 percent of the required deflection at rated load.
5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
7. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.
8. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
9. Self-centering hanger-rod cap to ensure concentricity between hanger rod and support spring coil.

2.9 SNUBBERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Kinetics Noise Control, Inc.
 2. Mason Industries, Inc.
 3. Vibration Mountings & Controls, Inc.

- B. Description: Factory fabricated using welded structural-steel shapes and plates, anchor bolts, and replaceable resilient isolation washers and bushings.
 - 1. Anchor bolts for attaching to concrete shall be seismic-rated, drill-in, and stud-wedge or female-wedge type.
 - 2. Resilient Isolation Washers and Bushings: Oil- and water-resistant neoprene.
 - 3. Maximum 1/4-inch air gap, and minimum 1/4-inch-thick resilient cushion.

2.10 RESTRAINT CHANNEL BRACINGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Cooper B-Line, Inc.
 - 2. Hilti, Inc.
 - 3. Mason Industries, Inc.
 - 4. Unistrut.
- B. Description: MFMA-4, shop- or field-fabricated bracing assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.11 RESTRAINT CABLES

- A. Manufacturers: Subject to compliance with requirements, provide products by the following provide products by one of the following:
 - 1. Kinetics Noise Control, Inc.
 - 2. Loos & Co., Inc.
 - 3. Vibration Mountings & Controls, Inc.
- B. Restraint Cables: ASTM A 492 stainless-steel cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; with a minimum of two clamping bolts for cable engagement.

2.12 SEISMIC-RESTRAINT ACCESSORIES

- A. Manufacturers: Subject to compliance with requirements, provide products by the following provide products by one of the following:
 - 1. Cooper B-Line, Inc.
 - 2. Kinetics Noise Control, Inc.
 - 3. Mason Industries, Inc.
 - 4. TOLCO.
- B. Hanger-Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections or reinforcing steel angle clamped to hanger rod.
- C. Hinged and Swivel Brace Attachments: Multifunctional steel connectors for attaching hangers to rigid channel bracings and restraint cables.

- D. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.
- E. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices used.
- F. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

2.13 MECHANICAL ANCHOR BOLTS

- A. Manufacturers: Subject to compliance with requirements, provide products by the following provide products by one of the following:
 - 1. Cooper B-Line, Inc.
 - 2. Hilti, Inc.
 - 3. Kinetics Noise Control, Inc.
 - 4. Mason Industries, Inc.
- B. Expansion-type anchor bolts are not permitted by ASCE/SEI 7 for nonisolated equipment in excess of 10 hp.
- C. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

2.14 ADHESIVE ANCHOR BOLTS

- A. Manufacturers: Subject to compliance with requirements, provide products by the following provide products by one of the following:
 - 1. Hilti, Inc.
 - 2. Kinetics Noise Control, Inc.
 - 3. Mason Industries, Inc.
- B. Adhesive Anchor Bolts: Drilled-in and capsule anchor system containing PVC or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and equipment to receive vibration isolation and seismic- and wind-control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

- B. Examine roughing-in of reinforcement and cast-in-place anchors to verify actual locations before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

- A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an agency acceptable to authorities having jurisdiction.
- B. Hanger-Rod Stiffeners: Install hanger-rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.
- C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength is adequate to carry present and future static and seismic loads within specified loading limits.

3.3 VIBRATION CONTROL AND SEISMIC-RESTRAINT DEVICE INSTALLATION

- A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 03300 "CAST-IN-PLACE CONCRETE."
- B. Installation of vibration isolators must not cause any change of position of equipment, piping, or ductwork resulting in stresses or misalignment.
- C. Comply with requirements in Section 07720 "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.
- D. Equipment Restraints:
 - 1. Install seismic snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.
 - 2. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
 - 3. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction that provides required submittals for component.
- E. Piping Restraints:
 - 1. Comply with requirements in MSS SP-127.
 - 2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.
 - 3. Brace a change of direction longer than 12 feet.
- F. Install cables so they do not bend across edges of adjacent equipment or building structure.
- G. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction that provides required submittals for component.

- H. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.
- I. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.
- J. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.
- K. Drilled-in Anchors:
 - 1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 - 2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 - 3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
 - 4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
 - 5. Set anchors to manufacturer's recommended torque, using a torque wrench.
 - 6. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.4 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

- A. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:
 - 1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
 - 2. Schedule test with MBTA, through Architect, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.
 - 3. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.

4. Test at least four of each type and size of installed anchors and fasteners selected by Architect.
 5. Test to 90 percent of rated proof load of device.
 6. Measure isolator restraint clearance.
 7. Measure isolator deflection.
 8. Verify snubber minimum clearances.
 9. Test and adjust restrained-air-spring isolator controls and safeties.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Adjust isolators after piping system is at operating weight.
- B. Adjust limit stops on restrained-spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

PART 4 - EXECUTION

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15077

IDENTIFICATION FOR PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections
 - 1. Section 09900 - PAINTING
 - 2. Section 15050 - BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 3. Section 15051 - BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 4. Section 15084 - PLUMBING EQUIPMENT INSULATION
 - 5. Section 15085 - PLUMBING PIPING INSULATION
 - 6. Section 15086 - DUCT INSULATION
 - 7. Section 15088 - HVAC PIPING INSULATION
 - 8. Section 15112 – GENERAL DUTY VALVES FOR PIPING
 - 9. Section 15145 – DOMESTIC WATER PIPING
 - 10. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 11. Section 15160 – STORM DRAINAGE PIPING
 - 12. Section 15181 – HYDRONIC PIPING
 - 13. Section 15183 – REFRIGERANT PIPING
 - 14. Section 15195 – FACILITY NATURAL GAS PIPING
 - 15. Section 15211 – GENERAL-SERVICE COMPRESSED AIR PIPING

1.2 SUMMARY

- A. Section Includes:
 - 1. Equipment labels.
 - 2. Warning signs and labels.
 - 3. Pipe labels.
 - 4. Duct labels.
 - 5. Valve tags.
 - 6. Warning tags.
 - 7. Nameplates.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.

- C. Valve numbering scheme.
- D. Valve Schedules: For each piping system to include in maintenance manuals.

1.4 STANDARDS

- A. All labels, colors, contrast, sizes and designations shall conform to ASME A13.1-2007, unless otherwise noted.

1.5 COORDINATION

- A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
- B. Coordinate installation of identifying devices with locations of access panels and doors.
- C. Install identifying devices before installing acoustical ceilings and similar concealment.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

- A. Plastic Labels for Equipment:
 - 1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
 - 2. Letter Color: Black.
 - 3. Background Color: White.
 - 4. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
 - 5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
 - 6. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
 - 7. Fasteners: Stainless-steel self-tapping screws.
 - 8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- B. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified.
- C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch bond paper. Tabulate equipment identification number and identify Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.2 WARNING SIGNS AND LABELS

- A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8-inch-thick, and having predrilled holes for attachment hardware.
- B. Letter Color: Red.
- C. Background Color: Yellow.
- D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
- E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
- F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
- G. Fasteners: Stainless-steel self-tapping screws.
- H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- I. Label Content: Include caution and warning information, plus emergency notification instructions.
- J. Buried gas and pressure water utilities within the building and to a point 10 feet outside the building shall have detectable buried label tape, minimum 4.5 mil thickness, buried plumb over the protected line.

2.3 PIPE LABELS

- A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.
- B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.
- C. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.
- D. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.
 - 1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.
 - 2. Lettering Size: At least 1-1/2 inches high.

2.4 DUCT LABELS

- A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8-inch-thick, and having predrilled holes for attachment hardware.

- B. Letter Color: White.
- C. Background Color: Blue or Yellow.
- D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
- E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
- F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
- G. Fasteners: Stainless-steel self-tapping screws.
- H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
- I. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.
 - 1. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions, or as separate unit on each duct label to indicate flow direction.
 - 2. Lettering Size: At least 1-1/2 inches high.

2.5 VALVE TAGS

Retain requirement in "Action Submittals" Article to submit numbering scheme for approval.

- A. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.
 - 1. Tag Material: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
 - 2. Fasteners: Brass beaded chain.
- B. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.
 - 1. Valve-tag schedule shall be included in operation and maintenance data.

2.6 WARNING TAGS

- A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.
 - 1. Size: 3 by 5-1/4 inches minimum.
 - 2. Fasteners: Brass grommet and wire.

3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
4. Color: Yellow background with black lettering.

2.7 NAMEPLATES

- A. Each piece of motorized or fuel-burning equipment shall bear a permanent operational data nameplate. The nameplate shall indicate the manufacturer, product name, model number, serial number, performance capacity, operating and power characteristics, labels of tested compliances and listings and other essential data. The nameplate shall be in an accessible and visible location on the equipment as installed and shall not be obscured by insulation, coverings, attached devices or services.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.2 EQUIPMENT LABEL INSTALLATION

- A. Install or permanently fasten labels on each major item of mechanical equipment.
- B. Locate equipment labels where accessible and visible.

3.3 PIPE LABEL INSTALLATION

- A. Piping Color-Coding: Painting of piping is specified in Section 09900 "Painting".
- B. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
 1. Within 36 inches of each valve and control device.
 2. Within 36 inches of each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
 3. Within 36 inches of penetrations through walls, floors, ceilings, and inaccessible enclosures.
 4. At access doors, manholes, and similar access points that permit view of concealed piping.
 5. Within 36 inches of major equipment items and other points of origination and termination.
 6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.
 7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.
- C. Pipe Label Color Schedule:
 1. Natural Gas Piping:

- a. Background Color: Yellow.
- b. Letter Color: Black.

3.4 DUCT LABEL INSTALLATION

- A. Install plastic-laminated self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:
 - 1. Blue: For cold-air supply ducts.
 - 2. Yellow: For hot-air supply ducts.
 - 3. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
 - 4. ANSI/ASME A13.1 Colors and Designs: For hazardous material exhaust.
- B. Locate labels Within 36 inches of points where ducts enter concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system.

3.5 VALVE-TAG INSTALLATION

- A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.
- B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:
 - 1. Valve-Tag Size and Shape:
 - a. 1-1/2 inches, round.
 - 2. Valve-Tag Color:
 - a. Natural.
 - 3. Letter Color:
 - a. Black.

3.6 WARNING-TAG AND LABEL INSTALLATION

- A. Machine-print required message on, and attach warning tags to, equipment and other items where required.
- B. Include warning labels on heat-traced lines maximum 25-foot spacing in addition to standard location requirements.
- C. Bury detectable labeled warning tape plumb over and within 12 inches of protected services within the building and to a point 10 feet outside the building.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15084
PLUMBING EQUIPMENT INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes insulating the following plumbing equipment:
1. Domestic water storage tanks.
- B. Related Sections:
1. Volume 2 Technical Provisions Exhibit 2I “Additional Project Requirements”
SUSTAINABILITY REQUIREMENTS
 2. Section 15085 - PLUMBING PIPING INSULATION
 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 6. Section 15400 – PLUMBING FIXTURES
 7. Section 15485 – ELECTRIC WATER HEATERS

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied, if any).
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
 2. Detail attachment and covering of heat tracing inside insulation.
 3. Detail removable insulation at equipment connections and access panels.
 4. Detail application of field-applied jackets.
 5. Detail application at linkages of control devices.
 6. Detail field application for each equipment type.
 7. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
- C. Field quality-control reports.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84 by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
 - 1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
 - 2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 15062 "HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT."
- B. Coordinate clearance requirements with equipment Installer for equipment insulation application.
- C. Coordinate installation and testing of heat tracing.

1.8 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Equipment Insulation Schedule" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied ASJ complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; CrimpWrap.
 - b. Johns Manville; MicroFlex.
 - c. Knauf Insulation; Pipe and Tank Insulation.
 - d. Manson Insulation Inc.; AK Flex.
 - e. Owens Corning; Fiberglas Pipe and Tank Insulation.

2.2 INSULATING CEMENTS

- A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Super-Stik.
- B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Thermokote V.
- C. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.

2.3 ADHESIVES

- A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.
- B. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-50.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
 - 1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
 - b. Vimasco Corporation; 749.
 2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
 5. Color: White.
- C. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
 - b. Eagle Bridges - Marathon Industries; 550.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
 - d. Mon-Eco Industries, Inc.; 55-50.
 - e. Vimasco Corporation; WC-1/WC-5.
 2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 4. Solids Content: 60 percent by volume and 66 percent by weight.
 5. Color: White.

2.5 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
 2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.

2.6 FIELD-APPLIED JACKETS

- A. Insulation system schedules indicate field-applied jackets in various applications. When field-applied jackets are indicated, these shall be applied over factory-applied jackets and shall comply with the following:
1. PVC: White, paintable polyvinyl chloride (PVC) field applied jacket system including solvent-weld adhesive, pre-cut fitting covers for standard pipe fittings and configurations. Material shall

conform to ASTM D-1784, "Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds".

2. A flame spread rating of 25 or less and a smoke developed rating of 50 or less according to ASTM E 84.
3. A default minimum thickness of 30 mils (0.030 inches/0.80 mm).

2.7 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 428 AWF ASJ.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
 - c. Compac Corporation; 104 and 105.
 - d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
 2. Width: 3 inches.
 3. Thickness: 11.5 mils.
 4. Adhesion: 90 ounces force/inch in width.
 5. Elongation: 2 percent.
 6. Tensile Strength: 40 lbf/inch in width.
 7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

2.8 SECUREMENTS

- A. Bands:
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ITW Insulation Systems; Gerrard Strapping and Seals.
 - b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
 2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304; 0.015 inch thick, 3/4 inch wide with closed seal.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 1. Verify that systems and equipment to be insulated have been tested and are free of defects.

2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range between 140 and 300 deg F . Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 2. Carbon Steel: Coat carbon steel operating at a service temperature between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment.
- B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Keep insulation materials dry during application and finishing.
- G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- H. Install insulation with least number of joints practical.
- I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.
 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- K. Install insulation with factory-applied jackets as follows:
1. Draw jacket tight and smooth.
 2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
 3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.
 - a. For below ambient services, apply vapor-barrier mastic over staples.
 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints.
- L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
- O. For above ambient services, do not install insulation to the following:
1. Vibration-control devices.
 2. Testing agency labels and stamps.
 3. Nameplates and data plates.
 4. Manholes.
 5. Handholes.
 6. Cleanouts.

3.4 INSTALLATION OF EQUIPMENT, TANK, AND VESSEL INSULATION

- A. Mineral-Fiber, Pipe, and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.
1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of tank and vessel surfaces.
 2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
 3. Protect exposed corners with secured corner angles.
 4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:
 - a. Do not weld anchor pins to ASME-labeled pressure vessels.
 - b. Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
 - c. On tanks and vessels, maximum anchor-pin spacing is 3 inches from insulation end joints, and 16 inches o.c. in both directions.
 - d. Do not overcompress insulation during installation.
 - e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
 - f. Impale insulation over anchor pins and attach speed washers.
 - g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
 5. Secure each layer of insulation with stainless-steel bands. Select band material compatible with insulation materials.
 6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.
 7. Stagger joints between insulation layers at least 3 inches.
 8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.
 9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.
 10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:
 - 1. Inspect field-insulated equipment, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each type of equipment defined in the "Equipment Insulation Schedule" Article. For large equipment, remove only a portion adequate to determine compliance.
- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.6 EQUIPMENT INSULATION SCHEDULE

- A. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.
- B. Insulate indoor and outdoor equipment that is not factory insulated.
- C. Domestic hot-water storage tank insulation shall be the following, of thickness to provide an R-value of 12.5:
 - 1. Mineral-fiber pipe and tank.
- D. Domestic hot water piping, valves and fittings: Minimum 1" thickness with ASJ to 1" NPS. 1-1/2" thickness for sizes 2" NPS and larger.
- E. Domestic cold water piping, (potable and non-potable) valves and fittings: Minimum 1" thickness with ASJ, sealed vapor barrier. All sizes.
- F. Domestic hot and cold water piping services noted above, where installed over heat tracing: Double the specified thickness in two (2) staggered layers.
- G. Provide a solvent-welded 30-mil PVC jacket system over all insulated piping as follows:
 - 1. All exterior piping to a point 12 inches inside the interior face of a building.
 - 2. All interior piping installed exposed, below 9 feet above finished floors or below finished ceilings, whichever is greater. Includes lavatory trap assemblies, pipe drops to hose bibbs and in janitor's closets.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15085

PLUMBING PIPING INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes insulating the following plumbing piping services:

1. Domestic cold-water piping.
2. Domestic hot-water piping.
3. Domestic recirculating hot-water piping.
4. Non-Potable water piping
5. Sanitary waste piping exposed to freezing conditions.
6. Storm-water piping above grade.
7. Roof drains and rainwater leaders.
8. Supplies and drains for handicap-accessible lavatories and sinks.

- B. Related Sections:

1. Volume 2 Technical Provisions Exhibit 2I "Additional Project Requirements" "SUSTAINABILITY REQUIRMENTS"
2. Section 07840 - FIRESTOPPING
3. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
4. Section 15062- HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
5. Section 15074 - VIBRATION AND SEISMIC CONTROLS FOR PIING AND EQUIPMENT
6. Section 15077 - IDENTIFICATION FOR PIPING AND EQUIPMENT
7. Section 15778 – HEAT TRACING FOR PLUMBING PIPING
8. Section 15084 "PLUMBING EQUIPMENT INSULATION "

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied, if any).
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
 2. Detail attachment and covering of heat tracing inside insulation.
 3. Detail insulation application at pipe expansion joints for each type of insulation.

4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
5. Detail removable insulation at piping specialties, equipment connections, and access panels.
6. Detail application of field-applied jackets.
7. Detail application at linkages of control devices.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
- C. Field quality-control reports.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84 by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
 1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
 2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.
- C. Comply with the following applicable standards and other requirements specified for miscellaneous components:
 1. Supply and Drain Protective Shielding Guards: ICC A117.1.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 15062 "Hangers and Supports for Piping and Equipment."

- B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.
- C. Coordinate installation and testing of heat tracing.

1.8 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," "Outdoor, Aboveground Piping Insulation Schedule," and "Insulation Schedule" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Mineral-Fiber, Preformed Pipe Insulation:
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Fibrex Insulations Inc.; Coreplus 1200.
 - b. Johns Manville; Micro-Lok.
 - c. Knauf Insulation; 1000-Degree Pipe Insulation.
 - d. Manson Insulation Inc.; Alley-K.
 - e. Owens Corning; Fiberglas Pipe Insulation.
 - 2. Type I, 850 Deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.2 INSULATING CEMENTS

- A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.
 - 1. Products: Subject to compliance with requirements, provide the following:
 - a. Ramco Insulation, Inc.; Super-Stik.
- B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.
 - 1. Products: Subject to compliance with requirements, provide the following:
 - a. Ramco Insulation, Inc.; Thermokote V.
- C. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.
 - 1. Products: Subject to compliance with requirements, provide the following:
 - a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.

2.3 ADHESIVES

- A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated, unless otherwise indicated.
- B. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
 - d. Mon-Eco Industries, Inc.; 22-25.
 - 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. ASJ Adhesive, and FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
 - b. Eagle Bridges - Marathon Industries; 225.

- c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-20.
 - d. Mon-Eco Industries, Inc.; 22-25.
- 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- D. PVC Jacket Adhesive: Compatible with PVC jacket.
- 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Dow Corning Corporation; 739, Dow Silicone.
 - b. Johns Manville; Zeston Perma-Weld, CEEL-TITE Solvent Welding Adhesive.
 - c. P.I.C. Plastics, Inc.; Welding Adhesive.
 - d. Speedline Corporation; Polyco VP Adhesive.
 - 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
- 1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.
- 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
 - b. Vimasco Corporation; 749.
 - 2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
 - 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 - 4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
 - 5. Color: White.
- C. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.
- 1. Products: Subject to compliance with requirements, provide one of the following:

- a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
 - b. Eagle Bridges - Marathon Industries; 550.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
 - d. Mon-Eco Industries, Inc.; 55-50.
 - e. Vimasco Corporation; WC-1/WC-5.
2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 4. Solids Content: 60 percent by volume and 66 percent by weight.
 5. Color: White.

2.5 SEALANTS

A. Joint Sealants:

1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Permanently flexible, elastomeric sealant.
3. Service Temperature Range: Minus 100 to plus 300 deg F
4. Color: White or gray.
5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

1. Products: Subject to compliance with requirements, provide the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.6 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
2. ASJ-SSL systems are deemed to be a Class 1 vapor retarder in full application.

2.7 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 428 AWF ASJ.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
 - c. Compac Corporation; 104 and 105.
 - d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
 2. Width: 3 inches.
 3. Thickness: 11.5 mils.
 4. Adhesion: 90 ounces force/inch in width.
 5. Elongation: 2 percent.
 6. Tensile Strength: 40 lbf/inch in width.
 7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

2.8 SECUREMENTS

- A. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel or Monel.

2.9 PROTECTIVE SHIELDING GUARDS

- A. Protective Shielding Pipe Covers, :
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Engineered Brass Company.
 - b. Insul-Tect Products Co.; a subsidiary of MVG Molded Products.
 - c. McGuire Manufacturing.
 - d. Plumberex.
 - e. Truebro; a brand of IPS Corporation.
 - f. Zurn Industries, LLC; Tubular Brass Plumbing Products Operation.
 2. Description: Manufactured plastic wraps for covering plumbing fixture hot- and cold-water supplies and trap and drain piping. Comply with Americans with Disabilities Act (ADA) requirements.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 - 1. Verify that systems to be insulated have been tested and are free of defects.
 - 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
 - 1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 milsthick and an epoxy finish 5 mils thick if operating in a temperature range between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
 - 2. Carbon Steel: Coat carbon steel operating at a service temperature between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.
- B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.

- F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
- G. Keep insulation materials dry during application and finishing.
- H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- I. Install insulation with least number of joints practical.
- J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 - 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 - 4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- L. Install insulation with factory-applied jackets as follows:
 - 1. Draw jacket tight and smooth.
 - 2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
 - 3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.
 - a. For below-ambient services, apply vapor-barrier mastic over staples.
 - 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 - 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.
- M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

P. For above-ambient services, do not install insulation to the following:

1. Vibration-control devices.
2. Testing agency labels and stamps.
3. Nameplates and data plates.
4. Cleanouts.

3.4 PENETRATIONS

- A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
 4. Seal jacket to roof flashing with flashing sealant.
- B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.
- C. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
1. Seal penetrations with flashing sealant.
 2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
 3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
 4. Seal jacket to wall flashing with flashing sealant.
- D. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- E. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.
1. Comply with requirements in Section 07840 "Firestopping" for firestopping and fire-resistive joint sealers.
- F. Insulation Installation at Floor Penetrations:
1. Pipe: Install insulation continuously through floor penetrations.
 2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 07840 "Firestopping ."

3.5 GENERAL PIPE INSULATION INSTALLATION

- A. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.
- B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:
1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
 2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
 3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
 4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
 5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
 6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
 7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
 8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.
 9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.
- C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.
- D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF MINERAL-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward clinched staples at 6 inches o.c.
4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.7 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:
 1. Inspect pipe, fittings, strainers, and valves, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.
- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.8 PIPING INSULATION SCHEDULE, GENERAL

- A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.
- B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
 1. Underground piping.
 2. Chrome-plated pipes and fittings unless there is a potential for personnel injury.
- C. Piping subject to freezing temperatures shall have heat tracing under insulation of at least twice the standard thickness for each application. "Freezing temperatures" is not limited to that piping installed outdoors. Piping within 50 feet of and not otherwise isolated from an operable door shall be treated as of exposed to the exterior. Refer to Section 15778 – HEAT TRACING FOR PLUMBING PIPING.
 1. The use of heat trace protection shall not be used to avoid interior routing in heated spaces; heat trace protection shall be "protection for the exception".
- D. It is the intent of this specification to insulate all piping carrying water greater than five degrees F. from ambient temperatures and where condensataion may occur, including continuous vapor retarders.

3.9 INDOOR PIPING INSULATION SCHEDULE

- A. Domestic Cold Water:
 - 1. NPS 4 and Smaller: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.
- B. Domestic Hot and Recirculated Hot Water:
 - 1. NPS 2 and Smaller: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.
- C. Stormwater and Overflow:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.
 - b. Includes both horizontal and vertical piping, complete to grade slab.
- D. Roof Drain and Overflow Drain Bodies, Rainwater Leaders:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.
 - b. Includes both horizontal and vertical piping, from roof drain to grade slab.
- E. Exposed Sanitary Drains, Domestic Water, Domestic Hot Water, and Stops for Plumbing Fixtures for People with Disabilities:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.
- F. Piping Where Heat Tracing Is Installed:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.
- G. Piping, Floor Drains, Traps, and Sanitary Drain Piping within 10 Feet of Drain Receiving Condensate and Equipment Drain Water below 60 Deg F:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1/2 inch thick.

3.10 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

- A. Domestic Water Piping where Heat Tracing Is Installed :
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.
- B. Domestic Hot and Recirculated Hot Water:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.
- C. Sanitary Waste and Storm Water Piping Where Heat Tracing Is Installed:
 - 1. All Pipe Sizes: Insulation shall be the following:
 - a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.
- D. Provide a solvent-welded 30-mil PVC jacket system over all insulated piping as follows:
 - 1. All exterior piping to a point 12 inches inside the interior face of a building.
 - 2. All interior piping installed exposed, below 9 feet above finished floors or below finished ceilings, whichever is greater. Includes lavatory trap assemblies, pipe drops to hose bibbs and in janitor's closets.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15086
DUCT INSULATION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15087 "HVAC EQUIPMENT INSULATION."
 - 2. Section 15088 "HVAC PIPING INSULATION."
 - 3. Section 15815 "METAL DUCTS" FOR DUCT LINERS.

1.2 SUMMARY

- A. Section includes insulating the following duct services:
 - 1. Indoor, concealed supply and outdoor air.
 - 2. Indoor, exposed supply and outdoor air.
 - 3. Indoor, concealed return located in unconditioned space.
 - 4. Indoor, exposed return located in unconditioned space.
 - 5. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
 - 6. Indoor, exposed exhaust between isolation damper and penetration of building exterior.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
 - 2. Detail insulation application at elbows, fittings, dampers, specialties and flanges for each type of insulation.
 - 3. Detail application of field-applied jackets.
 - 4. Detail application at linkages of control devices.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.
- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers,

attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

- C. Field quality-control reports.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.
- B. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
 - 1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 15062 "HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT."
- B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.
- C. Coordinate installation and testing of heat tracing.

1.8 SCHEDULING

- A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.
- B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Duct Insulation Schedule, General," "Indoor Duct and Plenum Insulation Schedule," and "Aboveground, Outdoor Duct and Plenum Insulation Schedule" articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.
- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type III with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; SoftTouch Duct Wrap.
 - b. Johns Manville; Microlite.
 - c. Knauf Insulation; Friendly Feel Duct Wrap.
 - d. Manson Insulation Inc.; Alley Wrap.
 - e. Owens Corning; SOFTR All-Service Duct Wrap.
- F. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory-applied ASJ. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; Commercial Board.
 - b. Fibrex Insulations Inc.; FBX.
 - c. Johns Manville; 800 Series Spin-Glas.
 - d. Knauf Insulation; Insulation Board.
 - e. Manson Insulation Inc.; AK Board.
 - f. Owens Corning; Fiberglas 700 Series.
- G. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied ASJ complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 deg F is 0.29 Btu x in./h x sq. ft. x deg F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. CertainTeed Corp.; CrimpWrap.
 - b. Johns Manville; MicroFlex.

- c. Knauf Insulation; Pipe and Tank Insulation.
- d. Manson Insulation Inc.; AK Flex.
- e. Owens Corning; Fiberglas Pipe and Tank Insulation.

2.2 ADHESIVES

- A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.
- B. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.Eagle Bridges - Marathon Industries; 225.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.Mon-Eco Industries, Inc.; 22-25.
 - 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. ASJ Adhesive, and FSK Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-82.
 - b. Eagle Bridges - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-50.Mon-Eco Industries, Inc.; 22-25.
 - 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.3 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
 - 1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below ambient services.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.
 - b. Vimasco Corporation; 749.
 2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
 5. Color: White.
- C. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-10.
 - b. Eagle Bridges - Marathon Industries; 550.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 46-50.
 - d. Mon-Eco Industries, Inc.; 55-50.
 - e. Vimasco Corporation; WC-1/WC-5.
 2. Water-Vapor Permeance: ASTM F 1249, 1.8 perms at 0.0625-inch dry film thickness.
 3. Service Temperature Range: Minus 20 to plus 180 deg F.
 4. Solids Content: 60 percent by volume and 66 percent by weight.
 5. Color: White.

2.4 SEALANTS

- A. FSK Flashing Sealants:
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76. Eagle Bridges - Marathon Industries; 405.
 - b. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 95-44.
 - c. Mon-Eco Industries, Inc.; 44-05.
 2. Materials shall be compatible with insulation materials, jackets, and substrates.
 3. Fire- and water-resistant, flexible, elastomeric sealant.
 4. Service Temperature Range: Minus 40 to plus 250 deg F.
 5. Color: Aluminum.
 6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

B. ASJ Flashing Sealants:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-76.
2. Materials shall be compatible with insulation materials, jackets, and substrates.
3. Fire- and water-resistant, flexible, elastomeric sealant.
4. Service Temperature Range: Minus 40 to plus 250 deg F.
5. Color: White.
6. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
7. Sealants shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.5 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
5. Vinyl Jacket: White vinyl with a permeance of 1.3 perms when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.6 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 428 AWF ASJ.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
 - c. Compac Corporation; 104 and 105.
 - d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
2. Width: 3 inches.
3. Thickness: 11.5 mils.
4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.

7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
- B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 491 AWF FSK.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
 - c. Compac Corporation; 110 and 111.
 - d. Venture Tape; 1525 CW NT, 1528 CW, and 1528 CW/SQ.
 2. Width: 3 inches.
 3. Thickness: 6.5 mils.
 4. Adhesion: 90 ounces force/inch in width.
 5. Elongation: 2 percent.
 6. Tensile Strength: 40 lbf/inch in width.
 7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

2.7 SECUREMENTS

A. Bands:

1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ITW Insulation Systems; Gerrard Strapping and Seals.
 - b. RPR Products, Inc.; Insul-Mate Strapping, Seals, and Springs.
2. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 316; 0.015 inch thick, 3/4 inch wide with closed seal.

B. Insulation Pins and Hangers:

1. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; Tactoo Perforated Base Insul-Hangers.
 - 2) GEMCO; Perforated Base.
 - 3) Midwest Fasteners, Inc.; Spindle.
 - b. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
 - c. Spindle: Stainless steel, fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.
 - d. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick, stainless-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
 - a. Products: Subject to compliance with requirements, provide one of the following:
 - 1) AGM Industries, Inc.; RC-150.
 - 2) GEMCO; R-150.
 - 3) Midwest Fasteners, Inc.; WA-150.
 - 4) Nelson Stud Welding; Speed Clips.
 - b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.
- A. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel or Monel.
- B. Wire: 0.062-inch soft-annealed, stainless steel.
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. C & F Wire.

2.8 CORNER ANGLES

- A. PVC Corner Angles: 30 mils thick, minimum 1 by 1 inch, PVC according to ASTM D 1784, Class 16354-C. White or color-coded to match adjacent surface.
- B. Stainless-Steel Corner Angles: 0.024 inch thick, minimum 1 by 1 inch, stainless steel according to ASTM A 167 or ASTM A 240/A 240M, Type 316.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 1. Verify that systems to be insulated have been tested and are free of defects.
 2. Verify that surfaces to be insulated are clean and dry.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.
- B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Keep insulation materials dry during application and finishing.
- G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- H. Install insulation with least number of joints practical.
- I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 - 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
- J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- K. Install insulation with factory-applied jackets as follows:
 - 1. Draw jacket tight and smooth.
 - 2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
 - 3. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 - 4. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

- L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
- N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.4 PENETRATIONS

- A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.
 - 1. Comply with requirements in Section 07841 "THROUGH-PENETRATION FIRESTOP SYSTEMS" for firestopping and fire-resistive joint sealers.
- C. Insulation Installation at Floor Penetrations:
 - 1. Duct: For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.
 - 2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 07841 "THROUGH-PENETRATION FIRESTOP SYSTEMS."

3.5 INSTALLATION OF MINERAL-FIBER INSULATION

- A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
 - 1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
 - 2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
 - 3. Install either capacitor-discharge-weld pins and speed washers on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
 - a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
 - b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
 - c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
 - d. Do not overcompress insulation during installation.
 - e. Impale insulation over pins and attach speed washers.
 - f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
 - a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
 - b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.
 5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.
 6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
 7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.
- B. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
 2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
 3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
 - a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
 - b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
 - c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
 - d. Do not overcompress insulation during installation.
 - e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
 4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier

consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

- a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
 - b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.
5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
 6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.6 FINISHES

- A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 09911 "EXTERIOR PAINTING" and Section 09912 "INTERIOR PAINTING."
 1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
- C. Do not field paint aluminum or stainless-steel jackets.

3.7 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.
- C. Tests and Inspections:
 1. Inspect ductwork, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.
- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.8 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply and outdoor air.
2. Indoor, exposed supply and outdoor air.
3. Indoor, concealed return located in unconditioned space.
4. Indoor, exposed return located in unconditioned space.
5. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
6. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
7. Outdoor, concealed supply and return.
8. Outdoor, exposed supply and return.

B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
3. Factory-insulated flexible ducts.
4. Factory-insulated plenums and casings.
5. Flexible connectors.
6. Vibration-control devices.
7. Factory-insulated access panels and doors.

3.9 INDOOR DUCT AND PLENUM INSULATION SCHEDULE

A. Concealed, round and flat-oval, supply-air duct insulation shall be[**one of**] the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.

B. Concealed, round and flat-oval, return-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.

C. Concealed, round and flat-oval, outdoor-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.

D. Concealed, round and flat-oval, exhaust-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.

E. Concealed, rectangular, supply-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.

F. Concealed, rectangular, return-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.

G. Concealed, rectangular, outdoor-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.
- H. Concealed, rectangular, exhaust-air duct insulation between isolation damper and penetration of building exterior shall be the following:
1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.
- I. Concealed, supply-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- J. Concealed, return-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- K. Concealed, outdoor-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- L. Concealed, exhaust-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- M. Exposed, round and flat-oval, supply-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.
- N. Exposed, round and flat-oval, return-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.
- O. Exposed, round and flat-oval, outdoor-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.
- P. Exposed, round and flat-oval, exhaust-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches thick and 3-lb/cu. ft. nominal density.
- Q. Exposed, rectangular, supply-air duct insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- R. Exposed, rectangular, return-air duct insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- S. Exposed, rectangular, outdoor-air duct insulation shall be the following:
1. Mineral-Fiber Board: 3 inches thick and 3-lb/cu. ft. nominal density.
- T. Exposed, rectangular, exhaust-air duct insulation shall be the following:

1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- U. Exposed, supply-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- V. Exposed, return-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 2 inches thick and 3-lb/cu. ft. nominal density.
- W. Exposed, outdoor-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 3 inches thick and 3-lb/cu. ft. nominal density.
- X. Exposed, exhaust-air plenum insulation shall be the following:
1. Mineral-Fiber Board: 3 inches thick and 3-lb/cu. ft. nominal density.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15088

HVAC PIPING INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes insulating the following HVAC piping systems:
 - 1. Condensate drain piping, indoors and outdoors.
 - 2. Refrigerant suction and hot-gas piping, indoors and outdoors.
- B. Related Sections:
 - 1. Section 01800 - SUSTAINABILITY REQUIRMENTS
 - 2. Section 07840 - FIRESTOPPING
 - 3. Section 09900 - PAINTING
 - 4. Section 15062 - HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 5. Section 15074 - VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 6. Section 15077 - IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 7. Section 15086 - DUCT INSULATION
 - 8. Section 15183 - REFRIGERANT PIPING

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
 - 2. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
 - 3. Detail removable insulation at piping specialties.
 - 4. Detail application of field-applied jackets.
 - 5. Detail application at linkages of control devices.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer.

- B. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.
- C. Field quality-control reports.

1.5 QUALITY ASSURANCE

- A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
 - 1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
 - 2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.7 COORDINATION

- A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 15062 "HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT."
- B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

1.8 SCHEDULING

- A. Schedule insulation application after pressure testing systems. Insulation application may begin on segments that have satisfactory test results.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

- A. Comply with requirements in "Piping Insulation Schedule, General," "Indoor Piping Insulation Schedule," and "Outdoor, Aboveground Piping Insulation Schedule," articles for where insulating materials shall be applied.
- B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

- C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
- D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
- E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
- F. Flexible Elastomeric Insulation: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Aeroflex USA, Inc.; Aerocel.
 - b. Armacell LLC; AP Armaflex.
 - c. K-Flex USA; Insul-Lock, Insul-Tube, and K-FLEX LS.
- G. Mineral-Fiber, Preformed Pipe Insulation:
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Fibrex Insulations Inc.; Coreplus 1200.
 - b. Johns Manville; Micro-Lok.
 - c. Knauf Insulation; 1000-Degree Pipe Insulation.
 - d. Manson Insulation Inc.; Alley-K.
 - e. Owens Corning; Fiberglas Pipe Insulation.
 - 2. Type I, 850 deg F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.2 INSULATING CEMENTS

- A. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Super-Stik.
- B. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Thermokote V.
- C. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449.
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Ramco Insulation, Inc.; Ramcote 1200 and Quik-Cote.

2.3 ADHESIVES

- A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.
- B. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Aeroflex USA, Inc.; Aeroseal.
 - b. Armacell LLC; Armaflex 520 Adhesive.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-75.
 - d. K-Flex USA; R-373 Contact Adhesive.
 2. For indoor applications, adhesive shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."
- C. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Childers Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; CP-127.
 - b. - Marathon Industries; 225.
 - c. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 85-60/85-70.
 - d. Mon-Eco Industries, Inc.; 22-25.
 2. For indoor applications, adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 3. Adhesive shall comply with the testing and product requirements of the California Department of Health Services' "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers."

2.4 MASTICS

- A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-PRF-19565C, Type II.
1. For indoor applications, use mastics that have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- B. Vapor-Barrier Mastic: Water based; suitable for indoor use on below-ambient services.
1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Foster Brand, Specialty Construction Brands, Inc., a business of H. B. Fuller Company; 30-80/30-90.

- b. Vimasco Corporation; 749.
2. Water-Vapor Permeance: ASTM E 96/E 96M, Procedure B, 0.013 perm at 43-mil dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Solids Content: ASTM D 1644, 58 percent by volume and 70 percent by weight.
5. Color: White.

2.5 FACTORY-APPLIED JACKETS

- A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
 1. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
 2. Vinyl Jacket: White vinyl with a permeance of 1.3 perms when tested according to ASTM E 96/E 96M, Procedure A, and complying with NFPA 90A and NFPA 90B.

2.6 FIELD-APPLIED JACKETS

- A. Insulation system schedules indicate field-applied jackets in various applications. When field-applied jackets are indicated, these shall be applied over factory-applied jackets and shall comply with the following:
 1. PVC: White, paintable polyvinyl chloride (PVC) field applied jacket system including solvent-weld adhesive, pre-cut fitting covers for standard pipe fittings and configurations. Material shall conform to ASTM D-1784, "Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds".
 2. A flame spread rating of 25 or less and a smoke developed rating of 50 or less according to ASTM E 84.
 3. A default minimum thickness of 30 mils (0.030 inches/0.80 mm).

2.7 TAPES

- A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. ABI, Ideal Tape Division; 428 AWF ASJ.
 - b. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0836.
 - c. Compac Corporation; 104 and 105.
 - d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
 2. Width: 3 inches.
 3. Thickness: 11.5 mils.

4. Adhesion: 90 ounces force/inch in width.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.
7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

2.8 SECUREMENTS

- A. Staples: Outward-clinching insulation staples, nominal 3/4-inch-wide, stainless steel or Monel.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
 1. Verify that systems to be insulated have been tested and are free of defects.
 2. Verify that surfaces to be insulated are clean and dry.
 3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
- B. Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
 1. Carbon Steel: Coat carbon steel operating at a service temperature between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
- C. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
- D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

- A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping including fittings, valves, and specialties.
- B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of pipe system as specified in insulation system schedules.
- C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

- D. Install insulation with longitudinal seams at top and bottom of horizontal runs.
- E. Install multiple layers of insulation with longitudinal and end seams staggered.
- F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
- G. Keep insulation materials dry during application and finishing.
- H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
- I. Install insulation with least number of joints practical.
- J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
 - 1. Install insulation continuously through hangers and around anchor attachments.
 - 2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
 - 3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
 - 4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
- K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
- L. Install insulation with factory-applied jackets as follows:
 - 1. Draw jacket tight and smooth.
 - 2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
 - 3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.
 - a. For below-ambient services, apply vapor-barrier mastic over staples.
 - 4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
 - 5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.
- M. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
- N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

- O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
- P. For above-ambient services, do not install insulation to the following:
 - 1. Vibration-control devices.
 - 2. Testing agency labels and stamps.
 - 3. Nameplates and data plates.
 - 4. Manholes.
 - 5. Handholes.
 - 6. Cleanouts.

3.4 PENETRATIONS

- A. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
- B. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.
 - 1. Comply with requirements in Section 07840 "FIRESTOPPING" for firestopping and fire-resistive joint sealers.
- C. Insulation Installation at Floor Penetrations:
 - 1. Pipe: Install insulation continuously through floor penetrations.
 - 2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 07840 "FIRESTOPPING."

3.5 GENERAL PIPE INSULATION INSTALLATION

- A. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.
- B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:
 - 1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
 - 2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
 - 3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
 - 4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For

- valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.
 6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
 7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
 8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.
 9. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.
- C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.
- D. Install removable insulation covers at locations indicated. Installation shall conform to the following:
1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.
 2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.
 3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.
 4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.
 5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF FLEXIBLE ELASTOMERIC INSULATION

- A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- B. Insulation Installation on Pipe Flanges:
 - 1. Install pipe insulation to outer diameter of pipe flange.
 - 2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
 - 3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
 - 4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- C. Insulation Installation on Pipe Fittings and Elbows:
 - 1. Install mitered sections of pipe insulation.
 - 2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
- D. Insulation Installation on Valves and Pipe Specialties:
 - 1. Install preformed valve covers manufactured of same material as pipe insulation when available.
 - 2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
 - 3. Install insulation to flanges as specified for flange insulation application.
 - 4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.7 INSTALLATION OF MINERAL-FIBER INSULATION

- A. Insulation Installation on Straight Pipes and Tubes:
 - 1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
 - 2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
 - 3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches o.c.
 - 4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.
- B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
 2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
 3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
 4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.
- C. Insulation Installation on Pipe Fittings and Elbows:
1. Install preformed sections of same material as straight segments of pipe insulation when available.
 2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.
- D. Insulation Installation on Valves and Pipe Specialties:
1. Install preformed sections of same material as straight segments of pipe insulation when available.
 2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
 3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
 4. Install insulation to flanges as specified for flange insulation application.

3.8 FINISHES

- A. Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Section 09900 "PAINTING".
1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
 - a. Finish Coat Material: Interior, flat, latex-emulsion size.
- B. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating. Coat all Flexible Elastomeric Insulation on the exterior of the building with U.V. resistant coating.
- C. Do not field paint aluminum or stainless-steel jackets.

3.9 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Perform tests and inspections.

C. Tests and Inspections:

1. Inspect pipe, fittings, strainers, and valves, randomly selected by Architect, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.

- D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.10 PIPING INSULATION SCHEDULE, GENERAL

- A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

3.11 INDOOR PIPING INSULATION SCHEDULE

- A. Condensate and Equipment Drain Water below 60 Deg F:

1. All Pipe Sizes: Insulation shall be the following:

- a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick. ASJ Factory Applied Jacket required.

- B. Refrigerant Suction and Hot-Gas Piping:

1. All Pipe Sizes: Insulation shall be the following:

- a. Flexible Elastomeric: 1 inch thick, two coats of manufacturer's protective coating.

3.12 OUTDOOR, ABOVEGROUND PIPING INSULATION SCHEDULE

- A. Heating-Hot-Water Supply and Return, 200 Deg F and Below:

1. NPS 12 and Smaller: Insulation shall be the following:

- a. Mineral-Fiber, Preformed Pipe, Type I: 2 inches thick.

- B. Refrigerant Suction and Hot-Gas Piping:

1. All Pipe Sizes: Insulation shall be the following:

- a. Flexible Elastomeric: 1 inches thick; with 30 mil PVC Jacket.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment" .

END OF SECTION

SECTION 15093

SLEEVES AND SLEEVE SEALS FOR PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Documents
 - 1. Section 07840 – FIRESTOPPING
 - 2. Section 15050 - BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 3. Section 15051 - BASIC - MATERIALS AND METHODS FOR PLUMBING WORK
 - 4. Section 15085 - PLUMBING PIPING INSULATION
 - 5. Section 15088 – HVAC PIPING INSULATION
 - 6. Section 15140 – DOMESTIC WATER PIPING
 - 7. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 8. Section 15160 – STORM DRAINAGE PIPING
 - 9. Section 15181 – HYDRONIC PIPING
 - 10. Section 15183 – REFRIGERANT PIPING
 - 11. Section 15195 – FACILITY NATURAL-GAS PIPING
 - 12. Section 15974 - FIRE-SUPPRESSION STANDPIPE
 - 13. Section 15935 – DRY – PIPE FIRE – SUPPRESSION SPRINKLERS

1.2 SUMMARY

- A. Section Includes:
 - 1. Sleeves.
 - 2. Stack-sleeve fittings.
 - 3. Sleeve-seal systems.
 - 4. Grout.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.

PART 2 - PRODUCTS

2.1 SLEEVES

- A. Galvanized-Steel-Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.

2.2 STACK-SLEEVE FITTINGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Smith, Jay R. Mfg. Co.
 - 2. Zurn Specification Drainage Operation; Zurn Plumbing Products Group.
- B. Description: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing.
 - 1. Underdeck Clamp: Clamping ring with setscrews.

2.3 SLEEVE-SEAL SYSTEMS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Advance Products & Systems, Inc.
 - 2. CALPICO, Inc.
 - 3. Metraflex Company (The).
 - 4. Pipeline Seal and Insulator, Inc.
 - 5. Proco Products, Inc.
- B. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
 - 1. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
 - 2. Pressure Plates: Stainless steel.
 - 3. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements.

2.4 GROUT

- A. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic- cement grout.
- B. Characteristics: Nonshrink; recommended for interior and exterior applications.
- C. Design Mix: 5000-psi, 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION

- A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls.
- B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1- inch annular clear space between piping and concrete slabs and walls.
 - 1. Sleeves are not required for core-drilled holes.
- C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
 - 1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
 - 2. Cut sleeves to length for mounting flush with both surfaces.
 - a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.
 - 3. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.
- D. Install sleeves for pipes passing through interior partitions.
 - 1. Cut sleeves to length for mounting flush with both surfaces.
 - 2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
 - 3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with requirements for sealants specified in Section 07920 "Joint Sealants."
- E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Section 07840 "Firestopping."

3.2 STACK-SLEEVE-FITTING INSTALLATION

- A. Install stack-sleeve fittings in new slabs as slabs are constructed.
 - 1. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
 - 2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with requirements for flashing specified in Section 07620 "SHEET METAL FLASHING AND TRIM."
 - 3. Install section of cast-iron soil pipe to extend sleeve to 2 inches above finished floor level.
 - 4. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
 - 5. Using grout, seal the space around outside of stack-sleeve fittings.

- B. Fire-Barrier Penetrations: Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping specified in Section 07840 "Firestopping."

3.3 SLEEVE-SEAL-SYSTEM INSTALLATION

- A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at service piping entries into building.
- B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.

3.4 SLEEVE AND SLEEVE-SEAL SCHEDULE

- A. Use sleeves and sleeve seals for the following piping-penetration applications:
 - 1. Exterior Concrete Walls above Grade:
 - a. Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves.
 - b. Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves.
 - 2. Exterior Concrete Walls below Grade:
 - a. Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves with sleeve-seal system.
 - 1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
 - b. Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves with sleeve-seal system.
 - 1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
 - 3. Concrete Slabs-on-Grade:
 - a. Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves with sleeve-seal system.
 - 1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
 - b. Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves with sleeve-seal system.
 - 1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
 - 4. Concrete Slabs above Grade:
 - a. Piping Smaller Than NPS 6: Stack-sleeve fittings.
 - b. Piping NPS 6 and Larger: Stack-sleeve fittings.
 - 5. Interior Partitions:

- a. Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves.
- b. Piping NPS 6 and Larger: Galvanized-steel-sheet sleeves.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15112

GENERAL-DUTY VALVES FOR PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:

1. Bronze angle valves.
2. Bronze ball valves.
3. Iron, single-flange butterfly valves.
4. Bronze swing check valves.
5. Iron swing check valves.
6. Bronze gate valves.
7. Iron gate valves.
8. Bronze globe valves.
9. Lubricated plug valves.
10. Eccentric plug valves.
11. Chainwheels.

- B. Related Sections:

1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
2. Section 15051 – BASIC MATHERIALS AND METHODS FOR PLUMBING WORK
3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
5. Section 15085 – PLUMBING PIPING INSULATION
6. Section 15088 – HVAC PIPING INSULATION
7. Section 15140 – DOMESTIC WATER PIPING
8. Section 15150 – SANITARY WASTE AND VENT PIPING
9. Section 15195 – FACILITY NATURAL –GAS PIPING
10. Section 15181 – HYDRONIC PIPING
11. Section 15183 – REFRIGERANT PIPING
12. Section 15195 – FACILITY NATURAL GAS PIPING

1.3 DEFINITIONS

- A. CWP: Cold working pressure.
- B. EPDM: Ethylene propylene copolymer rubber.

- C. HYDRONIC: Non-potable water or treated fluid including glycol used for heating functions.
- D. NBR: Acrylonitrile-butadiene, Buna-N, or nitrile rubber.
- E. NRS: Non-rising stem.
- F. OS&Y: Outside screw and yoke.
- G. RS: Rising stem.
- H. SWP: Steam working pressure.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve indicated.

1.5 QUALITY ASSURANCE

- A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.
- B. ASME Compliance:
 - 1. ASME B16.10 and ASME B16.34 for ferrous valve dimensions and design criteria.
 - 2. ASME B31.1 for power piping valves.
 - 3. ASME B31.9 for building services piping valves.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Prepare valves for shipping as follows:
 - 1. Protect internal parts against rust and corrosion.
 - 2. Protect threads, flange faces, grooves, and weld ends.
 - 3. Set angle, gate, and globe valves closed to prevent rattling.
 - 4. Set ball and plug valves open to minimize exposure of functional surfaces.
 - 5. Set butterfly valves closed or slightly open.
 - 6. Block check valves in either closed or open position.
- B. Use the following precautions during storage:
 - 1. Maintain valve end protection.
 - 2. Store valves indoors and maintain at higher than ambient dew point temperature. If outdoor storage is necessary, store valves off the ground in watertight enclosures.
- C. Use sling to handle large valves; rig sling to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR VALVES

- A. Refer to DIVISION 15 valve schedule articles for applications of valves.
- B. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures. Notwithstanding anything to the contrary, all valves shall conform to the pressure class and temperature/pressure criteria of the systems in which they are installed.
- C. Valve Sizes: Same as upstream piping unless otherwise indicated.
- D. Valve Actuator Types:
 - 1. Handwheel: For valves other than quarter-turn types.
 - 2. Handlever: For quarter-turn valves NPS 6 and smaller except plug valves.
 - 3. Wrench: For plug valves with square heads. Furnish Owner with 1 wrench for every 5 plug valves, for each size square plug-valve head.
 - 4. Chainwheel: Device for attachment to valve handwheel, stem, or other actuator; of size and with chain for mounting height, as indicated in the "Valve Installation" Article.
- E. Valves in Insulated Piping: With 2-inch stem extensions and the following features:
 - 1. Gate Valves: With rising stem.
 - 2. Ball Valves: With extended operating handle of non-thermal-conductive material, and protective sleeve that allows operation of valve without breaking the vapor seal or disturbing insulation.
 - 3. Butterfly Valves: With extended neck.
- F. Valve-End Connections:
 - 1. Flanged: With flanges according to ASME B16.1 for iron valves.
 - 2. Solder Joint: With sockets according to ASME B16.18.
 - 3. Threaded: With threads according to ASME B1.20.1.
- G. Valve Bypass and Drain Connections: MSS SP-45.

2.2 BRONZE ANGLE VALVES

- A. Class 125, Bronze Angle Valves with Bronze Disc:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hammond Valve.
 - b. Milwaukee Valve Company.
 - 2. Description:
 - a. Standard: MSS SP-80, Type 1.

- b. CWP Rating: 200 psig.
- c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
- d. Ends: Threaded.
- e. Stem and Disc: Bronze.
- f. Packing: Asbestos free.
- g. Handwheel: Malleable iron.

B. Class 150, Bronze Angle Valves with Bronze Disc:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Crane Co.; Crane Valve Group; Stockham Division.
 - b. Kitz Corporation.
- 2. Description:
 - a. Standard: MSS SP-80, Type 1.
 - b. CWP Rating: 300 psig.
 - c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.
 - d. Ends: Threaded.
 - e. Stem and Disc: Bronze.
 - f. Packing: Asbestos free.
 - g. Handwheel: Malleable iron.

2.3 BRONZE BALL VALVES

A. Two-Piece, Full-Port, Bronze Ball Valves with Stainless-Steel Trim:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Conbraco Industries, Inc.; Apollo Valves.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. Hammond Valve.
 - d. Lance Valves; a division of Advanced Thermal Systems, Inc.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
- 2. Description:
 - a. Standard: MSS SP-110.
 - b. SWP Rating: 150 psig.
 - c. CWP Rating: 600 psig.
 - d. Body Design: Two piece.
 - e. Body Material: Bronze.
 - f. Ends: Threaded.
 - g. Seats: PTFE or TFE.
 - h. Stem: Stainless steel.

- i. Ball: Stainless steel, vented.
- j. Port: Full.

2.4 IRON, SINGLE-FLANGE BUTTERFLY VALVES

A. 150 CWP, Iron, Single-Flange Butterfly Valves with EPDM Seat and Aluminum-Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bray Controls; a division of Bray International.
 - b. Conbraco Industries, Inc.; Apollo Valves.
 - c. Cooper Cameron Valves; a division of Cooper Cameron Corp.
 - d. Crane Co.; Crane Valve Group; Jenkins Valves.
 - e. Crane Co.; Crane Valve Group; Stockham Division.
 - f. DeZurik Water Controls.
 - g. Hammond Valve.
 - h. Kitz Corporation.
 - i. Milwaukee Valve Company.
 - j. NIBCO INC.
 - k. Red-White Valve Corporation.
 - l. Tyco Valves & Controls; a unit of Tyco Flow Control.
 - m. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
2. Description:
 - a. Standard: MSS SP-67, Type I.
 - b. CWP Rating: 150 psig.
 - c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
 - d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
 - e. Seat: EPDM.
 - f. Stem: One- or two-piece stainless steel.
 - g. Disc: Aluminum bronze.

B. 150 CWP, Iron, Single-Flange Butterfly Valves with EPDM Seat and Ductile-Iron Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bray Controls; a division of Bray International.
 - b. Conbraco Industries, Inc.; Apollo Valves.
 - c. Cooper Cameron Valves; a division of Cooper Cameron Corp.
 - d. Crane Co.; Crane Valve Group; Center Line.
 - e. Crane Co.; Crane Valve Group; Stockham Division.
 - f. DeZurik Water Controls.
 - g. Hammond Valve.
 - h. Kitz Corporation.
 - i. Milwaukee Valve Company.
 - j. Mueller Steam Specialty; a division of SPX Corporation.

- k. NIBCO INC.
- l. Tyco Valves & Controls; a unit of Tyco Flow Control.
- m. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

- a. Standard: MSS SP-67, Type I.
- b. CWP Rating: 150 psig.
- c. Body Design: Lug type; suitable for bidirectional dead-end service at rated pressure without use of downstream flange.
- d. Body Material: ASTM A 126, cast iron or ASTM A 536, ductile iron.
- e. Seat: EPDM.
- f. Stem: One- or two-piece stainless steel.
- g. Disc: Nickel-plated ductile iron.

C. 150 CWP, Iron, Single-Flange Butterfly Valves with NBR Seat and Stainless-Steel Disc:

2.5 BRONZE LIFT CHECK VALVES

A. Class 125, Lift Check Valves with Bronze Disc:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Jenkins Valves.
 - c. Crane Co.; Crane Valve Group; Stockham Division.
- 2. Description:
 - a. Standard: MSS SP-80, Type 1.
 - b. CWP Rating: 200 psig.
 - c. Body Design: Vertical flow.
 - d. Body Material: ASTM B 61 or ASTM B 62, bronze.
 - e. Ends: Threaded.
 - f. Disc: Bronze.

2.6 BRONZE SWING CHECK VALVES

A. Class 150, Bronze Swing Check Valves with Bronze Disc:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. American Valve, Inc.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. Crane Co.; Crane Valve Group; Jenkins Valves.
 - d. Crane Co.; Crane Valve Group; Stockham Division.
 - e. Kitz Corporation.

- f. Milwaukee Valve Company.
- g. NIBCO INC.
- h. Red-White Valve Corporation.
- i. Zy-Tech Global Industries, Inc.

2. Description:

- a. Standard: MSS SP-80, Type 3.
- b. CWP Rating: 300 psig.
- c. Body Design: Horizontal flow.
- d. Body Material: ASTM B 62, bronze.
- e. Ends: Threaded.
- f. Disc: Bronze.

2.7 IRON SWING CHECK VALVES

A. Class 125, Iron Swing Check Valves with Metal Seats:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Crane Co.; Crane Valve Group; Crane Valves.
- b. Crane Co.; Crane Valve Group; Jenkins Valves.
- c. Crane Co.; Crane Valve Group; Stockham Division.
- d. Hammond Valve.
- e. Kitz Corporation.
- f. Legend Valve.
- g. Milwaukee Valve Company.
- h. NIBCO INC.
- i. Powell Valves.
- j. Red-White Valve Corporation.
- k. Sure Flow Equipment Inc.
- l. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:

- a. Standard: MSS SP-71, Type I.
- b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
- c. NPS 14 to NPS 24, CWP Rating: 150 psig.
- d. Body Design: Clear or full waterway.
- e. Body Material: ASTM A 126, gray iron with bolted bonnet.
- f. Ends: Flanged.
- g. Trim: Bronze.
- h. Gasket: Asbestos free.

2.8 BRONZE GATE VALVES

A. Class 150, NRS Bronze Gate Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Hammond Valve.
 - b. Kitz Corporation.
 - c. Milwaukee Valve Company.
 - d. NIBCO INC.
 - e. Powell Valves.
 - f. Red-White Valve Corporation.
 - g. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

2. Description:
 - a. Standard: MSS SP-80, Type 1.
 - b. CWP Rating: 300 psig.
 - c. Body Material: ASTM B 62, bronze with integral seat and union-ring bonnet.
 - d. Ends: Threaded.
 - e. Stem: Bronze.
 - f. Disc: Solid wedge; bronze.
 - g. Packing: Asbestos free.
 - h. Handwheel: Malleable iron, bronze, or aluminum.

2.9 IRON GATE VALVES

A. Class 125, NRS, Iron Gate Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Jenkins Valves.
 - c. Crane Co.; Crane Valve Group; Stockham Division.
 - d. Flo Fab Inc.
 - e. Hammond Valve.
 - f. Kitz Corporation.
 - g. Legend Valve.
 - h. Milwaukee Valve Company.
 - i. NIBCO INC.
 - j. Powell Valves.
 - k. Red-White Valve Corporation.
 - l. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
 - m. Zy-Tech Global Industries, Inc.

2. Description:
 - a. Standard: MSS SP-70, Type I.
 - b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
 - c. NPS 14 to NPS 24, CWP Rating: 150 psig.
 - d. Body Material: ASTM A 126, gray iron with bolted bonnet.
 - e. Ends: Flanged.

- f. Trim: Bronze.
- g. Disc: Solid wedge.
- h. Packing and Gasket: Asbestos free.

B. Class 125, OS&Y, Iron Gate Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Jenkins Valves.
 - c. Crane Co.; Crane Valve Group; Stockham Division.
 - d. Flo Fab Inc.
 - e. Hammond Valve.
 - f. Kitz Corporation.
 - g. Legend Valve.
 - h. Milwaukee Valve Company.
 - i. NIBCO INC.
 - j. Powell Valves.
 - k. Red-White Valve Corporation.
 - l. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
 - m. Zy-Tech Global Industries, Inc.
2. Description:
 - a. Standard: MSS SP-70, Type I.
 - b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
 - c. NPS 14 to NPS 24, CWP Rating: 150 psig.
 - d. Body Material: ASTM A 126, gray iron with bolted bonnet.
 - e. Ends: Flanged.
 - f. Trim: Bronze.
 - g. Disc: Solid wedge.
 - h. Packing and Gasket: Asbestos free.

2.10 BRONZE GLOBE VALVES

A. Class 125, Bronze Globe Valves with Bronze Disc:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Stockham Division.
 - c. Hammond Valve.
 - d. Kitz Corporation.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Powell Valves.
 - h. Red-White Valve Corporation.
 - i. Watts Regulator Co.; a division of Watts Water Technologies, Inc.

j. Zy-Tech Global Industries, Inc.

2. Description:

- a. Standard: MSS SP-80, Type 1.
- b. CWP Rating: 200 psig.
- c. Body Material: ASTM B 62, bronze with integral seat and screw-in bonnet.
- d. Ends: Threaded or solder joint.
- e. Stem and Disc: Bronze.
- f. Packing: Asbestos free.
- g. Handwheel: Malleable iron, bronze, or aluminum.

2.11 LUBRICATED PLUG VALVES

A. Class 125, Regular-Gland, Lubricated Plug Valves with Threaded Ends:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Nordstrom Valves, Inc.

2. Description:

- a. Standard: MSS SP-78, Type II.
- b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
- c. NPS 14 to NPS 24, CWP Rating: 150 psig.
- d. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
- e. Pattern: Venturi.
- f. Plug: Cast iron or bronze with sealant groove.

B. Class 125, Regular-Gland, Lubricated Plug Valves with Flanged Ends:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

a. Nordstrom Valves, Inc.

2. Description:

- a. Standard: MSS SP-78, Type II.
- b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
- c. NPS 14 to NPS 24, CWP Rating: 150 psig.
- d. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
- e. Pattern: Venturi.
- f. Plug: Cast iron or bronze with sealant groove.

C. Class 125, Cylindrical, Lubricated Plug Valves with Threaded Ends:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Homestead Valve; a division of Olson Technologies, Inc.
 - b. Milliken Valve Company.
 - c. R & M Energy Systems; a unit of Robbins & Myers, Inc.

2. Description:
 - a. Standard: MSS SP-78, Type IV.
 - b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
 - c. NPS 14 to NPS 24, CWP Rating: 150 psig.
 - d. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
 - e. Pattern: Venturi.
 - f. Plug: Cast iron or bronze with sealant groove.

D. Class 125, Cylindrical, Lubricated Plug Valves with Flanged Ends:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Homestead Valve; a division of Olson Technologies, Inc.
 - b. Milliken Valve Company.
 - c. R & M Energy Systems; a unit of Robbins & Myers, Inc.

2. Description:
 - a. Standard: MSS SP-78, Type IV.
 - b. NPS 2-1/2 to NPS 12, CWP Rating: 200 psig.
 - c. NPS 14 to NPS 24, CWP Rating: 150 psig.
 - d. Body Material: ASTM A 48/A 48M or ASTM A 126, cast iron with lubrication-sealing system.
 - e. Pattern: Venturi.
 - f. Plug: Cast iron or bronze with sealant groove.

2.12 CHAINWHEELS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Babbitt Steam Specialty Co.
 2. Roto Hammer Industries.
 3. Trumbull Industries.

- B. Description: Valve actuation assembly with sprocket rim, brackets, and chain.
 1. Brackets: Type, number, size, and fasteners required to mount actuator on valve.
 2. Attachment: For connection to ball butterfly and plug valve stems.
 3. Sprocket Rim with Chain Guides: Cast iron, of type and size required for valve. Include zinc coating.

4. Chain: Stainless steel, of size required to fit sprocket rim.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine valve interior for cleanliness, freedom from foreign matter, and corrosion. Remove special packing materials, such as blocks, used to prevent disc movement during shipping and handling.
- B. Operate valves in positions from fully open to fully closed. Examine guides and seats made accessible by such operations.
- C. Examine threads on valve and mating pipe for form and cleanliness.
- D. Examine mating flange faces for conditions that might cause leakage. Check bolting for proper size, length, and material. Verify that gasket is of proper size, that its material composition is suitable for service, and that it is free from defects and damage.
- E. Do not attempt to repair defective valves; replace with new valves.

3.2 VALVE INSTALLATION

- A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
- B. Locate valves for easy access and provide separate support where necessary.
- C. Install valves in horizontal piping with stem at or above center of pipe.
- D. Install valves in position to allow full stem movement.
- E. Install chainwheels on operators for butterfly gate globe and plug valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor.
- F. Install check valves for proper direction of flow and as follows:
 1. Swing Check Valves: In horizontal position with hinge pin level.
 2. Lift Check Valves: With stem upright and plumb.

3.3 ADJUSTING

- A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

3.4 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

- A. If valve applications are not indicated, use the following:
1. Shutoff Service: Ball, butterfly, or gate valves.
 2. Butterfly Valve Dead-End Service: Single-flange (lug) type.
 3. Throttling Service except Steam: Globe or angle valves.
 4. Pump-Discharge Check Valves:
 - a. NPS 2 and Smaller: Bronze swing check valves with bronze disc.
 - b. NPS 2-1/2 and Larger: Iron swing check valves with lever and weight or with spring or iron, center-guided, metal or resilient-seat check valves.
- B. If valves with specified SWP classes or CWP ratings are not available, the same types of valves with higher SWP classes or CWP ratings may be substituted.
- C. Select valves, except wafer types, with the following end connections:
1. For Copper Tubing, NPS 2 and Smaller: Threaded ends except where solder-joint valve-end option is indicated in valve schedules below.
 2. For Copper Tubing, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in valve schedules below.
 3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
 4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
 5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in valve schedules below.
 6. For Steel Piping, NPS 5 and Larger: Flanged ends.

3.5 HEATING-WATER VALVE SCHEDULE

- A. Pipe NPS 2 and Smaller:
1. Bronze Valves: May be provided with solder-joint ends instead of threaded ends.
 2. Bronze Angle Valves: Class 150, bronze disc.
 3. Ball Valves: One piece, full port, bronze with stainless-steel trim.
 4. Bronze Swing Check Valves: Class 150, bronze disc.
 5. Bronze Gate Valves: Class 150, NRS.
 6. Bronze Globe Valves: Class 150, bronze disc.
- B. Pipe NPS 2-1/2 and Larger:
1. Iron Valves, NPS 2-1/2 to NPS 4: May be provided with threaded ends instead of flanged ends.
 2. Iron, Single-Flange Butterfly Valves, NPS 2-1/2 to NPS 12: 200 CWP, EPDM seat, aluminum-bronze, ductile-iron or stainless-steel disc.
 3. High-Performance Butterfly Valves: Class 300, single flange.
 4. Iron Swing Check Valves: Class 125, metal seats.
 5. Iron Swing Check Valves with Closure Control, NPS 2-1/2 to NPS 12: Class 125, lever and weight.
 6. Iron, Center-Guided Check Valves: Class 250, compact-wafer, resilient seat.

7. Iron Gate Valves: Class 125, Class 250, OS&Y.
8. Iron Globe Valves, NPS 2-1/2 to NPS 12: Class 250.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15124
EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Flexible, ball-joint, packed expansion joints.
 - 2. Slip-joint packed expansion joints.
 - 3. Expansion-compensator packless expansion joints.
 - 4. Flexible-hose packless expansion joints.
 - 5. Metal-bellows packless expansion joints.
 - 6. Rubber packless expansion joints.
 - 7. Pipe loops and swing connections.
 - 8. Alignment guides and anchors.

1.3 PERFORMANCE REQUIREMENTS

- A. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.
- B. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.

1.5 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Product Certificates: For each type of expansion joint, from manufacturer.
- C. Pipe expansion and anchor load calculations each anchor point, prepared, stamped and signed by a qualified Massachusetts-licensed Professional Engineer, including the applicable anchor detail with attachments, embedments and material components.

1.6 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For expansion joints to include in maintenance manuals.

1.7 QUALITY ASSURANCE

- B. Welding Qualifications: Qualify procedures and personnel per the following:
1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
 2. ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.1 PACKED EXPANSION JOINTS

- A. Flexible, Ball-Joint, Packed Expansion Joints:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advanced Thermal Systems, Inc.
 - b. Hyspan Precision Products, Inc.
 - c. Mason Industries, Inc.
 2. Standards: ASME Boiler and Pressure Vessel Code: Section II, "Materials"; and ASME B31.9, "Building Services Piping," for materials and design of pressure-containing parts and bolting.
 3. Material: Carbon-steel assembly with asbestos-free composition packing.
 4. Design: For 360-degree rotation and angular deflection.
 5. Minimum Pressure Rating: 250 psig at 400 deg F.
 6. Angular Deflection for NPS 6 and Smaller: 30 degree minimum.
 7. Angular Deflection for NPS 8 and Larger: 15 degree minimum.
- B. Weld end connections are available, if required, for NPS 2-1/2 (DN 65) and larger.
1. End Connections for NPS 2 and Smaller: Threaded.
 2. End Connections for NPS 2-1/2 and Larger: Flanged.
- C. Slip-Joint Packed Expansion Joints:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Adscos Manufacturing LLC.
 - b. Advanced Thermal Systems, Inc.
 - c. Hyspan Precision Products, Inc.
 - d. Mason Industries, Inc.
 2. Standard: ASTM F 1007.
 3. Material: Carbon steel with asbestos-free PTFE packing.

4. Design: With internal guide and injection device for repacking under pressure. Include drip connection if used for steam piping.
5. Configuration: Single joint class(es) unless otherwise indicated.
6. End Connections: Flanged or weld ends to match piping system.

2.2 PACKLESS EXPANSION JOINTS

D. Metal, Expansion-Compensator Packless Expansion Joints:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Adscos Manufacturing LLC.
 - b. Flex Pression Ltd.
 - c. Flex-Weld, Inc.
 - d. Flexicraft Industries.
 - e. Hyspan Precision Products, Inc.
 - f. Mason Industries, Inc.
 - g. Metraflex Company (The).
 - h. Senior Flexonics Pathway.
 - i. Unaflex.
 - j. Unisource Manufacturing, Inc.
2. Minimum Pressure Rating: 150 psig unless otherwise indicated.
3. Configuration for Copper Tubing: Two-ply, phosphor-bronze bellows with copper pipe ends.
 - a. End Connections for Copper Tubing NPS 2 and Smaller: Solder joint or threaded.
 - b. End Connections for Copper Tubing NPS 2-1/2 to NPS 4: Threaded.
4. Configuration for Steel Piping: Two-ply, stainless-steel bellows; steel-pipe end connections; and carbon-steel shroud.
 - a. End Connections for Steel Pipe NPS 2 and Smaller: Threaded.
 - b. End Connections for Steel Pipe NPS 2-1/2 to NPS 4: Flanged.

E. Rubber, Expansion-Compensator Packless Expansion Joints:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Amber/Booth Company, Inc.
 - b. Flex-Hose Co., Inc.
 - c. Flexicraft Industries.
 - d. General Rubber Corporation.
 - e. Mason Industries, Inc.
 - f. Proco Products, Inc.
 - g. Tozen Corporation.
 - h. Unaflex.
 - i. Unisource Manufacturing, Inc.

- j. Material: Twin reinforced-rubber spheres with external restraining cables.
 - k. Minimum Pressure Rating: 150 psig at 170 deg F unless otherwise indicated.
 - l. End Connections for NPS 2 and Smaller: Threaded.
 - m. Flexible-Hose Packless Expansion Joints.
2. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Flex Pression Ltd.
 - b. Flex-Hose Co., Inc.
 - c. Flexicraft Industries.
 - d. Mason Industries, Inc.
 - e. Metraflex Company (The).
 - f. Unisource Manufacturing, Inc.
 3. Description: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose.
 4. Flexible Hose: Corrugated-metal inner hoses and braided outer sheaths.
 5. Expansion Joints for Copper Tubing NPS 2 and Smaller: Copper-alloy fittings with solder-joint end connections.
 - a. Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F and 340 psig at 450 deg F ratings.
 6. Expansion Joints for Copper Tubing NPS 2-1/2 to NPS 4: Copper-alloy fittings with threaded end connections.
 - a. Stainless-steel hoses and single-braid, stainless-steel sheaths with 300 psig at 70 deg F and 225 psig at 450 deg F ratings.
 7. Expansion Joints for Steel Piping NPS 2 and Smaller: Carbon-steel fittings with threaded end connections.
 - a. Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F and 325 psig at 600 deg F ratings.
 8. Expansion Joints for Steel Piping NPS 2-1/2 to NPS 6: Carbon-steel fittings with flanged end connections.
 - a. Stainless-steel hoses and single-braid, stainless-steel sheaths with 200 psig at 70 deg F and 145 psig at 600 deg F ratings.

F. Metal-Bellows Packless Expansion Joints:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Adscos Manufacturing LLC.
 - b. American BOA, Inc.
 - c. Badger Industries, Inc.
 - d. Expansion Joint Systems, Inc.

- e. Flex Pression Ltd.
 - f. Flex-Hose Co., Inc.
 - g. Flex-Weld, Inc.
 - h. Flexicraft Industries.
 - i. Flo Fab inc.
 - j. Hyspan Precision Products, Inc.
 - k. Mason Industries, Inc.
 - l. Metraflex Company (The).
 - m. Proco Products, Inc.
 - n. Senior Flexonics Pathway.
 - o. Tozen Corporation.
 - p. U.S. Bellows, Inc.
 - q. Unaflex.
 - r. Unisource Manufacturing, Inc.
 - s. Universal Metal Hose.
 - t. WahlcoMetroflex.
2. Standards: ASTM F 1120 and EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
 3. Type: Circular, corrugated bellows with external tie rods.
 4. Minimum Pressure Rating: 150 psig unless otherwise indicated.
 5. Configuration: Single joint class(es) unless otherwise indicated.
 6. Expansion Joints for Copper Tubing: Single-ply phosphor-bronze bellows, copper pipe ends, and brass shrouds.
 - a. End Connections for Copper Tubing NPS 2 and Smaller: Solder joint or threaded.
 - b. End Connections for Copper Tubing NPS 2-1/2 to NPS 4: Solder joint or threaded.
 - c. End Connections for Copper Tubing NPS 5 and Larger: Flanged.
 7. Expansion Joints for Steel Piping: Single-ply stainless-steel bellows, steel pipe ends, and carbon-steel shroud.
 - a. End Connections for Steel Pipe NPS 2 and Smaller: Threaded.
 - b. End Connections for Steel Pipe NPS 2-1/2 and Larger: Flanged.

G. Rubber Packless Expansion Joints:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Amber/Booth Company, Inc.
 - b. Flex-Hose Co., Inc.
 - c. Flex-Weld, Inc.
 - d. Flexicraft Industries.
 - e. Garlock Sealing Technologies.
 - f. General Rubber Corporation.
 - g. Mason Industries, Inc; Mercer Rubber Co.
 - h. Metraflex Company (The).
 - i. Proco Products, Inc.

- j. Red Valve Company, Inc.
 - k. Tozen Corporation.
 - l. Unaflex.
 - m. Unisource Manufacturing, Inc.
2. Standards: ASTM F 1123 and FSA's "Technical Handbook: Non-Metallic Expansion Joints and Flexible Pipe Connectors."
 3. Material: Fabric-reinforced rubber complying with FSA-NMEJ-703.
 4. Arch Type: Single arches with external control rods.
 5. Spherical Type: Single spheres with external control rods.
 6. Minimum Pressure Rating for NPS 1-1/2 to NPS 4: 150 psig at 220 deg F.
 7. Minimum Pressure Rating for NPS 5 and NPS 6: 140 psig at 200 deg F.
 8. Material for Water: Buna-N.
 9. End Connections: Full-faced, integral steel flanges with steel retaining rings.

2.3 ALIGNMENT GUIDES AND ANCHORS

A. Alignment Guides:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Adscio Manufacturing LLC.
 - b. Advanced Thermal Systems, Inc.
 - c. Flex-Hose Co., Inc.
 - d. Flex-Weld, Inc.
 - e. Flexicraft Industries.
 - f. Hyspan Precision Products, Inc.
 - g. Mason Industries, Inc.
 - h. Metraflex Company (The).
 - i. Senior Flexonics Pathway.
 - j. U.S. Bellows, Inc.
 - k. Unisource Manufacturing, Inc.
2. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding spider for bolting to pipe.

B. Anchor Materials:

1. Steel Shapes and Plates: ASTM A 36/A 36M.
2. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel hex head.
3. Washers: ASTM F 844, steel, plain, flat washers.
4. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, with tension and shear capacities appropriate for application.

C. Stainless-steel studs are available

1. Stud: Threaded, hot-dipped galvanized carbon steel.
2. Expansion Plug: Hot-dipped galvanized steel.
3. Washer and Nut: Hot-dipped galvanized steel.

- D. Chemical Fasteners: Insert-type-stud, bonding-system anchor for use with hardened portland cement concrete, with tension and shear capacities appropriate for application.
 - 1. Bonding Material: ASTM C 881/C 881M, Type IV, Grade 3, two-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed. Application limited to shear, not tensile stresses.
- E. Stainless-steel studs are available.
 - 1. Stud: ASTM A 307, hot dipped galvanized carbon steel with continuous thread on stud unless otherwise indicated.
 - 2. Washer and Nut: Hot dipped galvanized steel.

PART 3 - EXECUTION

3.1 EXPANSION-JOINT INSTALLATION

- A. Install expansion joints of sizes matching sizes of piping in which they are installed.
- B. Install packed-type expansion joints with packing suitable for fluid service.
- C. Install metal-bellows expansion joints per EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
- D. Install rubber packless expansion joints per FSA-NMEJ-702.
- E. Install grooved-joint expansion joints to grooved-end steel piping

3.2 PIPE LOOP AND SWING CONNECTION INSTALLATION

- A. Connect risers and branch connections to mains with at least five pipe fittings including tee in main. Each segment leg shall be not less than six (6) nominal pipe diameters between fittings.
- B. Connect risers and branch connections to terminal units with at least four pipe fittings including tee in riser. Each segment leg shall be not less than six (6) nominal pipe diameters between fittings.
- C. Connect mains and branch connections to terminal units with at least four pipe fittings including tee in main. Each segment leg shall be not less than six (6) nominal pipe diameters between fittings.
- D. Pipe segments installed to free-float by design shall be suspended with welded eye-bolts to allow X and Y axial movement. All eye bolts shall be installed to allow a 30-degree cone of movement, measured from the center of the fixed eye, without obstruction.

3.3 ALIGNMENT-GUIDE AND ANCHOR INSTALLATION

- A. Install alignment guides to guide expansion and to avoid end-loading and torsional stress. Indicate locations and number of guides on Drawings.

- B. Install one guide(s) on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than four pipe diameters from expansion joint.
- C. Attach guides to pipe and secure guides to building structure.
- D. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.
- E. Anchor Attachments:
 - 1. Anchor Attachment to Steel Pipe: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
 - 2. Anchor Attachment to Copper Tubing: Attach with pipe hangers. Use MSS SP-69, Type 24, U-bolts bolted to anchor.
- F. Fabricate and install steel anchors by welding steel shapes, plates, and bars. Comply with ASME B31.9 and AWS D1.1/D1.1M.
 - 1. Anchor Attachment to Steel Structural Members: Attach by welding.
 - 2. Anchor Attachment to Concrete Structural Members: Attach by fasteners. Follow fastener manufacturer's written instructions.
- G. Use grout to form flat bearing surfaces for guides and anchors attached to concrete.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15127

METERS AND GAGES FOR PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC METATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15084 – PLUMBING EQUIPMENT INSULATION
 - 7. Section 15086 – DUCT INSULATION
 - 8. Section 15088 – HVAC PIPING INSULATION
 - 9. Section 15140 – DOMESTIC WATER PIPING
 - 10. Section 15179 – HYDRONIC PIPING SPECIALTIES
 - 11. Section 15181 – HYDRONIC PIPING
 - 12. Section 15183 – REFRIGERANT PIPING
 - 13. Section 15185 – HYDRONIC PUMPS
 - 14. Section 15815 – METAL DUCTS
 - 15. Section 15195 – FACILITY NATURAL-GAS PIPING"

1.2 SUMMARY

- A. Section Includes:
 - 1. Liquid-in-glass thermometers.
 - 2. Duct Thermometer Mounting Brackets
 - 3. Thermowells.
 - 4. Dial-type pressure gages.
 - 5. Gage attachments.
 - 6. Test plugs.
 - 7. Test-plug kits.
 - 8. Sight flow indicators.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Product Certificates: For each type of meter and gage, from manufacturer.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For meters and gages to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 LIQUID-IN-GLASS THERMOMETERS

- A. Metal-Case, Industrial-Style, Liquid-in-Glass Thermometers:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Flo Fab Inc.
 - b. Miljoco Corporation.
 - c. Palmer Wahl Instrumentation Group.
 - d. Tel-Tru Manufacturing Company.
 - e. Trerice, H. O. Co.
 - f. Weiss Instruments, Inc.
 - g. Winters Instruments - U.S.
 - 2. Standard: ASME B40.200.
 - 3. Case: Cast aluminum; 7-inch nominal size unless otherwise indicated.
 - 4. Case Form: Adjustable angle unless otherwise indicated.
 - 5. Tube: Glass with magnifying lens and blue or red organic liquid.
 - 6. Tube Background: Nonreflective aluminum with permanently etched scale markings graduated in deg F.
 - 7. Window: Glass.
 - 8. Stem: Aluminum and of length to suit installation.
 - a. Design for Air-Duct Installation: With ventilated shroud.
 - b. Design for Thermowell Installation: Bare stem.
 - 9. Connector: 1-1/4 inches, with ASME B1.1 screw threads.
 - 10. Accuracy: Plus or minus 1 percent of scale range or one scale division, to a maximum of 1.5 percent of scale range.

2.2 DUCT-THERMOMETER MOUNTING BRACKETS

- A. Description: Flanged bracket with screw holes, for attachment to air duct and made to hold thermometer stem.

2.3 THERMOWELLS

A. Thermowells:

1. Standard: ASME B40.200.
2. Description: Pressure-tight, socket-type fitting made for insertion into piping tee fitting.
3. Material for Use with Copper Tubing: CNR.
4. Material for Use with Steel Piping: CRES.
5. Type: Stepped shank unless straight or tapered shank is indicated.
6. External Threads: NPS 1/2, NPS 3/4, or NPS 1, ASME B1.20.1 pipe threads.
7. Internal Threads: 1/2, 3/4, and 1 inch, with ASME B1.1 screw threads.
8. Bore: Diameter required to match thermometer bulb or stem.
9. Insertion Length: Length required to match thermometer bulb or stem.
10. Lagging Extension: Include on thermowells for insulated piping and tubing.
11. Bushings: For converting size of thermowells internal screw thread to size of thermometer connection.

B. Heat Transfer Medium:

1. Paste or gel form, commercial brands. No liquid state below 200 degrees F.
2. Silicone, graphite ground in glycerin, aluminum or zinc powder ground in glycerin, mineral oil or petroleum jelly.

2.4 PRESSURE GAGES

A. Direct-Mounted, Metal-Case, Dial-Type Pressure Gages:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMETEK, Inc.; U.S. Gauge.
 - b. Ashcroft Inc.
 - c. Ernst Flow Industries.
 - d. Flo Fab Inc.
 - e. Marsh Bellofram.
 - f. Miljoco Corporation.
 - g. Noshok.
 - h. Palmer Wahl Instrumentation Group.
 - i. REOTEMP Instrument Corporation.
 - j. Tel-Tru Manufacturing Company.
 - k. Trelice, H. O. Co.
 - l. Watts Regulator Co.; a div. of Watts Water Technologies, Inc.
 - m. Weiss Instruments, Inc.
 - n. WIKA Instrument Corporation - USA.
 - o. Winters Instruments - U.S.
2. Standard: ASME B40.100
3. Case: Sealed type(s); cast aluminum or drawn steel; 4-1/2-inch nominal diameter.
4. Pressure-Element Assembly: Bourdon tube unless otherwise indicated.
5. Pressure Connection: Brass, with NPS 1/2, ASME B1.20.1 pipe threads and bottom-outlet type unless back-outlet type is indicated.
6. Movement: Mechanical, with link to pressure element and connection to pointer.

7. Dial: Nonreflective aluminum with permanently etched scale markings graduated in psi.
8. Pointer: Dark-colored metal.
9. Window: Glass.
10. Ring: Stainless steel.
11. Accuracy: ANSI Grade 1A, plus or minus 1 percent of scale range.

2.5 GAGE ATTACHMENTS

- A. Snubbers or impulse dampeners: ASME B40.100, brass; with NPS 1/2, ASME B1.20.1 pipe threads and piston-type surge- dampening device. Include extension for use on insulated piping.
- B. Siphons: Loop-shaped section of brass pipe with NPS 1/2 pipe threads.
- C. Valves: Brass or stainless-steel needle, with NPS 1/2, ASME B1.20.1 pipe threads.
- D. Connecting piping: Sch. 40 red brass pipe nipples conforming to ASTM B-687 and ASTM B43, with cast red brass fittings conforming to ASTM B-62. Sizes not less than 1/4" for pump gauges and not less than 3/4" for boiler instrumentation. For systems with pressure class above 125 psi, use stainless steel piping. Carbon steel piping will not be acceptable for gauge and instrumentation piping. Soft or hard temper copper will be acceptable only for final connections to panel-mounted instruments.

2.6 TEST PLUGS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Flow Design, Inc.
 2. Miljoco Corporation.
 3. National Meter, Inc.
 4. Peterson Equipment Co., Inc.
 5. Sisco Manufacturing Company, Inc.
 6. Trelice, H. O. Co.
 7. Watts Regulator Co.; a div. of Watts Water Technologies, Inc.
 8. Weiss Instruments, Inc.
- B. Description: Test-station fitting made for insertion into piping tee fitting.
- C. Body: Brass or stainless steel with core inserts and gasketed and threaded cap. Include extended stem on units to be installed in insulated piping.
- D. Thread Size: NPS 1/2, ASME B1.20.1 pipe thread.
- E. Minimum Pressure and Temperature Rating: 500 psig at 200 deg F.
- F. Core Inserts: EPDM self-sealing rubber.

2.7 TEST-PLUG KITS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Flow Design, Inc.
 2. Miljoco Corporation.
 3. National Meter, Inc.

4. Peterson Equipment Co., Inc.
 5. Sisco Manufacturing Company, Inc.
 6. Trelice, H. O. Co.
 7. Watts Regulator Co.; a div. of Watts Water Technologies, Inc.
 8. Weiss Instruments, Inc.
- B. Furnish two test-plug kit(s) containing two thermometer(s), one pressure gage and adapter, and carrying case. Thermometer sensing elements, pressure gage, and adapter probes shall be of diameter to fit test plugs and of length to project into piping.
- C. Low-Range Thermometer: Small, bimetallic insertion type with 1- to 2-inch- diameter dial and tapered-end sensing element. Dial range shall be at least 25 to 125 deg F.
- D. High-Range Thermometer: Small, bimetallic insertion type with 1- to 2-inch- diameter dial and tapered-end sensing element. Dial range shall be at least.
- E. Pressure Gage: Small, Bourdon-tube insertion type with 2- to 3-inch- diameter dial and probe. Dial range shall be at least 0 to 200 psig.
- F. Carrying Case: Metal or plastic, with formed instrument padding.

2.8 SIGHT FLOW INDICATORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Archon Industries, Inc.
 2. Dwyer Instruments, Inc.
 3. Emerson Process Management; Brooks Instrument.
 4. Ernst Co., John C., Inc.
 5. Ernst Flow Industries.
 6. KOBOLD Instruments, Inc. - USA; KOBOLD Messring GmbH.
 7. OPW Engineered Systems; a Dover company.
 8. Penberthy; A Brand of Tyco Valves & Controls - Prophetstown.
- B. Description: Piping inline-installation device for visual verification of flow.
- C. Construction: Bronze or stainless-steel body, with sight glass and ball, flapper, or paddle wheel indicator, and threaded or flanged ends.
- D. Minimum Pressure Rating: 125 psig.
- E. Minimum Temperature Rating: 200 deg F.
- F. End Connections for NPS 2 and Smaller: Threaded.
- G. End Connections for NPS 2-1/2 and Larger: Flanged.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install thermowells with socket extending to center of pipe and in vertical position in piping tees.
- B. Install thermowells of sizes required to match thermometer connectors. Include bushings if required to match sizes.
- C. Install thermowells with extension on insulated piping.
- D. Fill thermowells with heat-transfer medium to not more than 90 percent of well void volume. Rotate instrument to assure coverage.
- E. For non-threaded insertion type sensors and instruments, provide chrome-plated or stainless steel retainer clips matched to thermowell shoulder groove.
- F. Install direct-mounted thermometers in thermowells and adjust vertical and tilted positions.
- G. Install duct-thermometer mounting brackets in walls of ducts. Attach to duct with screws.
- H. Install direct-mounted pressure gages in piping tees with pressure gage located on pipe at the most readable position.
- I. Install valve and snubber in piping for each pressure gage for fluids.
- J. Install test plugs in piping tees.
- K. Install thermometers in the following locations:
 - 1. Inlet and outlet of each water heater.
- L. Install pressure gages in the following locations:
 - 1. Discharge of each pressure-reducing valve.
 - 2. Inlet and outlet of each backflow preventer
 - 3. Suction and discharge of each pump.

3.2 CONNECTIONS

- A. Install meters and gages adjacent to machines and equipment to allow service and maintenance of meters, gages, machines, and equipment.
- B. Install with Sch. 40 threaded red brass pipe and cast brass fittings and ball valves for pressure gauges and instrumentation without wells.
- C. Provide plugged valve and tee for test gauge.
- D. All differential function gauge connections shall be at identical elevations.

3.3 ADJUSTING

- A. After installation, calibrate meters according to manufacturer's written instructions.
- B. Adjust faces of meters and gages to proper angle for best visibility.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15140

DOMESTIC WATER PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15084 – PLUMBING EQUIPMENT INSULATION
 - 7. Section 15085 - PLUMBING PIPING INSULATION
 - 8. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 9. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 10. Section 15127 – METERS AND GAGES FOR PIPING
 - 11. Section 15145 – DOMESTIC WATER PIPING SPECIALTIES
 - 12. Section 15400 – PLUMBING FIXTURES
 - 13. Section 15412 – EMERGENCY PLUMBING FIXTURES
 - 14. Section 15485 – ELECTRIC WATER HEATERS

1.2 SUMMARY

- A. Section Includes:
 - 1. Under-building-slab and aboveground domestic water pipes, tubes, and fittings inside buildings.
 - 2. Encasement for piping.

1.3 ACTION SUBMITTALS

- A. Product Data: For transition fittings and dielectric fittings.
- B. Joining methods, solders and thread compounds.

1.4 INFORMATIONAL SUBMITTALS

- A. System purging and disinfecting activities report.
- B. Field quality-control reports.

1.5 FIELD CONDITIONS

- A. Interruption of Existing Water Service: Do not interrupt water service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary water service according to requirements indicated:
 - 1. Notify Construction Manager no fewer than 14 days in advance of proposed interruption of water service.
 - 2. Do not interrupt water service without Construction Manager's written permission.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

- A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, fitting materials, and joining methods for specific services, service locations, and pipe sizes.
- B. Potable-water piping and components shall comply with NSF 14 and NSF 61. Plastic piping components shall be marked with "NSF-pw."

2.2 COPPER TUBE AND FITTINGS

- A. Hard Copper Tube: ASTM B 88, Type L water tube, drawn temper.
- B. Soft Copper Tube: ASTM B 88, Type K water tube, annealed temper.
- C. Wrought-Copper, Solder-Joint Fittings: ASME B16.22, wrought-copper pressure fittings.
- D. Bronze Flanges: ASME B16.24, Class 150, with solder-joint ends.
- E. Copper Unions:
 - 1. MSS SP-123.
 - 2. Cast-copper-alloy, hexagonal-stock body.
 - 3. Ball-and-socket, metal-to-metal seating surfaces.
 - 4. Solder-joint or threaded ends.

2.3 PIPING JOINING MATERIALS

- A. Solder Filler Metals: ASTM B 32, lead-free alloys.
- B. Flux: ASTM B 813, water flushable.
- C. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for general-duty brazing unless otherwise indicated.

2.4 TRANSITION FITTINGS

- A. General Requirements:
 - 1. Same size as pipes to be joined.
 - 2. Pressure rating at least equal to pipes to be joined.
 - 3. End connections compatible with pipes to be joined.
- B. Fitting-Type Transition Couplings: Manufactured piping coupling or specified piping system fitting.
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cascade Waterworks Manufacturing.
 - b. Dresser, Inc.; Piping Specialties Products.
 - c. Ford Meter Box Company, Inc. (The).
 - d. JCM Industries.
 - e. Romac Industries, Inc.
 - f. Smith-Blair, Inc.; a Sensus company.
 - g. Viking Johnson.

PART 3 - EXECUTION

3.1 EARTHWORK

- A. Comply with requirements in Section 02300 "Earthwork" for excavating, trenching, and backfilling.

3.2 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of domestic water piping. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on coordination drawings.
- B. Install copper tubing under building slab according to "Copper Tube Handbook."
- C. Install shutoff valve, hose-end drain valve, strainer, pressure gage, and test tee with valve inside the building at each domestic water-service entrance. Comply with requirements for pressure gages in Section 15127 "METERS AND GAGES FOR PIPING" and with requirements for drain valves and strainers in Section 15145 "DOMESTIC WATER PIPING SPECIALTIES."
- D. Install shutoff valve immediately upstream of each dielectric fitting.
- E. Install water-pressure-reducing valves downstream from shutoff valves. Comply with requirements for pressure-reducing valves in Section 15145 "DOMESTIC WATER PIPING SPECIALTIES."
- F. Install domestic water piping level with 0.25 percent slope downward toward drain and plumb.
- G. Rough-in domestic water piping for water-meter installation according to utility company's requirements.

- H. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- I. Install piping concealed from view and protected from physical contact by building occupants unless otherwise indicated and except in equipment rooms and service areas.
- J. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- K. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal, and coordinate with other services occupying that space.
- L. Install piping to permit valve servicing.
- M. Install nipples, unions, special fittings, and valves with pressure ratings the same as or higher than the system pressure rating used in applications below unless otherwise indicated.
- N. Install piping free of sags and bends.
- O. Install fittings for changes in direction and branch connections.
- P. Install unions in copper tubing at final connection to each piece of equipment, machine, and specialty.
- Q. Install pressure gages on suction and discharge piping for each plumbing pump. Comply with requirements for pressure gages in Section 15127 "METERS AND GAGES FOR PIPING."
- R. Install thermometers on inlet and outlet piping from each water heater. Comply with requirements for thermometers in Section 15127 "METERS AND GAGES FOR PIPING."
- S. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- T. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons.

3.3 JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipes, tubes, and fittings before assembly.
- C. Soldered Joints for Copper Tubing: Apply ASTM B 813, water-flushable flux to end of tube. Join copper tube and fittings according to ASTM B 828 or CDA's "Copper Tube Handbook."
- D. Joints for Dissimilar-Material Piping: Make joints using adapters compatible with materials of both piping systems.

3.4 TRANSITION FITTING INSTALLATION

- A. Install transition couplings at joints of dissimilar piping.

- B. Transition Fittings in Underground Domestic Water Piping:
 - 1. Fittings for NPS 1-1/2 and Smaller: Fitting-type coupling.
 - 2. Fittings for NPS 2 and Larger: Sleeve-type coupling.
- C. Transition Fittings in Aboveground Domestic Water Piping NPS 2 and Smaller: Plastic-to-metal transition fittings or unions.

3.5 HANGER AND SUPPORT INSTALLATION

- A. Comply with requirements for seismic-restraint devices in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- B. Comply with requirements for pipe hanger, support products, and installation in Section 15062 "HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT."
 - 1. Vertical Piping: MSS Type 8 or 42, clamps.
 - 2. Individual, Straight, Horizontal Piping Runs:
 - a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
 - b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
 - c. Longer Than 100 Feet if Indicated: MSS Type 49, spring cushion rolls.
 - 3. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
 - 4. Base of Vertical Piping: MSS Type 52, spring hangers.
- C. Support vertical piping and tubing at base and at each floor.
- D. Rod diameter may be reduced one size for double-rod hangers, to a minimum of 3/8 inch.
- E. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:
 - 1. NPS 3/4 and Smaller: 60 inches with 3/8-inch rod.
 - 2. NPS 1 and NPS 1-1/4: 72 inches with 3/8-inch rod.
 - 3. NPS 1-1/2 and NPS 2: 96 inches with 3/8-inch rod.
 - 4. NPS 2-1/2: 108 inches with 1/2-inch rod.
 - 5. NPS 3 to NPS 5: 10 feet with 1/2-inch rod.
 - 6. NPS 6: 10 feet with 5/8-inch rod.
- F. Install supports for vertical copper tubing every 10 feet.
- G. Install supports for vertical stainless-steel piping every 15 feet.
- H. Support piping and tubing not listed in this article according to MSS SP-69 and manufacturer's written instructions.

3.6 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.

- B. When installing piping adjacent to equipment and machines, allow space for service and maintenance.
- C. Connect domestic water piping to exterior water-service piping. Use transition fitting to join dissimilar piping materials.
- D. Connect domestic water piping to water-service piping with shutoff valve; extend and connect to the following:
 - 1. Water Heaters: Cold-water inlet and hot-water outlet piping in sizes indicated, but not smaller than sizes of water heater connections.
 - 2. Plumbing Fixtures: Cold- and hot-water-supply piping in sizes indicated, but not smaller than that required by plumbing code.
 - 3. Equipment: Cold- and hot-water-supply piping as indicated, but not smaller than equipment connections. Provide shutoff valve and union for each connection. Use flanges instead of unions for NPS 2-1/2 and larger.

3.7 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification materials and installation in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."
- B. Label pressure piping with system operating pressure.

3.8 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Piping Inspections:
 - a. Do not enclose, cover, or put piping into operation until it has been inspected and approved by authorities having jurisdiction.
 - b. During installation, notify authorities having jurisdiction at least one day before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction:
 - 1) Roughing-in Inspection: Arrange for inspection of piping before concealing or closing in after roughing in and before setting fixtures.
 - 2) Final Inspection: Arrange for authorities having jurisdiction to observe tests specified in "Piping Tests" Subparagraph below and to ensure compliance with requirements.
 - c. Reinspection: If authorities having jurisdiction find that piping will not pass tests or inspections, make required corrections and arrange for reinspection.
 - d. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.
 - 2. Piping Tests:
 - a. Fill domestic water piping. Check components to determine that they are not air bound and that piping is full of water.

- b. Test for leaks and defects in new piping and parts of existing piping that have been altered, extended, or repaired. If testing is performed in segments, submit a separate report for each test, complete with diagram of portion of piping tested.
- c. Leave new, altered, extended, or replaced domestic water piping uncovered and unconcealed until it has been tested and approved. Expose work that was covered or concealed before it was tested.
- d. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow it to stand for four hours. Leaks and loss in test pressure constitute defects that must be repaired.
- e. Repair leaks and defects with new materials, and retest piping or portion thereof until satisfactory results are obtained.
- f. Prepare reports for tests and for corrective action required.

B. Domestic water piping will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.9 ADJUSTING

A. Perform the following adjustments before operation:

- 1. Close drain valves, hydrants, and hose bibbs.
- 2. Open shutoff valves to fully open position.
- 3. Open throttling valves to proper setting.
- 4. Adjust balancing valves in hot-water-circulation return piping to provide adequate flow.
 - a. Manually adjust ball-type balancing valves in hot-water-circulation return piping to provide hot-water flow in each branch.
 - b. Adjust calibrated balancing valves to flows indicated.
- 5. Remove plugs used during testing of piping and for temporary sealing of piping during installation.
- 6. Remove and clean strainer screens. Close drain valves and replace drain plugs.
- 7. Remove filter cartridges from housings and verify that cartridges are as specified for application where used and are clean and ready for use.
- 8. Check plumbing specialties and verify proper settings, adjustments, and operation.

3.10 CLEANING

A. Clean and disinfect potable domestic water piping as follows:

- 1. Purge new piping and parts of existing piping that have been altered, extended, or repaired before using.
- 2. Use purging and disinfecting procedures prescribed by authorities having jurisdiction, specifically 248 CMR 10.00:
 - a. Flush piping system with clean, potable water until dirty water does not appear at outlets.
 - b. Fill and isolate system according to either of the following:

- 1) Fill system or part thereof with water/chlorine solution with at least 50 ppm of chlorine. Isolate with valves and allow to stand for a minimum of six (6) hours.
 - 2) Fill system or part thereof with water/chlorine solution with at least 200 ppm of chlorine. Isolate and allow to stand for two (2) hours.
- c. After elapse of the above chlorine residence times, flush system with clean, potable water until no chlorine is in water coming from system after the standing time.
 - d. Repeat procedures if biological examination shows contamination.
 - e. Submit water samples in sterile bottles to authorities having jurisdiction.
 - f. Upon completion and approvals of the authorities having jurisdiction, place potable water systems into service.
- B. Prepare and submit reports of purging and disinfecting activities. Include copies of water-sample approvals from authorities having jurisdiction.
- C. Clean interior of domestic water piping system. Remove dirt and debris as work progresses.

3.11 PIPING SCHEDULE

- A. Transition and special fittings with pressure ratings at least equal to piping rating may be used in applications below unless otherwise indicated.
- B. Flanges and unions may be used for aboveground piping joints unless otherwise indicated.
- C. Fitting Option: Extruded-tee connections and brazed joints may be used on aboveground copper tubing.
- D. Under-building-slab, domestic water, building-service piping, NPS 3 and smaller, shall be the following:
1. Soft copper tube, ASTM B 88, Type K;
- E. Under-building-slab, domestic water, building-service piping, NPS 4 to NPS 8 and larger, shall be the following:
1. Soft copper tube, ASTM B 88, Type K; wrought-copper, solder-joint fittings; and brazed joints.
- F. Aboveground domestic water piping, NPS 3 and smaller, shall be the following:
1. Hard copper tube, ASTM B 88, Type L; wrought-copper, solder-joint fittings; and soldered joints.

3.12 VALVE SCHEDULE

- A. Drawings indicate valve types to be used. Where specific valve types are not indicated, the following requirements apply:
1. Shutoff Duty: Use ball or gate valves for piping NPS 2 and smaller. Use ball, valves with flanged ends for piping NPS 2-1/2 and larger.
 2. Throttling Duty: Use ball for piping NPS 2 and smaller. Use ball valves with flanged ends for piping NPS 2-1/2 and larger.

3. Hot-Water Circulation Piping, Balancing Duty: Memory-stop balancing valves.
 4. Drain Duty: Hose-end drain valves.
- B. Use check valves to maintain correct direction of domestic water flow to and from equipment.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15145

DOMESTIC WATER PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Requirements:
 - 1. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 4. Section 15077- IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15084 – PLUMBING EQUIPMENT INSULATION
 - 6. Section 15085 – PLUMBING PIPING INSULATION
 - 7. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 8. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 9. Section 15127 – METERS AND GAGES FOR PIPING
 - 10. Section 15140 – DOMESTIC WATER PIPING
 - 11. Section 15400 – PLUMBING FIXTURES
 - 12. Section 15412 – EMERGENCY PLUMBING FIXTURES
 - 13. Section 15485 – ELECTRIC WATER HEATERS
 - 14. Section 15778 – HEAT TRACING FOR PLUMBING PIPING
 - 15. Section 16060 – GROUNDING AND BONDING

1.2 SUMMARY

- A. Section Includes:
 - 1. Vacuum breakers.
 - 2. Backflow preventers.
 - 3. Water pressure-reducing valves.
 - 4. Balancing valves.
 - 5. Temperature-actuated, water mixing valves.
 - 6. Strainers.
 - 7. Wall hydrants.
 - 8. Drain valves.
 - 9. Water-hammer arresters.
 - 10. Air vents.
 - 11. Trap-seal primer valves.
 - 12. Specialty valves.
 - 13. Flexible connectors.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
- B. Shop Drawings: For domestic water piping specialties.
 - 1. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For domestic water piping specialties to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR PIPING SPECIALTIES

- A. Potable-water piping and components shall comply with NSF 61 and NSF 14.

2.2 PERFORMANCE REQUIREMENTS

- A. Minimum Working Pressure for Domestic Water Piping Specialties: 150 psig unless otherwise indicated.

2.3 VACUUM BREAKERS

- A. Pipe-Applied, Atmospheric-Type Vacuum Breakers:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ames Fire & Waterworks; a division of Watts Water Technologies, Inc.
 - b. Cash Acme; a division of Reliance Worldwide Corporation.
 - c. Conbraco Industries, Inc.
 - d. FEBCO; a division of Watts Water Technologies, Inc.
 - e. Rain Bird Corporation.
 - f. Toro Company (The); Irrigation Div.
 - g. Watts; a division of Watts Water Technologies, Inc.; Watts Regulator Company.
 - h. Zurn Industries, LLC; Plumbing Products Group; Wilkins Water Control Products.
 - 2. Standard: ASSE 1001.
 - 3. Size: NPS 1/4 to NPS 3, as required to match connected piping.
 - 4. Body: Bronze.

5. Inlet and Outlet Connections: Threaded.
6. Finish: Rough bronze.

2.4 BACKFLOW PREVENTERS

A. Reduced-Pressure-Principle Backflow Preventers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Ames Fire & Waterworks; a division of Watts Water Technologies, Inc.
 - b. Conbraco Industries, Inc.
 - c. FEBCO; a division of Watts Water Technologies, Inc.
 - d. Flomatic Corporation.
 - e. Watts; a division of Watts Water Technologies, Inc.; Watts Regulator Company.
 - f. Zurn Industries, LLC; Plumbing Products Group; Wilkins Water Control Products.
2. Standard: ASSE 1013.
3. Operation: Continuous-pressure applications.
4. Pressure Loss: 12 psi
5. Body: Bronze for NPS 2 and smaller; steel with interior lining that complies with AWWA C550 or that is FDA approved for NPS 2-1/2 and larger.
6. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and larger.
7. Configuration: Designed for horizontal, straight-through flow.
8. Accessories:
 - a. Valves NPS 2 and Smaller: Ball type with threaded ends on inlet and outlet.
 - b. Valves NPS 2-1/2 and Larger: Outside-screw and yoke-gate type with flanged ends on inlet and outlet.
 - c. Air-Gap Fitting: ASME A112.1.2, matching backflow-preventer connection.

2.5 WATER PRESSURE-REDUCING VALVES

A. Water Regulators:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cash Acme; a division of Reliance Worldwide Corporation.
 - b. Conbraco Industries, Inc.
 - c. Honeywell International Inc.
 - d. Watts; a division of Watts Water Technologies, Inc.; Watts Regulator Company.
 - e. Zurn Industries, LLC; Plumbing Products Group; Wilkins Water Control Products.
2. Standard: ASSE 1003.
3. Pressure Rating: Initial working pressure of 150 psig.
4. Body: Bronze for NPS 2 and smaller; cast iron for NPS 2-1/2 and NPS 3.
5. Valves for Booster Heater Water Supply: Include integral bypass.
6. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and NPS 3.

2.6 BALANCING VALVES

A. Memory-Stop Balancing Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Conbraco Industries, Inc.
 - b. Crane Co.; Crane Valve Group; Crane Valves.
 - c. Crane Co.; Crane Valve Group; Jenkins Valves.
 - d. Crane Co.; Crane Valve Group; Stockham Div.
 - e. Hammond Valve.
 - f. Milwaukee Valve Company.
 - g. NIBCO Inc.
 - h. Red-White Valve Corp.
2. Standard: MSS SP-110 for two-piece, copper-alloy ball valves.
3. Pressure Rating: 400-psig minimum CWP.
4. Size: NPS 2 or smaller.
5. Body: Copper alloy.
6. Port: Standard or full port.
7. Ball: Chrome-plated brass.
8. Seats and Seals: Replaceable.
9. End Connections: Solder joint or threaded.
10. Handle: Vinyl-covered steel with memory-setting device.

2.7 TEMPERATURE-ACTUATED, WATER MIXING VALVES

A. Individual-Fixture, Water Tempering Valves:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Cash Acme; a division of Reliance Worldwide Corporation.
 - b. Conbraco Industries, Inc.
 - c. Honeywell International Inc.
 - d. Lawler Manufacturing Company, Inc.
 - e. Leonard Valve Company.
 - f. Powers; a division of Watts Water Technologies, Inc.
 - g. Watts; a division of Watts Water Technologies, Inc.; Watts Regulator Company.
 - h. Zurn Industries, LLC; Plumbing Products Group; Wilkins Water Control Products.
2. Standard: ASSE 1016, thermostatically controlled, water tempering valve.
3. Pressure Rating: 125 psig minimum unless otherwise indicated.
4. Body: Bronze body with corrosion-resistant interior components.
5. Temperature Control: Adjustable.

2.8 STRAINERS FOR DOMESTIC WATER PIPING

A. Y-Pattern Strainers:

1. Pressure Rating: 125 psig minimum unless otherwise indicated.
2. Body: Bronze for NPS 2 and smaller; cast iron with interior lining that complies with AWWA C550 or that is FDA approved, epoxy coated and for NPS 2-1/2 and larger.
3. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and larger.
4. Screen: Stainless steel with round perforations unless otherwise indicated.
5. Perforation Size:
 - a. Strainers NPS 2 and Smaller: 0.020 inch.
 - b. Strainers NPS 2-1/2 to NPS 4: 0.045 inch.
6. Drain: Pipe plug.

2.9 WALL HYDRANTS

A. Nonfreeze Wall Hydrants:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company.
 - b. MIFAB, Inc.
 - c. Prier Products, Inc.
 - d. Smith, Jay R. Mfg. Co.; Division of Smith Industries, Inc.
 - e. Tyler Pipe; Wade Div.
 - f. Watts Drainage Products.
 - g. Woodford Manufacturing Company; a division of WCM Industries, Inc.
 - h. Zurn Industries, LLC; Plumbing Products Group; Light Commercial Products.
 - i. Zurn Industries, LLC; Plumbing Products Group; Specification Drainage Products.
2. Standard: ASME A112.21.3M for concealed-outlet, self-draining wall hydrants.
3. Pressure Rating: 125 psig.
4. Operation: Loose key.
5. Casing and Operating Rod: Of length required to match wall thickness. Include wall clamp.
6. Inlet: NPS 3/4 or NPS 1.
7. Outlet: Concealed, with integral vacuum breaker and garden-hose thread complying with ASME B1.20.7.
8. Box: Deep, flush mounted with cover.
9. Box and Cover Finish: Polished nickel bronze.
10. Operating Keys(s): Two with each wall hydrant.

2.10 DRAIN VALVES

A. Ball-Valve-Type, Hose-End Drain Valves:

1. Standard: MSS SP-110 for standard-port, two-piece ball valves.
2. Pressure Rating: 400-psig minimum CWP.
3. Size: NPS 3/4.
4. Body: Copper alloy.
5. Ball: Chrome-plated brass.
6. Seats and Seals: Replaceable.
7. Handle: Vinyl-covered steel.

8. Inlet: Threaded or solder joint.
9. Outlet: Threaded, short nipple with garden-hose thread complying with ASME B1.20.7 and cap with brass chain.

2.11 WATER-HAMMER ARRESTERS

A. Water-Hammer Arresters:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Josam Company.
 - c. MIFAB, Inc.
 - d. Precision Plumbing Products, Inc.
 - e. Sioux Chief Manufacturing Company, Inc.
 - f. Smith, Jay R. Mfg. Co.; Division of Smith Industries, Inc.
 - g. Tyler Pipe; Wade Div.
 - h. Watts Drainage Products.
 - i. Zurn Industries, LLC; Plumbing Products Group; Specification Drainage Products.
2. Standard: ASSE 1010 or PDI-WH 201.
3. Type: Metal bellows.
4. Size: ASSE 1010, Sizes AA and A through F, or PDI-WH 201, Sizes A through F.

2.12 AIR VENTS

A. Bolted-Construction Automatic Air Vents:

1. Body: Bronze.
2. Pressure Rating and Temperature: 125-psig minimum pressure rating at 140 deg F.
3. Float: Replaceable, corrosion-resistant metal.
4. Mechanism and Seat: Stainless steel.
5. Size: NPS 1/2 minimum inlet.
6. Inlet and Vent Outlet End Connections: Threaded.

2.13 TRAP-SEAL PRIMER DEVICE

A. Supply-Type, Trap-Seal Primer Device:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. MIFAB, Inc.
 - b. Precision Plumbing Products, Inc.
 - c. Sioux Chief Manufacturing Company, Inc.
 - d. Smith, Jay R. Mfg. Co.; Division of Smith Industries, Inc.
 - e. Watts; a division of Watts Water Technologies, Inc.; Watts Regulator Company.
2. Standard: ASSE 1018.

3. Pressure Rating: 125 psig minimum.
4. Body: Bronze.
5. Inlet and Outlet Connections: NPS 1/2 threaded, union, or solder joint.
6. Gravity Drain Outlet Connection: NPS 1/2 threaded or solder joint.
7. Finish: Chrome plated, or rough bronze for units used with pipe or tube that is not chrome finished.

2.14 SPECIALTY VALVES

- A. Comply with requirements for general-duty metal valves in Section 15112 "GENERAL-DUTY VALVES FOR PIPING."

2.15 FLEXIBLE CONNECTORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Flex-Hose Co., Inc.
 2. Flexicraft Industries.
 3. Flex Pression, Ltd.
 4. Flex-Weld Incorporated.
 5. Hyspan Precision Products, Inc.
 6. Mercer Gasket & Shim, Inc.
 7. Metraflex, Inc.
 8. Proco Products, Inc.
 9. TOZEN Corporation.
 10. Unaflex.Universal Metal Hose; a Hyspan company.
- B. Stainless-Steel-Hose Flexible Connectors: Corrugated-stainless-steel tubing with stainless-steel wire-braid covering and ends welded to inner tubing.
 1. Working-Pressure Rating: Minimum 200 psig.
 2. End Connections NPS 2 and Smaller: Threaded steel-pipe nipple.
 3. End Connections NPS 2-1/2 and Larger: Flanged steel nipple.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install backflow preventers in each water supply to mechanical equipment and systems and to other equipment and water systems that may be sources of contamination. Comply with authorities having jurisdiction.
 1. Locate backflow preventers in same room as connected equipment or system.
 2. Install drain for backflow preventers with atmospheric-vent drain connection with air-gap fitting, fixed air-gap fitting, or equivalent positive pipe separation of at least two pipe diameters in drain piping and pipe-to-floor drain. Locate air-gap device attached to or under backflow preventer. Simple air breaks are unacceptable for this application.
 3. Do not install bypass piping around backflow preventers.

- B. Install water regulators with inlet and outlet shutoff valves. Install pressure gages on inlet and outlet.
- C. Install balancing valves in locations where they can easily be adjusted.
- D. Install temperature-actuated, water mixing valves with check stops or shutoff valves on inlets and with shutoff valve on outlet.
 - 1. Install cabinet-type units recessed in or surface mounted on wall as specified.
- E. Install Y-pattern strainers for water on supply side of each water pressure-reducing valve and pump.
- F. Install water-hammer arresters in water piping according to PDI-WH 201.
- G. Install air vents at high points of water piping. Install drain piping and discharge onto floor drain.
- H. Install supply-type, trap-seal primer valves with outlet piping pitched down toward drain trap a minimum of 1 percent, and connect to floor-drain body, trap, or inlet fitting. Adjust valve for proper flow.
- I. Install drainage-type, trap-seal primer valves as lavatory trap with outlet piping pitched down toward drain trap a minimum of 1 percent, and connect to floor-drain body, trap, or inlet fitting.
- J. Install trap-seal primer systems with outlet piping pitched down toward drain trap a minimum of 1 percent, and connect to floor-drain body, trap, or inlet fitting. Adjust system for proper flow.

3.2 CONNECTIONS

- A. Comply with requirements for ground equipment in Section 16060 "GROUNDING AND BONDING."

3.3 LABELING AND IDENTIFYING

- A. Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplate or sign on or near each of the following:
 - 1. Reduced-pressure-principle backflow preventers.
 - 2. Water pressure-reducing valves.
 - 3. Supply-type, trap-seal primer valves.
- B. Distinguish among multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations, in addition to identifying unit. Nameplates and signs are specified in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Test each reduced-pressure-principle backflow preventer according to authorities having jurisdiction and the device's reference standard.

- B. Domestic water piping specialties will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Set field-adjustable pressure set points of water pressure-reducing valves.
- B. Set field-adjustable flow set points of balancing valves.
- C. Set field-adjustable temperature set points of temperature-actuated, water mixing valves.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15150

SANITARY WASTE AND VENT PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15085 – PLUMBING PIPING INSULATION
 - 7. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 8. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 9. Section 15127 – METERS AND GAGES FOR PIPING
 - 10. Section 15155 – SANITARY WASTE PIPING SPECIALTIES
 - 11. Section 15156 – SEWAGE EJECTOR PUMP SYSTEMS

1.2 SUMMARY

- A. Section Includes:
 - 1. Pipe, tube, and fittings.
 - 2. Specialty pipe fittings.

1.3 PERFORMANCE REQUIREMENTS

- A. Components and installation shall withstand the following minimum working pressure unless otherwise indicated:
 - 1. Soil, Waste, and Vent Piping: 10-foot head of water.
 - 2. Waste, Force-Main Piping: 100 psig.
- B. Seismic Performance: Soil, waste, and vent piping and support and installation shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For waste and vent piping, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Detailed description of piping anchorage devices on which the certification is based and their installation requirements.
- B. Field quality-control reports.

1.6 QUALITY ASSURANCE

- A. Piping materials shall bear label, stamp, or other markings of specified testing agency.

1.7 PROJECT CONDITIONS

- A. Interruption of Existing Sanitary Waste Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary service according to requirements indicated:
 - 1. Notify Construction Manager no fewer than 14 days in advance of proposed interruption of sanitary waste service.
 - 2. Do not proceed with interruption of sanitary waste service without Construction Manager's written permission.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

- A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, fitting materials, and joining methods for specific services, service locations, and pipe sizes.

2.2 HUB-AND-SPIGOT, CAST-IRON SOIL PIPE AND FITTINGS

- A. Pipe and Fittings: ASTM A 74, Extra Heavy class underground.
- B. Gaskets: ASTM C 564, rubber.

2.3 HUBLESS, CAST-IRON SOIL PIPE AND FITTINGS

- A. Pipe and Fittings: ASTM A 888 or CISPI 301.

B. Heavy-Duty, Hubless-Piping Couplings:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. ANACO-Husky.
 - b. Clamp-All Corp.
 - c. Dallas Specialty & Mfg. Co.
 - d. MIFAB, Inc.
 - e. Mission Rubber Company; a division of MCP Industries, Inc.
 - f. Stant.
 - g. Tyler Pipe.
2. Standards: ASTM C 1277 and ASTM C 1540.
3. Description: Stainless-steel shield with stainless-steel bands and tightening devices; and ASTM C 564, rubber sleeve with integral, center pipe stop.

2.4 COPPER TUBE AND FITTINGS

- A. Copper Drainage Fittings: ASME B16.23, cast copper or ASME B16.29, wrought copper, solder-joint fittings.
- B. Hard Copper Tube: ASTM B 88, Type L, water tube, drawn temper.
- C. Solder: ASTM B 32, lead free with ASTM B 813, water-flushable flux.

PART 3 - EXECUTION

3.1 EARTH MOVING

- A. Comply with requirements for excavating, trenching, and backfilling specified in Section 02300 "Earthwork."

3.2 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on coordination drawings.
- B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

- E. Install piping to permit valve servicing.
- F. Install piping at indicated slopes.
- G. Install piping free of sags and bends.
- H. Install fittings for changes in direction and branch connections.
- I. Install piping to allow application of insulation.
- J. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- K. Make changes in direction for soil and waste drainage and vent piping using appropriate branches, bends, and long-sweep bends. Sanitary tees and short-sweep 1/4 bends may be used on vertical stacks if change in direction of flow is from horizontal to vertical. Use long-turn, double Y-branch and 1/8- bend fittings if two fixtures are installed back to back or side by side with common drain pipe. Straight tees, elbows, and crosses may be used on vent lines. Do not change direction of flow more than 90 degrees. Use proper size of standard increasers and reducers if pipes of different sizes are connected. Reducing size of drainage piping in direction of flow is prohibited.
- L. Lay buried building drainage piping beginning at low point of each system. Install true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets according to manufacturer's written instructions for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.
- M. Install soil and waste drainage and vent piping at the following minimum slopes unless otherwise indicated:
 - 1. Building Sanitary Drain: 2 percent downward in direction of flow for piping NPS 3 and smaller; 1 percent downward in direction of flow for piping NPS 4 and larger.
 - 2. Horizontal Sanitary Drainage Piping: downward in direction of flow.
 - 3. Vent Piping: down toward vertical fixture vent or toward vent stack.
- N. Install cast-iron soil piping according to CISPI's "Cast Iron Soil Pipe and Fittings Handbook," Chapter IV, "Installation of Cast Iron Soil Pipe and Fittings."
 - 1. Install encasement on underground piping according to ASTM A 674 or AWWA C105/A 21.5.
- O. Install aboveground copper tubing according to CDA's "Copper Tube Handbook."
- P. Install engineered soil and waste drainage and vent piping systems as follows:
 - 1. Combination Waste and Vent: Comply with standards of authorities having jurisdiction.
 - 2. Reduced-Size Venting: Comply with standards of authorities having jurisdiction.
- Q. Install underground, copper, force-main tubing according to CDA's "Copper Tube Handbook."
 - 1. Install encasement on piping according to ASTM A 674 or AWWA C105/A 21.5.
- R. Install force mains at elevations indicated.

S. Plumbing Specialties:

1. Install backwater valves in sanitary waster gravity-flow piping. Comply with requirements for backwater valves specified in Section 15155 "SANITARY WASTE PIPING SPECIALTIES."
 2. Install cleanouts at grade and extend to where building sanitary drains connect to building sanitary sewers in sanitary drainage gravity-flow piping. Install cleanout fitting with closure plug inside the building in sanitary drainage force-main piping. Comply with requirements for cleanouts specified in Section 15155 "SANITARY WASTE PIPING SPECIALTIES."
 3. Install drains in sanitary drainage gravity-flow piping. Comply with requirements for drains specified in Section 15155 "SANITARY WASTE PIPING SPECIALTIES."
- T. Do not enclose, cover, or put piping into operation until it is inspected and approved by authorities having jurisdiction.
- U. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- V. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- W. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 15051 "BASIC MATERIALS AND METHODS FOR PLUMBING WORK."

3.3 JOINT CONSTRUCTION

- A. Join hub-and-spigot, cast-iron soil piping with gasket joints according to CISPI's "Cast Iron Soil Pipe and Fittings Handbook" for compression joints.
- B. Join hubless, cast-iron soil piping according to CISPI 310 and CISPI's "Cast Iron Soil Pipe and Fittings Handbook" for hubless-piping coupling joints.
- C. Flanged Joints: Align bolt holes. Select appropriate gasket material, size, type, and thickness. Install gasket concentrically positioned. Use suitable lubricants on bolt threads. Torque bolts in cross pattern.

3.4 VALVE INSTALLATION

- A. General valve installation requirements are specified in Section 15112 "GENERAL-DUTY VALVES FOR PIPING."
- B. Shutoff Valves:
 1. Install shutoff valve on each sewage pump discharge.
 2. Install full-port ball valve for piping NPS 3 and smaller.
- C. Check Valves: Install swing check valve, between pump and shutoff valve, on each sewage pump discharge.

3.5 HANGER AND SUPPORT INSTALLATION

- A. Comply with requirements for seismic-restraint devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- B. Comply with requirements for pipe hanger and support devices and installation specified in Section 15062 "Hangers and Supports for Piping and Equipment."
 - 1. Install carbon-steel pipe hangers for horizontal piping in noncorrosive environments.
 - 2. Install stainless-steel pipe hangers for horizontal piping in corrosive environments.
 - 3. Install carbon-steel pipe support clamps for vertical piping in noncorrosive environments.
 - 4. Install stainless-steel pipe support clamps for vertical piping in corrosive environments.
 - 5. Vertical Piping: MSS Type 8 or Type 42, clamps.
 - 6. Install individual, straight, horizontal piping runs:
 - a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
 - b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
 - 7. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
 - 8. Base of Vertical Piping: MSS Type 52, spring hangers.
- C. Support horizontal piping and tubing within 12 inches of each fitting, valve, and coupling.
- D. Support vertical piping and tubing at base and at each floor.
- E. Rod diameter may be reduced one size for double-rod hangers, with 3/8-inch minimum rods.
- F. Install hangers for cast-iron soil piping with the following maximum horizontal spacing and minimum rod diameters:
 - 1. NPS 1-1/2 and NPS 2: 60 inches with 3/8-inch rod.
 - 2. NPS 3: 60 inches with 1/2-inch rod.
 - 3. NPS 4 and NPS 5: 60 inches with 5/8-inch rod.
 - 4. NPS 6 and NPS 8: 60 inches with 3/4-inch rod.
 - 5. Spacing for 10-foot lengths may be increased to 10 feet. Spacing for fittings is limited to 60 inches.
- G. Install supports for vertical cast-iron soil piping every 15 feet.
- H. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:
 - 1. NPS 1-1/4: 72 inches with 3/8-inch rod.
 - 2. NPS 1-1/2 and NPS 2: 96 inches with 3/8-inch rod.
 - 3. NPS 2-1/2: 108 inches with 1/2-inch rod.
 - 4. NPS 3 and NPS 5: 10 feet with 1/2-inch rod.
 - 5. NPS 6: 10 feet with 5/8-inch rod.
 - 6. NPS 8: 10 feet with 3/4-inch rod.
- I. Install supports for vertical copper tubing every 10 feet.

3.6 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect soil and waste piping to exterior sanitary sewerage piping. Use transition fitting to join dissimilar piping materials.
- C. Connect drainage and vent piping to the following:
 - 1. Plumbing Fixtures: Connect drainage piping in sizes indicated, but not smaller than required by plumbing code.
 - 2. Plumbing Fixtures and Equipment: Connect atmospheric vent piping in sizes indicated, but not smaller than required by authorities having jurisdiction.
 - 3. Plumbing Specialties: Connect drainage and vent piping in sizes indicated, but not smaller than required by plumbing code.
 - 4. Install test tees (wall cleanouts) in conductors near floor and floor cleanouts with cover flush with floor.
 - 5. Comply with requirements for cleanouts and drains specified in Section 15155 "Sanitary Waste Piping Specialties."
- D. Connect force-main piping to the following:
 - 1. Sanitary Sewer: To exterior force main.
 - 2. Sewage Pump: To sewage pump discharge.
- E. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
- F. Make connections according to the following unless otherwise indicated:
 - 1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
 - 2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.

3.7 IDENTIFICATION

- A. Identify exposed sanitary waste and vent piping. Comply with requirements for identification specified in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

3.8 FIELD QUALITY CONTROL

- A. During installation, notify authorities having jurisdiction at least 24 hours before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction.
 - 1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in and before setting fixtures.
 - 2. Final Inspection: Arrange for final inspection by authorities having jurisdiction to observe tests specified below and to ensure compliance with requirements.

- B. Reinspection: If authorities having jurisdiction find that piping will not pass test or inspection, make required corrections and arrange for reinspection.
- C. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.
- D. Test sanitary drainage and vent piping according to procedures of authorities having jurisdiction or, in absence of published procedures, as follows:
 - 1. Test for leaks and defects in new piping and parts of existing piping that have been altered, extended, or repaired. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 - 2. Leave uncovered and unconcealed new, altered, extended, or replaced drainage and vent piping until it has been tested and approved. Expose work that was covered or concealed before it was tested.
 - 3. Roughing-in Plumbing Test Procedure: Test drainage and vent piping except outside leaders on completion of roughing-in. Close openings in piping system and fill with water to point of overflow, but not less than 10-foot head of water. From 15 minutes before inspection starts to completion of inspection, water level must not drop. Inspect joints for leaks.
 - 4. Finished Plumbing Test Procedure: After plumbing fixtures have been set and traps filled with water, test connections and prove they are gastight and watertight. Plug vent-stack openings on roof and building drains where they leave building. Introduce air into piping system equal to pressure of 1-inch wg. Use U-tube or manometer inserted in trap of water closet to measure this pressure. Air pressure must remain constant without introducing additional air throughout period of inspection. Inspect plumbing fixture connections for gas and water leaks.
 - 5. Repair leaks and defects with new materials and retest piping, or portion thereof, until satisfactory results are obtained.
 - 6. Prepare reports for tests and required corrective action.
- E. Test force-main piping according to procedures of authorities having jurisdiction or, in absence of published procedures, as follows:
 - 1. Leave uncovered and unconcealed new, altered, extended, or replaced force-main piping until it has been tested and approved. Expose work that was covered or concealed before it was tested.
 - 2. Cap and subject piping to static-water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow to stand for four hours. Leaks and loss in test pressure constitute defects that must be repaired.
 - 3. Repair leaks and defects with new materials and retest piping, or portion thereof, until satisfactory results are obtained.
 - 4. Prepare reports for tests and required corrective action.

3.9 CLEANING AND PROTECTION

- A. Clean interior of piping. Remove dirt and debris as work progresses.
- B. Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.
- C. Place plugs in ends of uncompleted piping at end of day and when work stops.

3.10 PIPING SCHEDULE

- A. Flanges and unions may be used on aboveground pressure piping unless otherwise indicated.
- B. Aboveground, soil and waste piping NPS 6 and smaller shall be the following:
 - 1. Service class, cast-iron soil pipe and fittings; gaskets; and gasketed joints.
 - 2. Hubless, cast-iron soil pipe and fittings, stack fittings; heavy-duty hubless-piping couplings; and coupled joints.
 - 3. Copper, copper drainage fittings, and soldered joints.
- C. Underground, soil, waste, and vent piping NPS 6 and smaller shall be the following:
 - 1. Extra Heavy class, cast-iron soil piping; gaskets; and gasketed joints.
- D. Aboveground sanitary-sewage force mains NPS 2-1/2 to NPS 6 shall be the following:
 - 1. Hard copper tube, Type L; copper pressure fittings; and soldered joints.
- E. Underground sanitary-sewage force mains NPS 4 and smaller shall be the following:
 - 1. Hard copper tube, Type L; wrought-copper pressure fittings; and soldered joints.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15155

SANITARY WASTE PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Requirements:
 - 1. Section 02400 - DRAINAGE AND SEWER SYSTEMS
 - 2. Section 03300 – CAST IN PLACE CONCRETE
 - 3. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 4. Section 15058 – COMMON MOTOR REQUIRMENTS FOR EQUIPMENT
 - 5. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 6. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 7. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 8. Section 15084 – PLUMBING EQUIPMENT IDENTIFICATION
 - 9. Section 15085 – PLUMBING PIPING INSULATION
 - 10. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 11. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 12. Section 15156 – SEWAGE EJECTOR PUMP SYSTEMS
 - 13. Section 15165 - STORM DRAINAGE PIPING SPECIALTIES"
 - 14. Section 16060 – GROUNDING AND BONDING

1.2 SUMMARY

- A. Section Includes:
 - 1. Cleanouts.
 - 2. Floor drains.
 - 3. Through-penetration firestop assemblies.
 - 4. Miscellaneous sanitary drainage piping specialties.
 - 5. Flashing materials.
 - 6. Oil interceptors.
 - 7. Solids interceptors.

1.3 DEFINITIONS

- A. ABS: Acrylonitrile-butadiene-styrene plastic.
- B. FOG: Fats, oils, and greases.
- C. FRP: Fiberglass-reinforced plastic.

- D. HDPE: High-density polyethylene plastic.
- E. PE: Polyethylene plastic.
- F. PP: Polypropylene plastic.
- G. PVC: Polyvinyl chloride plastic.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and accessories for the following:
 - 1. Oil interceptors.
- B. Shop Drawings: Show fabrication and installation details for frost-resistant vent terminals.
 - 1. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Manufacturer Seismic Qualification Certification: Submit certification that oil interceptors, accessories, and components will withstand seismic forces defined in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For drainage piping specialties to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. Drainage piping specialties shall bear label, stamp, or other markings of specified testing agency.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Comply with NSF 14, "PLASTICS PIPING COMPONENTS AND RELATED MATERIALS," for plastic sanitary piping specialty components.

1.8 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 03300 "CAST-IN-PLACE CONCRETE."
- B. Coordinate size and location of roof penetrations.

PART 2 - PRODUCTS

2.1 CLEANOUTS

- A. Exposed Metal Cleanouts:
 - 1. ASME A112.36.2M, Cast-Iron Cleanouts:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Josam Company.
 - 2) MIFAB, Inc.
 - 3) Smith, Jay R. Mfg. Co.
 - 4) Tyler Pipe.
 - 5) Watts Drainage Products.
 - 6) Zurn Plumbing Products Group.
 - 2. Standard: ASME A112.36.2M for cast iron for cleanout test tee.
 - 3. Size: Same as connected drainage piping
 - 4. Body Material: Hubless, cast-iron soil pipe test tee as required to match connected piping.
 - 5. Closure: Countersunk or raised-head, cast-iron plug.
 - 6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.
 - 7. Closure: Stainless-steel plug with seal.
- B. Metal Floor Cleanouts:
 - 1. ASME A112.36.2M, Cast-Iron Cleanouts:

a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1) Josam Company.
- 2) Oatey.
- 3) Sioux Chief Manufacturing Co., Inc.
- 4) Smith, Jay R. Mfg. Co.
- 5) Tyler Pipe.
- 6) Watts Drainage Products.
- 7) Zurn Plumbing Products Group.

2. Standard: ASME A112.36.2M for heavy-duty, adjustable housing cleanout.
3. Size: Same as connected branch.
4. Type: Heavy-duty, adjustable housing.
5. Body or Ferrule: Cast iron.
6. Clamping Device: Required.
7. Outlet Connection: Spigot.
8. Closure: Brass plug with tapered threads.
9. Adjustable Housing Material: Cast iron with threads.
10. Frame and Cover Material and Finish: Nickel-bronze, copper alloy.
11. Frame and Cover Shape: Round.
12. Top Loading Classification: Extra Heavy Duty.
13. Riser: ASTM A 74, Extra-Heavy class, cast-iron drainage pipe fitting and riser to cleanout.
14. Standard: ASME A112.3.1.
15. Size: Same as connected branch.
16. Housing: Stainless steel.
17. Closure: Stainless steel with seal.
18. Riser: Stainless-steel drainage pipe fitting to cleanout.

C. Wall Cleanouts

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company; Josam Div.
 - b. MIFAB, Inc.
 - c. Smith, Jay R. Mfg. Co.
 - d. Tyler Pipe; Wade Div.
 - e. Watts Drainage Products.
 - f. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.36.2M. Include wall access.
3. Size: Same as connected drainage piping.
4. Body: Hubless, cast-iron soil pipe test tee as required to match connected piping.
5. Closure: Countersunk or raised-head, drilled-and-threaded brass plug.
6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.
7. Wall Access: Round, deep, chrome-plated bronze cover plate with screw.

2.2 FLOOR DRAINS

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Commercial Enameling Co.
 - b. Josam Company; Josam Div.
 - c. MIFAB, Inc.
 - d. Smith, Jay R. Mfg. Co.
 - e. Watts Drainage Products.
 - f. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.6.3.
3. Pattern: Floor Sanitary drain.
4. Body Material: Gray iron.
5. Seepage Flange: Required.
6. Anchor Flange: Required.
7. Clamping Device: Required.
8. Outlet: Bottom.
9. Sediment Bucket: Refer to drawings
10. Top or Strainer Material: Nickel bronze.
11. Top of Body and Strainer Finish: Nickel bronze.
12. Top Shape: Refer to Drawings.
13. Top Loading Classification: Extra Heavy-Duty.
14. Inlet Fitting: Gray iron, with threaded inlet and threaded or spigot outlet, and trap-seal primer valve connection.
15. Trap Material: Cast iron.
16. Trap Pattern: Deep-seal P-trap.

2.3 THROUGH-PENETRATION FIRESTOP ASSEMBLIES

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. ProSet Systems Inc.
 - b. Hilti .
2. Standard: UL 1479 assembly of sleeve and stack fitting with firestopping plug.
3. Size: Same as connected soil, waste, or vent stack.
4. Sleeve: Molded PVC plastic, of length to match slab thickness and with integral nailing flange on one end for installation in cast-in-place concrete slabs.
5. Stack Fitting: ASTM A 48/A 48M, gray-iron, hubless-pattern, wye branch with neoprene O- ring at base and gray-iron plug in thermal-release harness. Include PVC protective cap for plug.
6. Special Coating: Corrosion resistant on interior of fittings.

2.4 FLASHING MATERIALS

- A. Lead Sheet: ASTM B 749, Type L51121, copper bearing, with the following minimum weights and thicknesses, unless otherwise indicated:

1. General Use: 4.0-lb/sq. ft., 0.0625-inch thickness.
 2. Vent Pipe Flashing: 3.0-lb/sq. ft., 0.0469-inch thickness.
 3. Burning: 6-lb/sq. ft., 0.0938-inch thickness.
- B. Fasteners: Metal compatible with material and substrate being fastened.
- C. Metal Accessories: Sheet metal strips, clamps, anchoring devices, and similar accessory units required for installation; matching or compatible with material being installed.
- D. Solder: ASTM B 32, lead-free alloy.

2.5 OIL INTERCEPTORS

1. Cast-Iron or Steel Oil Interceptors:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Applied Chemical Technology, Incorporated.
 - 2) Josam Company.
 - 3) MIFAB, Inc.
 - 4) Rockford Sanitary Systems, Inc.
 - 5) Schier Products Company.
 - 6) Smith, Jay R. Mfg. Co.
 - 7) Tyler Pipe.
 - 8) Watts Drainage Products.
 - 9) Thermaco-Trapzilla
 - 10) Zurn Plumbing Products Group.
 2. Type: Factory-fabricated interceptor for separating and removing light oil from wastewater.
 3. Body Material: Cast iron or steel.
 4. Exterior Coating: Corrosion-resistant enamel.
 5. Mounting: Recessed, flush with floor.
 6. Flow-Control Fitting: Required.

2.6 SOLIDS INTERCEPTORS

7. Cast-Iron or Steel Solids Interceptors:
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Applied Chemical Technology, Incorporated.
 - 2) Josam Company.
 - 3) MIFAB, Inc.
 - 4) Rockford Sanitary Systems, Inc.
 - 5) Schier Products Company.
 - 6) Smith, Jay R. Mfg. Co.
 - 7) Thermaco-Trapzilla

- 8) Tyler Pipe.
 - 9) Watts Drainage Products.
 - 10) Zurn Plumbing Products Group.
- 8. Type: Factory-fabricated interceptor for separating and removing sand, grit and other heavier-than-water solids from wastewater.
 - 9. Body Material: Cast iron or steel.
 - 10. Exterior Coating: Corrosion-resistant enamel.
 - 11. Mounting: Recessed, flush with floor.
 - 12. Flow-Control Fitting: Required.

2.7 MOTORS

- A. General requirements for motors are specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
 - 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Equipment Mounting:
 - 1. Comply with requirements for vibration isolation and seismic control devices specified in Section 15024 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- B. Install cleanouts in aboveground piping and building drain piping according to the following, unless otherwise indicated:
 - 1. Size same as drainage piping up to NPS 4. Use NPS 4 for larger drainage piping unless larger cleanout is indicated.
 - 2. Locate at each change in direction of piping greater than 45 degrees.
 - 3. Locate at minimum intervals of 50 feet for piping NPS 4 and smaller and 100 feet for larger piping.
 - 4. Locate at base of each vertical soil and waste stack.
- C. For floor cleanouts for piping below floors, install cleanout deck plates with top flush with finished floor.
- D. For cleanouts located in concealed piping, install cleanout wall access covers, of types indicated, with frame and cover flush with finished wall.
- E. Install floor drains at low points of surface areas to be drained. Set grates of drains flush with finished floor, unless otherwise indicated.
 - 1. Position floor drains for easy access and maintenance.
 - 2. Set floor drains below elevation of surrounding finished floor to allow floor drainage. Set

with grates depressed according to the following drainage area radii:

- a. Radius, 30 to 60 Inches: Equivalent to 1 percent slope.
3. Install floor-drain flashing collar or flange so no leakage occurs between drain and adjoining flooring. Maintain integrity of waterproof membranes where penetrated.
 4. Install individual traps for floor drains connected to sanitary building drain, unless otherwise indicated.
- F. Install trench drains at low points of surface areas to be drained. Set grates of drains flush with finished surface, unless otherwise indicated.
 - G. Install flashing fittings on sanitary stack vents and vent stacks that extend through roof.
 - H. Assemble open drain fittings and install with top of hub 1 inch above floor.
 - I. Install deep-seal traps on floor drains and other waste outlets, if indicated.
 - J. Install floor-drain, trap-seal primer fittings on inlet to floor drains that require trap-seal primer connection.
 1. Exception: Fitting may be omitted if trap has trap-seal primer connection.
 - K. Install sleeve flashing device with each riser and stack passing through floors with waterproof membrane.
 - L. Install vent caps on each vent pipe passing through roof.
 - M. Install oil interceptors, including trapping, venting, and flow-control fitting, according to authorities having jurisdiction and with clear space for servicing.
 - N. Install solids interceptors with cleanout immediately downstream from interceptors that do not have integral cleanout on outlet. Install trap on interceptors that do not have integral trap and are connected to sanitary drainage and vent systems.

3.2 CONNECTIONS

- A. Comply with requirements in Section 15150 "SANITARY WASTE AND VENT PIPING" for piping installation requirements. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to equipment to allow service and maintenance.
- C. Oil Interceptors: Connect inlet, outlet, vent, and gravity drawoff piping to unit; flow-control fitting and vent to unit inlet piping; and gravity drawoff and suction piping to oil storage tank.
- D. Ground equipment according to Section 16460 "GROUNDING AND BONDING ."
- E. Connect wiring according to Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

3.3 FLASHING INSTALLATION

- A. Fabricate flashing from single piece unless large pans, sumps, or other drainage shapes are required.
Join flashing according to the following if required:
 - 1. Lead Sheets: Burn joints of lead sheets 6.0-lb/sq. ft., 0.0938-inch thickness or thicker.
Solder joints of lead sheets 4.0-lb/sq. ft., 0.0625-inch thickness or thinner.
- B. Secure flashing into sleeve and specialty clamping ring or device.
- C. Install flashing for piping passing through roofs with counterflashing or commercially made flashing fittings.
- D. Extend flashing up vent pipe passing through roofs and turn down into pipe, or secure flashing into cast-iron sleeve having calking recess.
- E. Fabricate and install flashing and pans, sumps, and other drainage shapes.

3.4 LABELING AND IDENTIFYING

- A. Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplate or sign on or near each of the following:
 - 1. Oil interceptors.
 - 2. Solids interceptors.
- B. Distinguish among multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations, in addition to identifying unit. Nameplates and signs are specified in Section 15077 "IDENTIFICATION FOR PLUMBING PIPING AND EQUIPMENT."

3.5 FIELD QUALITY CONTROL

- A. Tests and Inspections:
 - 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.6 PROTECTION

- A. Protect drains during remainder of construction period to avoid clogging with dirt or debris and to prevent damage from traffic or construction work.
- B. Place plugs in ends of uncompleted piping at end of each day or when work stops.

3.7 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15156

SEWAGE EJECTOR PUMP SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
 - 4. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 5. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 6. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 7. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 8. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 9. Section 15127 – METERS AND GAGES FOR PIPING
 - 10. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 11. Section 15155 – SANITARY WASTE PIPING SPECIALTIES
 - 12. Section 16060 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK

1.2 SUMMARY

- A. Section Includes:
 - 1. Packaged, submersible sewage-pump units.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Wiring Diagrams: For power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For pumps and controls, to include in operation and maintenance manuals.

1.5 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. UL Compliance: Comply with UL 778 for motor-operated water pumps.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Retain shipping flange protective covers and protective coatings during storage.
- B. Protect bearings and couplings against damage.
- C. Comply with pump manufacturer's written rigging instructions for handling.

PART 2 - PRODUCTS

2.1 SEWAGE-PUMP BASINS AND BASIN COVERS

- A. Basins: Factory-fabricated, watertight, cylindrical, basin sump with top flange and sidewall openings for pipe connections.
 - 1. Material: Steel.
 - 2. Reinforcement: Mounting plates for pumps, fittings, guide-rail supports if used, and accessories.
 - 3. Anchor Flange: Same material as or compatible with basin sump, cast in or attached to sump, in location and of size required to anchor basin in concrete slab.
- B. Basin Covers: Fabricate metal cover with openings having gaskets, seals, and bushings; for access to pumps, pump shafts, control rods, discharge piping, vent connections, and power cables.
 - 1. Reinforcement: Steel or cast iron, capable of supporting foot traffic for basins installed in foot-traffic areas.

2.2 PACKAGED, SUBMERSIBLE SEWAGE-PUMP UNITS

- A. Packaged, Submersible, Grinder, Sewage-Pump Units:
 - 1. Products: Subject to compliance with requirements, provide one of the following:
 - a. Barnes; a Crane Pumps & Systems brand; Crane Pumps & Systems.
 - b. Environment One Corporation.
 - c. Goulds Water Technology; a Xylem brand; ITT Corporation.
 - d. Liberty Pumps.
 - e. Pentair Pump Group; Myers.
 - f. Zoeller Company.
 - 2. Description: Factory-assembled and -tested, automatic-operation, basin-mounted, grinder, sewage-pump unit.

3. Pump Type: Submersible, end-suction, single-stage, close-coupled, overhung-impeller centrifugal pump as defined in HI 1.1-1.2 and HI 1.3.
4. Pump Casing: Cast iron.
5. Impeller: Stainless-steel grinder type with shredding ring.
6. Motor: Hermetically sealed, capacitor-start type; with built-in overload protection; and three-conductor, waterproof power cable of length required and with grounding plug and cable-sealing assembly for connection at pump.
7. Control: Manufacturer's standard panel for one pump.
8. Controls: Automatic, with mechanical- or mercury-float switches and alternator.
9. Pump Discharge Piping: Factory or field fabricated, galvanized, ASTM A 53/A 53M, Schedule 40, steel pipe with ASME B16.4, Class 125, gray iron threaded fittings.
10. Basin: Watertight Fiberglass and of size required for pumps, with inlet pipe connection and gastight cover with pump discharge and vent connections.

2.3 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- B. Motors for submersible pumps shall be hermetically sealed.

2.4 RBTPSS SEWAGE EJECTOR PIT ASSEMBLY

- A. Provide a wet pit and valve pit sewage ejector assembly. The pumps shall discharge through the side wall of the wet pit. Provision shall also be made in the side wall for venting and for control and power wires. Furnish a dual leaf weather tight access door for installation in the top slab of the concrete wet pit. Pit sizes and door sizes shall be as shown on the drawings.
- B. The access door shall be dual-leaf with steel frame, diamond steel leaf steel hinges and torsion bars for easy opening. The door and frame shall have a corrosion resistant coating plus required brackets for Quick Disconnect guide rails.
- C. The wet pit shall house the pumps, quick disconnect removal rails and level switches.
- D. The reinforced concrete structure shall be made with a single monolithic pour with 3500 psi concrete with 6" walls and 10" floors. Reinforcement shall include #4 rebar at 6" centers horizontally and vertically. Provide 18" epoxy coating on all interior surfaces. The concrete walls shall be keyed to the base plate.
- E. Link Seals and schedule 40 steel sleeves shall be utilized for all piping and conduit penetrations.
- F. Installation shall include 1.5" crushed stone aggregate, minimum 24" thick all sides at 2'-0" below grade all around pit assembly.

PART 3 - EXECUTION

3.1 EARTHWORK

- A. Excavation and filling are specified in Section 02300 "EARTHWORK."

3.2 EXAMINATION

- A. Examine roughing-in for plumbing piping to verify actual locations of sanitary drainage and vent piping connections before sewage pump installation.

3.3 INSTALLATION

- A. Pump Installation Standards:
 - 1. Comply with HI 1.4 for installation of centrifugal pumps.
- B. Equipment Mounting:
 - 1. Comply with requirements for vibration isolation and seismic control devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- C. Wiring Method: Comply with requirements in Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
- D. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

3.4 CONNECTIONS

- A. Comply with requirements for piping specified in Section 15150 "SANITARY WASTE AND VENT PIPING." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to equipment to allow service and maintenance.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

- C. Tests and Inspections:
 - 1. Perform each visual and mechanical inspection.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Pumps and controls will be considered defective if they do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.6 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.

3.7 ADJUSTING

- A. Adjust pumps to function smoothly, and lubricate as recommended by manufacturer.
- B. Adjust control set points.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain controls and pumps.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15160

STORM DRAINAGE PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. The drawings and general provisions of the Contract, including the General and Supplementary Conditions, all other Contract Terms and Conditions, and all other Technical Provisions apply to the work of this Section.
- B. Related Sections:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 02400 – DRAINAGE AND SEWER SYSTEMS
 - 3. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 4. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 5. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 6. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 7. Section 15085 – PLUMBING PIPING INSULATION
 - 8. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 9. Section 15165 – STORM DRAINAGE PIPING SPECIALTIES

1.2 SUMMARY

- A. Section Includes:
 - 1. Pipe, tube, and fittings.
 - 2. Specialty pipe fittings.

1.3 PERFORMANCE REQUIREMENTS

- A. Components and installation shall be capable of withstanding the following minimum working pressure unless otherwise indicated:
 - 1. Storm Drainage Piping: 10-foot head of water.
- B. Seismic Performance: Storm drainage piping and support and installation shall withstand the effects of earthquake motions determined per ASCE/SEI 7.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For storm drainage piping, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Field quality-control reports.

1.6 QUALITY ASSURANCE

- A. Piping materials shall bear label, stamp, or other markings of specified testing agency.

1.7 PROJECT CONDITIONS

- A. Interruption of Existing Storm-Drainage Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary service per requirements indicated:
 - 1. Notify Construction Manager no fewer than 14 days in advance of proposed interruption of storm-drainage service.
 - 2. Do not proceed with interruption of storm-drainage service without Construction Manager's written permission.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

- A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, fitting materials, and joining methods for specific services, service locations, and pipe sizes.

2.2 HUB-AND-SPIGOT, CAST-IRON SOIL PIPE AND FITTINGS

- A. Pipe and Fittings: ASTM A 74, Extra Heavy classes.
- B. Gaskets: ASTM C 564, rubber.

2.3 HUBLESS, CAST-IRON SOIL PIPE AND FITTINGS

- A. Pipe and Fittings: ASTM A 888 or CISPI 301.
- B. Heavy-Duty, Hubless-Piping Couplings:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. ANACO-Husky.
 - b. Clamp-All Corp.
 - c. Dallas Specialty & Mfg. Co.
 - d. MIFAB, Inc.
 - e. Mission Rubber Company; a division of MCP Industries, Inc.
 - f. Stant.
 - g. Tyler Pipe.
- 2. Standards: ASTM C 1277 and ASTM C 1540.
 - 3. Description: Stainless-steel shield with stainless-steel bands and tightening devices; and ASTM C 564, rubber sleeve with integral, center pipe stop.

2.4 GALVANIZED-STEEL PIPE AND FITTINGS

- A. Galvanized-Steel Pipe: ASTM A 53/A 53M, Type E, Standard Weight. Include square-cut-grooved or threaded ends matching joining method.
- B. Galvanized-Cast-Iron Drainage Fittings: ASME B16.12 threaded.
- C. Steel-Pipe Pressure Fittings:
 - 1. Galvanized-Steel Pipe Nipples: ASTM A 733, made of ASTM A 53/A 53M or ASTM A 106/A 106M, Schedule 40, seamless steel pipe. Include ends matching joining method.
 - 2. Galvanized-Gray-Iron, Threaded Fittings: ASME B16.4, Class 125, standard pattern.

2.5 STAINLESS-STEEL PIPE AND FITTINGS

- A. Pipe and Fittings: 302 SS; ASME A112.3.1, drainage pattern with socket and spigot ends.
- B. Internal Sealing Rings: Elastomeric gaskets shaped to fit socket groove.

PART 3 - EXECUTION

3.1 EARTH MOVING

- A. Comply with requirements for excavating, trenching, and backfilling specified in Section 02300 "Earthwork."

3.2 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations from layout are approved on coordination drawings.

- B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- C. All exposed storm water piping shall be galvanized steel pipe with threaded fittings and painted.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- F. Install piping to permit valve servicing.
- G. Install piping at indicated slopes.
- H. Install piping free of sags and bends.
- I. Install fittings for changes in direction and branch connections.
- J. Install piping to allow application of insulation.
- K. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- L. Make changes in direction for storm drainage piping using appropriate branches, bends, and long-sweep bends. Do not change direction of flow more than 90 degrees. Use proper size of standard increasers and reducers if pipes of different sizes are connected. Reducing size of drainage piping in direction of flow is prohibited.
- M. Lay buried building storm drainage piping beginning at low point of each system. Install true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets per manufacturer's written instructions for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.
- N. Install storm drainage piping at the following minimum slopes unless otherwise indicated:
 - 1. Building Storm Drain: 2 percent downward in direction of flow for piping NPS 3 and smaller; 1 percent downward in direction of flow for piping NPS 4 and larger.
 - 2. Horizontal Storm-Drainage Piping: 2 percent downward in direction of flow.
- O. Install cast-iron soil piping per CISPI's "Cast Iron Soil Pipe and Fittings Handbook," Chapter IV, "Installation of Cast Iron Soil Pipe and Fittings."
 - 1. Install encasement on underground piping per ASTM A 674 or AWWA C105.
- P. Install exposed steel piping per applicable plumbing code.
- Q. Plumbing Specialties:
 - 1. Install cleanouts at grade and extend to where building storm drains connect to building storm sewers in storm drainage gravity-flow piping. Install cleanout fitting with closure plug inside the building in storm drainage force-main piping. Comply with requirements for cleanouts specified in Section 15165 "STORM DRAINAGE PIPING SPECIALTIES."

- R. Do not enclose, cover, or put piping into operation until it is inspected and approved by authorities having jurisdiction.
- S. Install sleeves for piping penetrations of walls, ceilings, and floors.
- T. Install sleeve seals for piping penetrations of concrete walls and slabs.
- U. Install escutcheons for piping penetrations of walls, ceilings, and floors.

3.3 JOINT CONSTRUCTION

- A. Hub-and-Spigot, Cast-Iron Soil Piping Gasketed Joints: Join per CISPI's "Cast Iron Soil Pipe and Fittings Handbook" for compression joints.
- B. Hubless, Cast-Iron Soil Piping Coupled Joints: Join per CISPI 310 and CISPI's "Cast Iron Soil Pipe and Fittings Handbook" for hubless-piping coupling joints.
- C. Threaded Joints: Thread pipe with tapered pipe threads per ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

3.4 HANGER AND SUPPORT INSTALLATION

- A. Comply with requirements for seismic-restraint devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- B. Comply with requirements for pipe hanger and support devices and installation specified in Section 15062 "HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT."
 - 1. Install carbon-steel pipe hangers for horizontal piping in noncorrosive environments.
 - 2. Install carbon-steel pipe support clamps for vertical piping in noncorrosive environments.
 - 3. Install stainless-steel pipe support clamps for vertical piping in corrosive environments.
 - 4. Vertical Piping: MSS Type 8 or Type 42, clamps.
 - 5. Individual, Straight, Horizontal Piping Runs:
 - a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
 - b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
 - 6. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
 - 7. Base of Vertical Piping: MSS Type 52, spring hangers.
- C. Support horizontal piping and tubing within 12 inches of each fitting and coupling.
- D. Support vertical piping and tubing at base and at each floor.

- E. Rod diameter may be reduced one size for double-rod hangers, with 3/8-inch minimum rods.
- F. Install hangers for cast-iron soil piping with the following maximum horizontal spacing and minimum rod diameters:
 - 1. NPS 1-1/2 and NPS 2: 60 inches with 3/8-inch rod.
 - 2. NPS 3: 60 inches with 1/2-inch rod.
 - 3. NPS 4 and NPS 5: 60 inches with 5/8-inch rod.
 - 4. NPS 6 and NPS 8: 60 inches with 3/4-inch rod.
 - 5. NPS 10 and NPS 12: 60 inches with 7/8-inch rod.
 - 6. Spacing for 10-foot pipe lengths may be increased to 10 feet. Spacing for fittings is limited to 60 inches.
- G. Install supports for vertical cast-iron soil piping every 15 feet.
- H. Install hangers for steel piping with the following maximum horizontal spacing and minimum rod diameters:
 - 1. NPS 1-1/4: 84 inches with 3/8-inch rod.
 - 2. NPS 1-1/2: 108 inches with 3/8-inch rod.
 - 3. NPS 2: 10 feet with 3/8-inch rod.
 - 4. NPS 2-1/2: 11 feet with 1/2-inch rod.
 - 5. NPS 3: 12 feet with 1/2-inch rod.
 - 6. NPS 4 and NPS 5: 12 feet with 5/8-inch rod.
 - 7. NPS 6 and NPS 8: 12 feet with 3/4-inch rod.
 - 8. NPS 10 and NPS 12: 12 feet with 7/8-inch rod.
- I. Install supports for vertical steel piping every 15 feet.

3.5 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect interior storm drainage piping to exterior storm drainage piping. Use transition fitting to join dissimilar piping materials.
- C. Connect storm drainage piping to roof drains and storm drainage specialties.
 - 1. Install test tees (wall cleanouts) in conductors near floor, and floor cleanouts with cover flush with floor.
 - 2. Comply with requirements for cleanouts and drains specified in Section 15165 "STORM DRAINAGE PIPING SPECIALTIES."
- D. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.

3.6 IDENTIFICATION

- A. Identify exposed storm drainage piping. Comply with requirements for identification specified in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

3.7 FIELD QUALITY CONTROL

- A. During installation, notify authorities having jurisdiction at least 24 hours before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction.
 - 1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in.
 - 2. Final Inspection: Arrange for final inspection by authorities having jurisdiction to observe tests specified below and to ensure compliance with requirements.
- B. Reinspection: If authorities having jurisdiction find that piping will not pass test or inspection, make required corrections and arrange for reinspection.
- C. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.
- D. Test storm drainage piping per procedures of authorities having jurisdiction or, in absence of published procedures, as follows:
 - 1. Test for leaks and defects in new piping and parts of existing piping that have been altered, extended, or repaired. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 - 2. Leave uncovered and unconcealed new, altered, extended, or replaced storm drainage piping until it has been tested and approved. Expose work that was covered or concealed before it was tested.
 - 3. Test Procedure: Test storm drainage piping on completion of roughing-in. Close openings in piping system and fill with water to point of overflow, but not less than 10-foot head of water. From 15 minutes before inspection starts until completion of inspection, water level must not drop. Inspect joints for leaks.
 - 4. Repair leaks and defects with new materials and retest piping, or portion thereof, until satisfactory results are obtained.
 - 5. Prepare reports for tests and required corrective action.
- E. Test force-main piping per procedures of authorities having jurisdiction or, in absence of published procedures, as follows:
 - 1. Leave uncovered and unconcealed new, altered, extended, or replaced force-main piping until it has been tested and approved. Expose work that was covered or concealed before it was tested.
 - 2. Cap and subject piping to static-water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow to stand for four hours. Leaks and loss in test pressure constitute defects that must be repaired.
 - 3. Repair leaks and defects with new materials and retest piping, or portion thereof, until satisfactory results are obtained.
 - 4. Prepare reports for tests and required corrective action.

3.8 CLEANING

- A. Clean interior of piping. Remove dirt and debris as work progresses.
- B. Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.
- C. Place plugs in ends of uncompleted piping at end of day and when work stops.

3.9 PIPING SCHEDULE

- A. Aboveground storm drainage piping NPS 8 and smaller shall be the following:
 - 1. Service class, cast-iron soil pipe and fittings; gaskets; and gasketed joints.
 - 2. Hubless, cast-iron soil pipe and fittings; heavy-duty, hubless-piping couplings; and coupled joints.
 - 3. Exposed to Public View on platforms, concourses and Head Houses - Stainless Steel pipe, drainage fittings, and threaded joints.
- B. Underground storm drainage piping NPS 10 and smaller shall be the following:
 - 1. Extra Heavy class, cast-iron soil pipe and fittings; gaskets; and gasketed joints.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

**SECTION 15165
STORM DRAINAGE PIPING SPECIALTIES**

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Section:
 - 1. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15085 – PLUMBING PIPING INSULATION
 - 6. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 7. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 8. Section 15160 – STORM DRAINAGE PIPING

1.2 SUMMARY

- A. Section Includes:
 - 1. Roof drains.
 - 2. Cleanouts.
 - 3. Trench drains.
 - 4. Through-penetration firestop assemblies.
 - 5. Flashing materials.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.

1.4 QUALITY ASSURANCE

- A. Drainage piping specialties shall bear label, stamp, or other markings of specified testing agency.

PART 2 - PRODUCTS

2.1 METAL ROOF DRAINS

- A. Cast-Iron, Large-Sump, Special-Purpose Roof Drains:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company.
 - b. Marathon Roofing Products.
 - c. MIFAB, Inc.
 - d. Smith, Jay R. Mfg. Co.
 - e. Tyler Pipe.
 - f. Watts Water Technologies, Inc.
 - g. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.6.4, for general-purpose roof drains.
3. Body Material: Cast iron.
4. Dimension of Body: Nominal 15-inch diameter.
5. Combination Flashing Ring and Gravel Stop: Required.
6. Flow-Control Weirs: Not required.
7. Outlet: Bottom.
8. Extension Collars: Required.
9. Underdeck Clamp: Required.
10. Expansion Joint: Not required.
11. Sump Receiver Plate: Required.
12. Dome Material: Cast iron.
13. Vandal-Proof Dome: Required.

2.2 CLEANOUTS

A. Floor Cleanouts:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company.
 - b. Oatey.
 - c. Sioux Chief Manufacturing Company, Inc.
 - d. Smith, Jay R. Mfg. Co.
 - e. Tyler Pipe.
 - f. Watts Water Technologies, Inc.
 - g. Zurn Plumbing Products Group; Light Commercial Products Operation.
 - h. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.36.2M for heavy-duty, adjustable housing cleanout.
3. Size: Same as connected branch.
4. Type: Heavy-duty, adjustable housing.
5. Body or Ferrule: Cast iron.
6. Clamping Device: Required.
7. Outlet Connection: Spigot.
8. Closure: Brass plug with tapered threads.
9. Adjustable Housing Material: Cast iron with threads.
10. Frame and Cover Material and Finish: Nickel-bronze, copper alloy.
11. Frame and Cover Shape: Round.

12. Top Loading Classification: Extra Heavy Duty.
13. Riser: ASTM A 74, Extra-Heavy class, cast-iron drainage pipe fitting and riser to cleanout.
14. Standard: ASME A112.3.1.
15. Size: Same as connected branch.
16. Housing: Stainless steel.
17. Closure: Stainless steel with seal.

B. Test Tees:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company.
 - b. MIFAB, Inc.
 - c. Smith, Jay R. Mfg. Co.
 - d. Tyler Pipe.
 - e. Watts Water Technologies, Inc.
 - f. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.36.2M and ASTM A 74, ASTM A 888, or CISPI 301, for cleanout test tees.
3. Size: Same as connected drainage piping.
4. Body Material: Hub-and-spigot, cast-iron soil-pipe T-branch or hubless, cast-iron soil-pipe test tee as required to match connected piping.
5. Closure Plug: Countersunk or raised head.
6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.

C. Wall Cleanouts:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company.
 - b. MIFAB, Inc.
 - c. Smith, Jay R. Mfg. Co.
 - d. Tyler Pipe.
 - e. Watts Water Technologies, Inc.
 - f. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.36.2M. Include wall access.
3. Size: Same as connected drainage piping.
4. Body: Hubless, cast-iron soil pipe test tee as required to match connected piping.
5. Closure: Countersunk or raised-head, drilled-and-threaded brass plug.
6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.
7. Wall Access: Round, deep, chrome-plated bronze cover plate with screw.

2.3 TRENCH DRAINS

A. Trench Drains:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Josam Company.
 - b. MIFAB, Inc.
 - c. Smith, Jay R. Mfg. Co.
 - d. Tyler Pipe.
 - e. Watts Water Technologies, Inc.
 - f. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.6.3, for trench drains.
3. Body Material: Cast iron.
4. Flange: Anchor with weep holes.
5. Clamping Device: Required.
6. Outlet: End.
7. Grate Material: Ductile iron or gray iron.
8. Grate Finish: Painted.
9. Top-Loading Classification: Extra-Heavy Duty.

2.4 THROUGH-PENETRATION FIRESTOP ASSEMBLIES

A. Through-Penetration Firestop Assemblies:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. ProSet Systems Inc.
 - b. Hilti
2. Standard: ASTM E 814, for through-penetration firestop assemblies.
3. Certification and Listing: Insert testing agency acceptable to authorities having jurisdiction for through-penetration firestop assemblies.
4. Size: Same as connected pipe.
5. Sleeve: Molded PVC plastic, of length to match slab thickness and with integral nailing flange on one end for installation in cast-in-place concrete slabs.
6. Stack Fitting: ASTM A 48/A 48M, gray-iron, hubless-pattern, wye branch with neoprene O-ring at base and gray-iron plug in thermal-release harness. Include PVC protective cap for plug.

2.5 FLASHING MATERIALS

- A. Zinc-Coated Steel Sheet: ASTM A 653/A 653M, with 0.20 percent copper content and 0.04-inch minimum thickness unless otherwise indicated. Include G90 hot-dip galvanized, mill-phosphatized finish for painting if indicated.
- B. Fasteners: Metal compatible with material and substrate being fastened.
- C. Metal Accessories: Sheet metal strips, clamps, anchoring devices, and similar accessory units required for installation; matching or compatible with material being installed.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install roof drains at low points of roof areas according to roof membrane manufacturer's written installation instructions.
 - 1. Install flashing collar or flange of roof drain to prevent leakage between drain and adjoining roofing. Maintain integrity of waterproof membranes where penetrated.
 - 2. Install expansion joints, if indicated, in roof drain outlets.
 - 3. Position roof drains for easy access and maintenance.
- B. Install cleanouts in aboveground piping and building drain piping according to the following instructions unless otherwise indicated:
 - 1. Use cleanouts the same size as drainage piping up to NPS 4. Use NPS 4 for larger drainage piping unless larger cleanout is indicated.
 - 2. Locate cleanouts at each change in direction of piping greater than 45 degrees.
 - 3. Locate cleanouts at minimum intervals of 50 feet for piping NPS 4 and smaller and 100 feet for larger piping.
 - 4. Locate cleanouts at base of each vertical stack.
- C. For floor cleanouts for piping below floors, install cleanout deck plates with top flush with finished floor.
- D. For cleanouts located in concealed piping, install cleanout wall access covers, of types indicated, with frame and cover flush with finished wall.
- E. Install test tees in vertical conductors and near floor.
- F. Install wall cleanouts in vertical conductors. Install access door in wall if indicated.
- G. Install sleeve flashing device with each conductor passing through floors with waterproof membrane.

3.2 CONNECTIONS

- A. Comply with requirements for piping specified in Section 15160 "Storm Drainage Piping." Drawings indicate general arrangement of piping, fittings, and specialties.

3.3 FLASHING INSTALLATION

- A. Fabricate flashing from single piece of metal unless large pans, sumps, or other drainage shapes are required. Join flashing according to the following if required:
 - 1. Lead Sheets: Burn joints of 6.0-lb/sq. ft. lead sheets, 0.0938-inch thickness or thicker.
Solder joints of 4.0-lb/sq. ft. lead sheets, 0.0625-inch thickness or thinner.

3.4 PROTECTION

- A. Protect drains during remainder of construction period to avoid clogging with dirt or debris and to prevent damage from traffic or construction work.
- B. Place plugs in ends of uncompleted piping at end of each day or when work stops.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15179

HYDRONIC PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes special-duty valves and specialties for the following:
 - 1. Hot-water heating piping.
 - 2. Condenser-water piping.
 - 3. Makeup-water piping.
 - 4. Air-vent piping.
 - 5. Safety-valve-inlet and -outlet piping.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
 - 1. Valves: Include flow and pressure drop curves based on manufacturer's testing for calibrated-orifice balancing valves and automatic flow-control valves.
 - 2. Air-control devices.
 - 3. Hydronic specialties.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-control devices, hydronic specialties, and special-duty valves to include in emergency, operation, and maintenance manuals.

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Differential Pressure Meter: For each type of balancing valve and automatic flow control valve, include flowmeter, probes, hoses, flow charts, and carrying case.

1.6 QUALITY ASSURANCE

- A. Pipe Welding: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code: Section IX.

1. Safety valves and pressure vessels shall bear the appropriate ASME label. Fabricate and stamp air separators and expansion tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Hydronic piping components and installation shall withstand the following minimum working pressure and temperature unless otherwise indicated:
 1. Hot-Water Heating Piping: 100 psig at 200 deg F.
 2. Condenser-Water Piping: 90 psig at 150 deg F.
 3. Makeup-Water Piping: 80 psig at 150 deg F.
 4. Air-Vent Piping: 200 deg F.
 5. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 VALVES

- A. Gate, Globe, Check, Ball, and Butterfly Valves: Comply with requirements specified in Section 15112 GENERAL-DUTY VALVES FOR HVAC PIPING.
- B. Automatic Temperature-Control Valves, Actuators, and Sensors: Comply with requirements specified in Section 15900 HVAC INSTRUMENTATION AND CONTROLS.
- C. Bronze, Calibrated-Orifice, Balancing Valves:
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Armstrong Pumps, Inc.
 - b. Bell & Gossett Domestic Pump.
 - c. Taco.
 - d. Tour & Andersson; available through Victaulic Company.
 2. Body: Bronze, ball or plug type with calibrated orifice or Venturi.
 3. Ball: Brass or stainless steel.
 4. Plug: Resin.
 5. Seat: PTFE.
 6. End Connections: Threaded or socket.
 7. Pressure Gage Connections: Integral seals for portable differential pressure meter.
 8. Handle Style: Lever, with memory stop to retain set position.
 9. CWP Rating: Minimum 125 psig.
 10. Maximum Operating Temperature: 250 deg F.
- D. Cast-Iron or Steel, Calibrated-Orifice, Balancing Valves:
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Armstrong Pumps, Inc.
 - b. Bell & Gossett Domestic Pump.
 - c. Taco.
 - d. Tour & Andersson.
2. Body: Cast-iron or steel body, ball, plug, or globe pattern with calibrated orifice or venturi.
 3. Ball: Brass or stainless steel.
 4. Stem Seals: EPDM O-rings.
 5. Disc: Glass and carbon-filled PTFE.
 6. Seat: PTFE.
 7. End Connections: Flanged or grooved.
 8. Pressure Gage Connections: Integral seals for portable differential pressure meter.
 9. Handle Style: Lever, with memory stop to retain set position.
 10. CWP Rating: Minimum 125 psig.
 11. Maximum Operating Temperature: 250 deg F.
- E. Diaphragm-Operated, Pressure-Reducing Valves: ASME labeled.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Conbraco Industries, Inc.
 - e. Spence Engineering Company, Inc.
 - f. Watts Regulator Co.
 2. Body: Bronze or brass.
 3. Disc: Glass and carbon-filled PTFE.
 4. Seat: Brass.
 5. Stem Seals: EPDM O-rings.
 6. Diaphragm: EPT.
 7. Low inlet-pressure check valve.
 8. Inlet Strainer: stainless steel, removable without system shutdown.
 9. Valve Seat and Stem: Noncorrosive.
 10. Valve Size, Capacity, and Operating Pressure: Selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.
- F. Diaphragm-Operated Safety Valves: ASME labeled.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Conbraco Industries, Inc.
 - e. Spence Engineering Company, Inc.
 - f. Watts Regulator Co.
 2. Body: Bronze or brass.
 3. Disc: Glass and carbon-filled PTFE.

4. Seat: Brass.
5. Stem Seals: EPDM O-rings.
6. Diaphragm: EPT.
7. Wetted, Internal Work Parts: Brass and rubber.
8. Inlet Strainer: Removable without system shutdown.
9. Valve Seat and Stem: Noncorrosive.
10. Valve Size, Capacity, and Operating Pressure: Comply with ASME Boiler and Pressure Vessel Code: Section IV, and selected to suit system in which installed, with operating pressure and capacity factory set and field adjustable.

2.3 AIR-CONTROL DEVICES

A. Manual Air Vents:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Nexus Valve, Inc.
 - e. Taco, Inc.
2. Body: Bronze.
3. Internal Parts: Nonferrous.
4. Operator: Screwdriver or thumbscrew.
5. Inlet Connection: NPS 1/2 (DN 15).
6. Discharge Connection: NPS 1/8 (DN 6).
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 225 deg F.

B. Automatic Air Vents:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Nexus Valve, Inc.
 - e. Taco, Inc.
2. Body: Bronze or cast iron.
3. Internal Parts: Nonferrous.
4. Operator: Noncorrosive metal float.
5. Inlet Connection: NPS 1/2 (DN 15).
6. Discharge Connection: NPS 1/4 (DN 8).
7. CWP Rating: 150 psig.
8. Maximum Operating Temperature: 240 deg F.

C. Bladder-Type Expansion Tanks:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Taco, Inc.
2. Tank: Welded steel, rated for 125-psig working pressure and 375 deg F. maximum operating temperature. Factory test after taps are fabricated and supports installed and are labeled according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Bladder: Securely sealed into tank to separate air charge from system water to maintain required expansion capacity.
4. Air-Charge Fittings: Schrader valve, stainless steel with EPDM seats.

D. Tangential and In-Line Type Air/Dirt Separators:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Spirovent, Inc.
 - e. Taco, Inc.
2. Tank: Welded steel; ASME constructed and labeled for 125-psig minimum working pressure and 375 deg F. maximum operating temperature.
3. Air Collector Tube for tangential types: Perforated stainless steel, constructed to direct released air into atmosphere via an air vent.
4. Microbubble Resorber Array for in-line types: Bronze or stainless steel wound bristle brush, stainless steel pall rings, or similar high-surface contact area matrix, designed to collect air out of moving solution, all to be vented from the vessel.
5. Tangential Inlet and Outlet Connections: Threaded for NPS 2 and smaller; flanged connections for NPS 2-1/2 (DN 65) and larger.
6. Blowdown Connection: Threaded, with full-port ball valve.
7. Size: Match system flow capacity.

E. Air Purgers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL, Inc.
 - b. Armstrong Pumps, Inc.
 - c. Bell & Gossett Domestic Pump.
 - d. Taco, Inc.
2. Body: Cast iron with internal baffles that slow the water velocity to separate the air from solution and divert it to the vent for quick removal.
3. Maximum Working Pressure: 150 psig.
4. Maximum Operating Temperature: 250 deg F.

2.4 HYDRONIC PIPING SPECIALTIES

A. Y-Pattern Strainers:

1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: Stainless-steel, 60-mesh strainer, or perforated stainless-steel basket.
4. CWP Rating: 125 psig).

B. Basket Strainers:

1. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
3. Strainer Screen: 60-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
4. CWP Rating: 125 psig.

C. Stainless-Steel Bellow, Flexible Connectors:

1. Body: Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
2. End Connections: Threaded or flanged to match equipment connected.
3. Performance: Capable of 3/4-inch misalignment.
4. CWP Rating: 150 psig.
5. Maximum Operating Temperature: 250 deg F.

D. Expansion Fittings: Comply with requirements in Section 15124 EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING.

PART 3 - EXECUTION

3.1 VALVE APPLICATIONS

- A. Install shutoff-duty valves at each branch connection to supply mains and at supply connection to each piece of equipment.
- B. Install calibrated-orifice, balancing valves at each branch connection to return main.
- C. Install calibrated-orifice, balancing valves in the return pipe of each heating or cooling terminal.
- D. Install check valves at each pump discharge and elsewhere as required to control flow direction.
- E. Install safety valves at hot-water generators and elsewhere as required by ASME Boiler and Pressure Vessel Code. Install drip-pan elbow on safety-valve outlet and pipe without valves to the outdoors; pipe drain to nearest floor drain or as indicated on Drawings. Comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, for installation requirements. Provide multiple safety relief valves in parallel to meet required relief capacity. Pipe individually in parallel without reduction or restriction in size. Terminate ends with a 45 degree cut-off.
- F. Install pressure-reducing valves at makeup-water connection to regulate system fill pressure.

3.2 HYDRONIC SPECIALTIES INSTALLATION

- A. Install manual air vents at high points in piping, at heat-transfer coils, and elsewhere as required for system air venting.
- B. Install automatic air vents at high points of system piping in mechanical equipment rooms only. Install manual vents at heat-transfer coils and elsewhere as required for air venting. Provide vent outlet piping without dips or traps, conducted to nearest floor drain or receptor.
- C. Install piping from boiler air outlet, air separator, or air purger to a high-capacity main air vent.
- D. Install tangential or inline air/dirt separator in main piping to pump suction. Install blowdown piping with gate or full-port ball valve; extend full size to nearest floor drain.
- E. Install expansion tanks on the floor. Vent and purge air from hydronic system, and ensure that tank is properly charged with air to suit system Project requirements.
 - 1. Install tank fittings that are shipped loose.
 - 2. Support tank from floor or structure above with sufficient strength to carry weight of tank, piping connections, fittings, plus tank full of water. Do not overload building components and structural members.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15181
HYDRONIC PIPING
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes pipe and fitting materials and joining methods for the following:
1. Hot-water heating piping.
 2. Makeup-water piping.
 3. Condensate-drain piping.
 4. Air-vent piping.
 5. Safety-valve-inlet and -outlet piping.
- B. Related sections:
1. Section 15179 – HYDRONIC PIPING SPECIALTIES
 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 3. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 4. Section 15088 – HVAC PIPING INSULATION
 5. Section 15112 – GENERAL DUTY VALVES FOR HVAC PIPING
 6. Section 15127 – METERS AND GAGES FOR PIPING
 7. Section 15188 – WATER TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
1. RTRP and RTRF with adhesive.
 2. Pressure-seal fittings.
 3. Chemical treatment.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Piping layout, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Suspended ceiling components.
 2. Other building services.
 3. Structural members.

- B. Qualification Data: For Installer.
- C. Welding certificates.
- D. Field quality-control reports.

1.5 QUALITY ASSURANCE

- A. Steel Support Welding: Qualify procedures and personnel per AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding: Qualify procedures and operators per ASME Boiler and Pressure Vessel Code: Section IX.
 - 1. Comply with ASME B31.9, "Building Services Piping," for materials, products, and installation.
 - 2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Hydronic piping components and installation shall withstand the following minimum working pressure and temperature unless otherwise indicated:
 - 1. Hot-Water Heating Piping: 100 psig at 200 deg F.
 - 2. Makeup Water Piping: 80 psig at 150 deg.
 - 3. Condensate-Drain Piping: 150 deg F.
 - 4. Air-Vent Piping: 200 deg F.
 - 5. Safety-Valve-Inlet and -Outlet Piping: Equal to the pressure of the piping system to which it is attached.

2.2 COPPER TUBE AND FITTINGS

- A. Drawn-Temper Copper Tubing: ASTM B 88, Type L.
- B. Wrought-Copper Unions: ASME B16.22.

2.3 STEEL PIPE AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; welded and seamless, Grade B, and wall thickness as indicated in "Piping Applications" Article.
- B. Malleable-Iron Threaded Fittings: ASME B16.3, Classes 150 and 300 as indicated in "Piping Applications" Article.

- C. Malleable-Iron Unions: ASME B16.39; Classes 150, 250, and 300 as indicated in "Piping Applications" Article.
- D. Wrought-Steel Fittings: ASTM A 234/A 234M, wall thickness to match adjoining pipe.
- E. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - 1. Material Group: 1.1.
 - 2. End Connections: Butt welding.
 - 3. Facings: Raised face.

2.4 JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
 - 1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless otherwise indicated.
 - a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
- B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.
- D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux per ASTM B 813.
- E. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for joining copper with copper; or BAg-1, silver alloy for joining copper with bronze or steel.
- F. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.5 DIELECTRIC FITTINGS

- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.
- B. Dielectric Unions:
 - 1. Dielectric unions will not be acceptable. At a minimum use bronze ball valves.
 - 2. Refer to Section 15112 – GENERAL DUTY VALVES FOR HVAC PIPING
- C. Dielectric Flanges:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by the following:
 - a. Capitol Manufacturing Company.
 - b. Central Plastics Company.
 - c. Matco-Norca.

- d. Watts Regulator Co.
 - e. Zurn Industries, LLC; AquaSpec Commercial Faucet Products.
2. Description:
- a. Standard: ASSE 1079.
 - b. Factory-fabricated, bolted, companion-flange assembly.
 - c. Pressure Rating: 150 psig.
 - d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.
- D. Dielectric-Flange Insulating Kits:
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Advance Products & Systems, Inc.
 - b. Calpico, Inc.
 - c. Central Plastics Company.
 - d. Pipeline Seal and Insulator, Inc.
 - 2. Description:
 - a. Nonconducting materials for field assembly of companion flanges.
 - b. Pressure Rating: 150 psig.
 - c. Gasket: Neoprene or phenolic.
 - d. Bolt Sleeves: Phenolic or polyethylene.
 - e. Washers: Phenolic with steel backing washers.
 - 3. Dielectric Nipples:
 - 4. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Elster Perfection.
 - b. Grinnell Mechanical Products.
 - c. Matco-Norca.
 - d. Precision Plumbing Products, Inc.
 - e. Victaulic Company.
 - 5. Description:
 - a. Standard: IAPMO PS 66.
 - b. Electroplated steel nipple, complying with ASTM F 1545.
 - c. Pressure Rating: 300 psig at 225 deg F.
 - d. End Connections: Male threaded or grooved.
 - e. Lining: Inert and noncorrosive, propylene.

2.6 BYPASS CHEMICAL FILTER FEEDER

- A. Description: Welded steel construction; 125-psig working pressure; 5-gal. capacity; with fill funnel and inlet, outlet, and drain valves, stainless steel internal basket with a selection of spun inorganic fiber filters ranging from 50 microns to 1 micron. A selection of not less than two (2) filters at 50, 25, 10 and 5 microns shall be provided for each feeder.

1. Chemicals: Specially formulated, based on analysis of makeup water, to prevent accumulation of scale and corrosion in piping and connected equipment.
2. Refer to Section 15188 – WATER TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

- A. Hot-water heating piping, aboveground, NPS 2 and smaller, shall be of the following:
 1. Type L drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
- B. Hot-water heating piping, aboveground, NPS 2-1/2 and larger, shall be the following:
 1. Schedule 40 steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.
- C. Makeup-water piping installed aboveground shall be the following:
 1. Type L drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
- D. Condensate-Drain Piping: Type L, drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
- E. Air-Vent Piping:
 1. Inlet: Same as service where installed.
 2. Outlet: Type K annealed-temper copper tubing with soldered or flared joints.
- F. Safety-Valve-Inlet and -Outlet Piping for Hot-Water Piping: Same materials and joining methods as for piping specified for the service in which safety valve is installed with metal-to-plastic transition fittings for plastic piping systems per piping manufacturer's written instructions.

3.2 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- E. Install piping to permit valve servicing.
- F. Install piping at indicated slopes.
- G. Install piping free of sags and bends.

- H. Install fittings for changes in direction and branch connections.
- I. Install piping to allow application of insulation.
- J. Select system components with pressure rating equal to or greater than system operating pressure.
- K. Install groups of pipes parallel to each other, spaced to permit applying insulation and servicing of valves.
- L. Install drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 nipple with threaded cap, at low points in piping system mains and elsewhere as required for system drainage.
- M. Install piping at a uniform grade of 0.2 percent upward in direction of flow.
- N. Reduce pipe sizes using eccentric reducer fitting installed with level side up.
- O. Install branch connections to mains using tee fittings in main pipe, with the branch connected to the bottom of the main pipe. For up-feed risers, connect the branch to the top of the main pipe.
- P. Install valves per Section 15112 "GENERAL-DUTY VALVES FOR HVAC PIPING."
- Q. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.
- R. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated.
- S. Install shutoff valve immediately upstream of each dielectric fitting.
- T. Comply with requirements in Section 15124 "EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING" for installation of expansion loops, expansion joints, anchors, and pipe alignment guides.
- U. Comply with requirements in Section 15077 "IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT" for identifying piping.
- V. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR HVAC PIPING."
- W. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR HVAC PIPING."
- X. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 15098 "ESCUTCHEONS FOR HVAC PIPING."

3.3 DIELECTRIC FITTING INSTALLATION

- A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.
- B. Dielectric Fittings for NPS 2 and Smaller: Use bronze ball valve.
- C. Dielectric Fittings for NPS 2-1/2 and larger: Use dielectric flange kits.

3.4 HANGERS AND SUPPORTS

- A. Comply with requirements in Section 15062 "HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT" for hanger, support, and anchor devices. Comply with the following requirements for maximum spacing of supports.
- B. Comply with requirements in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR HVAC" for seismic restraints.
- C. Install the following pipe attachments:
 - 1. Adjustable steel clevis hangers for individual horizontal piping less than 20 feet long.
 - 2. Adjustable roller hangers and spring hangers for individual horizontal piping 20 feet or longer.
 - 3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
 - 4. Spring hangers to support vertical runs.
 - 5. Provide copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
- D. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:
 - 1. NPS 3/4: Maximum span, 7 feet
 - 2. NPS 1 : Maximum span, 7 feet.
 - 3. NPS 1-1/2 : Maximum span, 9 feet.
 - 4. NPS 2: : Maximum span, 10 feet.
 - 5. NPS 2-1/2: Maximum span, 11 feet.
 - 6. NPS 3: and Larger: Maximum span, 12 feet.
- E. Install hangers for drawn-temper copper piping with the following maximum spacing and minimum rod sizes:
 - 1. NPS 3/4 (DN 20): Maximum span, 5 feet (1.5 m); minimum rod size, 1/4 inch (6.4 mm).
 - 2. NPS 1 (DN 25): Maximum span, 6 feet (1.8 m); minimum rod size, 1/4 inch (6.4 mm).
 - 3. NPS 1-1/4 (DN 32:): Maximum span, 7 feet (2.1 m); minimum rod size, 3/8 inch (10 mm).
 - 4. NPS 1-1/2 (DN 40): Maximum span, 8 feet (2.4 m); minimum rod size, 3/8 inch (10 mm).
 - 5. NPS 2 (DN 50): Maximum span, 8 feet (2.4 m); minimum rod size, 3/8 inch (10 mm).
 - 6. NPS 2-1/2 (DN 65): Maximum span, 9 feet (2.7 m); minimum rod size, 3/8 inch (10 mm).
 - 7. NPS 3 (DN 80) and Larger: Maximum span, 10 feet (3 m); minimum rod size, 3/8 inch (10 mm).
- F. Support vertical runs at roof, at each floor, and at 10-foot intervals between floors.

3.5 PIPE JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints per ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
- D. Threaded Joints: Thread pipe with tapered pipe threads per ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

- E. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
- F. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- G. Welded Joints: Construct joints per AWS D10.12M/D10.12, using qualified processes and welding operators per "Quality Assurance" Article.
- H. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.6 TERMINAL EQUIPMENT CONNECTIONS

- A. Sizes for supply and return piping connections shall be the same as or larger than equipment connections.
- B. Install control valves in accessible locations close to connected equipment.
- C. Install bypass piping with globe valve around control valve. If parallel control valves are installed, only one bypass is required.
- D. Install ports for pressure gages and thermometers at coil inlet and outlet connections. Comply with requirements in Section 15127 "METERS AND GAGES FOR HVAC PIPING."

3.7 FIELD QUALITY CONTROL

- A. Prepare hydronic piping per ASME B31.9 and as follows:
 - 1. Leave joints, including welds, uninsulated and exposed for examination during test.
 - 2. Provide temporary restraints for expansion joints that cannot sustain reactions due to test pressure. If temporary restraints are impractical, isolate expansion joints from testing.
 - 3. Flush hydronic piping systems with clean water; then remove and clean or replace strainer screens.
 - 4. Isolate equipment from piping. If a valve is used to isolate equipment, its closure shall be capable of sealing against test pressure without damage to valve. Install blinds in flanged joints to isolate equipment.
 - 5. Install safety valve, set at a pressure no more than one-third higher than test pressure, to protect against damage by expanding liquid or other source of overpressure during test.
- B. Perform the following tests on hydronic piping:
 - 1. Use ambient temperature water as a testing medium unless there is risk of damage due to freezing. Another liquid that is safe for workers and compatible with piping may be used.
 - 2. While filling system, use vents installed at high points of system to release air. Use drains installed at low points for complete draining of test liquid.

3. Isolate expansion tanks and determine that hydronic system is full of water.
 4. Subject piping system to hydrostatic test pressure that is not less than 1.5 times the system's working pressure. Test pressure shall not exceed maximum pressure for any vessel, pump, valve, or other component in system under test. Verify that stress due to pressure at bottom of vertical runs does not exceed 90 percent of specified minimum yield strength or 1.7 times the "SE" value in Appendix A in ASME B31.9, "Building Services Piping."
 5. After hydrostatic test pressure has been applied for at least 10 minutes, examine piping, joints, and connections for leakage. Eliminate leaks by tightening, repairing, or replacing components, and repeat hydrostatic test until there are no leaks.
 6. Prepare written report of testing.
- C. Perform the following before operating the system:
1. Open manual valves fully.
 2. Inspect pumps for proper rotation.
 3. Set makeup pressure-reducing valves for required system pressure.
 4. Inspect air vents at high points of system and determine if all are installed and operating freely (automatic type), or bleed air completely (manual type).
 5. Set temperature controls so all coils are calling for full flow.
 6. Inspect and set operating temperatures of hydronic equipment, such as boilers, chillers, cooling towers, to specified values.
 7. Verify lubrication of motors and bearings.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15183

REFRIGERANT PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS AND PIPING AND EQUIPMENT
 - 3. Section 15074 – VIBRATION AND SEIMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15088 – HVAC PIPING INSULATION
 - 6. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 7. Section 15739 – SPLIT-SYSTEM AIR-CONDITIONING UNITS

1.2 SUMMARY

- A. This Section includes refrigerant piping used for air-conditioning applications.

1.3 PERFORMANCE REQUIREMENTS

- A. Line Test Pressure for Refrigerant R-410A:
 - 1. Suction Lines for Air-Conditioning Applications: 300 psig.
 - 2. Suction Lines for Heat-Pump Applications: 535 psig.
 - 3. Hot-Gas and Liquid Lines: 535 psig.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of valve and refrigerant piping specialty indicated. Include pressure drop, based on manufacturer's test data, for the following:
 - 1. Piping.
- B. Shop Drawings: Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes, flow capacities, valve arrangements and locations, slopes of horizontal runs, oil traps, double risers, wall and floor penetrations, and equipment connection details. Show interface and spatial relationships between piping and equipment.
 - 1. Shop Drawing Scale: 3/8 inch equals 1 foot.
 - 2. Refrigerant piping indicated on Drawings is schematic only. Size piping and design actual piping layout, including oil traps, double risers, specialties, and pipe and tube sizes to

accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.

3. Shop drawing shall be signed by a Manufacturer's Representative indicating the layout complies with the Manufacturer's Recommendations.

1.5 QUALITY ASSURANCE

- A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
- B. Comply with ASHRAE 15, "Safety Code for Refrigeration Systems."
- C. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."

1.6 PRODUCT STORAGE AND HANDLING

- A. Store piping in a clean and protected area with end caps in place to ensure that piping interior and exterior are clean when installed.

1.7 COORDINATION

- A. Coordinate size and location of roof curbs, equipment supports, and roof penetrations.

PART 2 - PRODUCT

2.1 COPPER TUBE AND FITTINGS

- A. Copper Tube: ASTM B 280, Type ACR.
- B. Wrought-Copper Fittings: ASME B16.22.
- C. Brazing Filler Metals: AWS A5.8.
- D. Flexible Connectors:
 1. Body: Tin-bronze bellows with woven, flexible, tinned-bronze-wire-reinforced protective jacket.
 2. End Connections: Socket ends.
 3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
 4. Pressure Rating: Factory test at minimum 600 psig.
 5. Maximum Operating Temperature: 250 deg F.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS FOR REFRIGERANT R-410A

- A. Suction Lines for Conventional Air-Conditioning Applications: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with brazed joints.
- B. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with brazed joints.

3.2 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems; indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop Drawings.
- B. Install refrigerant piping according to ASHRAE 15.
- C. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
- D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
- E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
- F. Install piping adjacent to machines to allow service and maintenance.
- G. Install piping free of sags and bends.
- H. Install fittings for changes in direction and branch connections.
- I. Select system components with pressure rating equal to or greater than system operating pressure.
- J. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.
- K. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as required if valves or equipment requiring maintenance is concealed behind finished surfaces.
- L. When brazing or soldering, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.
- M. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.
- N. Identify refrigerant piping and valves according to Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

- O. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- P. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 15050 "BASIC MATERIALS AND METHODS FOR HVAC WORK."

3.3 PIPE JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

Retain first paragraph below for steel pipe.

- C. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube."
 - 1. Use Type BcuP, copper-phosphorus alloy for joining copper socket fittings with copper pipe.
 - 2. Use Type BA_g, cadmium-free silver alloy for joining copper with bronze or steel.
- D. All brazing shall be performed under a continuous positive purge of dry nitrogen.

3.4 HANGERS AND SUPPORTS

- A. Hanger, support, and anchor products are specified in Section 15062 "HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT."
- B. Install the following pipe attachments:
 - 1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
 - 2. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
 - 3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
 - 4. Spring hangers to support vertical runs.
 - 5. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
- C. Install hangers for copper tubing with the following maximum spacing and minimum rod sizes:
 - 1. NPS 1/2: Maximum span, 60 inches; minimum rod size, 1/4 inch.
 - 2. NPS 5/8: Maximum span, 60 inches; minimum rod size, 1/4 inch.
 - 3. NPS 1: Maximum span, 72 inches; minimum rod size, 1/4 inch.
 - 4. NPS 1-1/4: Maximum span, 96 inches; minimum rod size, 3/8 inch.
 - 5. NPS 1-1/2: Maximum span, 96 inches; minimum rod size, 3/8 inch.
- D. Support multifloor vertical runs at least at each floor.

3.5 FIELD QUALITY CONTROL

- A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:

1. Comply with ASME B31.5, Chapter VI.
2. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
3. Test high- and low-pressure side piping of each system separately at not less than the pressures indicated in Part 1 "Performance Requirements" Article.
 - a. Fill system with nitrogen to the required test pressure.
 - b. System shall maintain test pressure at the manifold gage throughout duration of test.
 - c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
 - d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

3.6 SYSTEM CHARGING

A. Charge system using the following procedures:

1. Install core in filter dryers after leak test but before evacuation.
2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
4. Charge system with a new filter-dryer core in charging line.

3.7 ADJUSTING

- A. Adjust thermostatic expansion valve to obtain proper evaporator superheat.
- B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.
- C. Adjust set-point temperature of air-conditioning or chilled-water controllers to the system design temperature.
- D. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:
1. Verify that compressor oil level is correct.
 2. Open compressor suction and discharge valves.
 3. Open refrigerant valves except bypass valves that are used for other purposes.
 4. Check open compressor-motor alignment and verify lubrication for motors and bearings.
- E. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15185
HYDRONIC PUMPS
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Section:
 - 1. Section 03300 - CAST IN PLACE CONCRETE
 - 2. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 7. Section 15127 – METERS AND GAGES FOR PIPING

1.2 SUMMARY

- A. Section Includes:
 - 1. Close-coupled, in-line centrifugal pumps.
 - 2. Separately coupled, base-mounted, end-suction centrifugal pumps.
 - 3. Wet-rotor pumps.
 - 4. Automatic condensate pump units.

1.3 DEFINITIONS

- A. Buna-N: Nitrile rubber.
- B. EPT: Ethylene propylene terpolymer.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of pump. Include certified performance curves and rated capacities, operating characteristics, furnished specialties, final impeller dimensions, and accessories for each type of product indicated. Indicate pump's operating point on curves.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For pumps to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Mechanical Seals: One mechanical seal(s) for each pump.

PART 2 - PRODUCTS

2.1 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Armstrong Pumps Inc.
 - 2. Aurora Pump; Division of Pentair Pump Group.
 - 3. Flowserve Corporation.
 - 4. Grundfos Pumps Corporation.
 - 5. ITT Corporation; Bell & Gossett.
 - 6. Patterson Pump Co.; a subsidiary of the Gorman-Rupp Co.
 - 7. Peerless Pump Company.
 - 8. TACO Incorporated.
 - 9. Thrush Company Inc.
- B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, close-coupled, in-line pump as defined in HI 1.1-1.2 and HI 1.3; designed for installation with pump and motor shafts mounted horizontally or vertically.
- C. Pump Construction:
 - 1. Casing: Radially split, cast iron, with threaded gage tappings at inlet and outlet, replaceable bronze wear rings, and threaded companion-flange connections.
 - 2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For constant-speed pumps, trim impeller to match specified performance.
 - 3. Pump Shaft: Steel, with copper-alloy shaft sleeve.
 - 4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket. Include water slinger on shaft between motor and seal.
 - 5. Pump Bearings: Permanently lubricated ball bearings.
- D. Motor: Single speed and rigidly mounted to pump casing.
 - 1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT."
 - a. Enclosure: Open, dripproof.
 - b. Enclosure Materials: Cast aluminum.
 - c. Motor Bearings: Permanently lubricated ball bearings.

- d. Efficiency: Premium efficient.
- e. NEMA Design: A.
- f. Service Factor: 1.15.

E. Capacities and Characteristics: As indicated on drawings.

2.2 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- 1. Armstrong Pumps Inc.
- 2. Aurora Pump; Division of Pentair Pump Group.
- 3. Flowserve Corporation.
- 4. ITT Corporation; Bell & Gossett.
- 5. Peerless Pump Company.
- 6. TACO Incorporated.
- 7. Thrush Company Inc.

B. Description: Factory-assembled and -tested, centrifugal, overhung-impeller, separately coupled, end-suction pump as defined in HI 1.1-1.2 and HI 1.3; designed for base mounting, with pump and motor shafts horizontal.

C. Pump Construction:

- 1. Casing: Radially split, cast iron, with replaceable bronze wear rings, threaded gage tappings at inlet and outlet, drain plug at bottom and air vent at top of volute, and flanged connections. Provide integral mount on volute to support the casing, and provide attached piping to allow removal and replacement of impeller without disconnecting piping or requiring the realignment of pump and motor shaft.
- 2. Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, keyed to shaft, and secured with a locking cap screw. For pumps not frequency-drive controlled, trim impeller to match specified performance.
- 3. Pump Shaft: Steel, with copper-alloy shaft sleeve.
- 4. Seal: Mechanical seal consisting of carbon rotating ring against a ceramic seat held by a stainless-steel spring, and Buna-N bellows and gasket.
- 5. Pump Bearings: Grease-lubricated ball bearings in cast-iron housing with grease fittings.

D. Shaft Coupling: Molded-rubber insert and interlocking spider capable of absorbing vibration. Couplings shall be drop-out type to allow disassembly and removal without removing pump shaft or motor. EPDM coupling sleeve for variable-speed applications.

E. Coupling Guard: Dual rated; ANSI B15.1, Section 8; OSHA 1910.219 approved; steel; removable; attached to mounting frame.

F. Mounting Frame: Welded-steel frame and cross members, factory fabricated from ASTM A 36/A 36M channels and angles. Fabricate to mount pump casing, coupling guard, and motor.

G. Motor: Single speed, secured to mounting frame, with adjustable alignment.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT."
 - a. Enclosure: Open, dripproof.
 - b. Enclosure Materials: Rolled steel.
 - c. Motor Bearings: Permanently lubricated ball bearings.
 - d. Efficiency: Premium efficient.
 - e. NEMA Design: A.
 - f. Service Factor: 1.15.
- H. Capacities and Characteristics: As indicated on drawings.

2.3 WET-ROTOR PUMPS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Armstrong Pumps Inc.
 2. Flowserve Corporation.
 3. Grundfos Pumps Corporation.
 4. ITT Corporation; Bell & Gossett.
 5. TACO Incorporated.
 6. Wilo
- B. Description: Factory-assembled and -tested, wet-rotor pump.
- C. Pump Construction:
1. Body: Cast iron.
 2. Impeller: Stainless steel.
 3. Pump Shaft: Stainless steel.
 4. Bearings: Carbon Sleeve.
- D. Motor: variable speed, electronically commutated (ECM, brushless DC)
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT."
 - a. Efficiency: Premium efficient.
 - b. NEMA Design: A.
 - c. Service Factor: 1.15.
- E. Capacities and Characteristics: As scheduled on drawings.

2.4 AUTOMATIC CONDENSATE PUMP UNITS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following :
1. Beckett Corporation.
 2. Hartell Pumps Div.; Milton Roy Co.
 3. Tecumseh Little Giant Pump Co.
 4. Mepco, LLC.
- B. Description: Packaged units with corrosion-resistant pump, plastic tank with cover, and automatic controls. Include factory- or field-installed check valve and a 72-inch-minimum, electrical power cord with plug.
- C. Capacities and Characteristics:
1. Capacity: 30 gph.
 2. Total Dynamic Head: 12 feet.
 3. Inlet and Outlet Size: ¾ inch.
 4. Motor Speed: 3450 rpm.
 5. Motor Horsepower: 1/10 HP.
 6. Electrical Characteristics:
 - a. Volts: 120V.
 - b. Phase: Single.
 - c. Hertz: 60.
 - d. Full-Load Amperes: 2.5.
 - e. Maximum Overcurrent Protection: ISA.

2.5 PUMP SPECIALTY FITTINGS

- A. Suction Diffuser:
1. Angle pattern.
 2. 175-psig pressure rating, ductile-iron body and end cap, pump-inlet fitting.
 3. Bronze startup and bronze or stainless-steel permanent strainers.
 4. Bronze or stainless-steel straightening vanes.
 5. Drain plug.
 6. Factory-fabricated support.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine equipment foundations and anchor-bolt locations for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before pump installation.
- C. Examine foundations and inertia bases for suitable conditions where pumps are to be installed.

- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PUMP INSTALLATION

- A. Comply with HI 1.4.
- B. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.
- C. Independently support pumps and piping so weight of piping is not supported by pumps and weight of pumps is not supported by piping.
- D. Automatic Condensate Pump Units: Install units for collecting condensate and extend to open drain.
- E. Equipment Mounting:
 - 1. Install base-mounted pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 03300 "CAST-IN-PLACE CONCRETE."
 - 2. Comply with REQUIREMENTS FOR VIBRATION ISOLATION AND SEISMIC CONTROL DEVICES SPECIFIED IN Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR HVAC."
 - 3. Comply with requirements for vibration isolation devices specified in Section 15068 "VIBRATION CONTROLS FOR HVAC."
- F. Equipment Mounting: Install in-line pumps with continuous-thread hanger rods and elastomeric hangers of size required to support weight of in-line pumps.
 - 1. Comply with requirements for hangers and supports specified in Section 15062 "HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT."

3.3 ALIGNMENT

- A. Perform laser alignment service in coupled motor-pump assemblies.
- B. Comply with requirements in Hydronics Institute standards for alignment of pump and motor shaft. Add shims to the motor feet and bolt motor to base frame. Do not use grout between motor feet and base frame.
- C. Comply with pump and coupling manufacturers' written instructions.
- D. After alignment is correct, tighten foundation bolts evenly and torqued to manufacturer's recommendations. Completely fill baseplate with non-shrink, nonmetallic grout while metal blocks and shims or wedges are in place. After grout has cured, fully tighten foundation bolts.

3.4 CONNECTIONS

- A. Where installing piping adjacent to pump, allow space for service and maintenance.
- B. Connect piping to pumps. Install valves that are same size as piping connected to pumps.

- C. Install suction and discharge pipe sizes equal to or greater than diameter of pump nozzles.
- D. Install piping independently of pumps. Pumps shall bear no weight of connecting piping.
- E. Install check valve and isolation valve on discharge side of pumps.
- F. Install multi-turn balancing valve on discharge side of pumps, on pump side of constant volume pumps. Do not install balancing valves at the outlet of pumps controlled by variable frequency drives. Instead, use the VFD as the volume determinant and measure flow in the common line with a low-pressure drop flow meter.
- G. Install suction diffuser and shutoff valve on suction side of base-mounted pumps.
- H. Install flexible connectors on suction and discharge sides of base-mounted pumps between pump casing and valves.
- I. Install pressure gages on pump suction and discharge at a common elevation, with isolation valves and as indicated on drawings.
- J. Install check valve and ball valve on each condensate pump unit discharge.
- K. Ground equipment per Section 16060 "GROUNDING AND BONDING" by DIV 16 contractor.
- L. Connect wiring per Section 16120 "CONDUCTORS AND CABLES" by DIV 16 contractor.

3.5 STARTUP SERVICE

- A. Perform startup service.
 - 1. Complete installation and startup checks per manufacturer's written instructions.
 - 2. Check piping connections for tightness.
 - 3. Clean strainers on suction piping.
 - 4. Perform the following startup checks for each pump before starting:
 - a. Verify bearing lubrication.
 - b. Verify that pump is free to rotate by hand and that pump for handling hot liquid is free to rotate with pump hot and cold. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
 - c. Verify that pump is rotating in the correct direction.
 - 5. Prime pump by opening suction valves and closing drains, and prepare pump for operation.
 - 6. Start motor.
 - 7. Open discharge valve slowly.

3.6 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15188

WATER TREATMENT FOR CLOSED-LOOP HYDRONIC SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15062 "Hangers and Supports for Piping and Equipment"
 - 2. Section 15112 "GENERAL-DUTY VALVES FOR HVAC PIPING."
 - 3. Section 15145 "DOMESTIC WATER PIPING SPECIALTIES"
 - 4. Section 15179 "HYDRONIC PIPING SPECIALTIES."
 - 5. Section 15181 "HYDRONIC PIPING."

1.2 SUMMARY

- A. Section includes the following water treatment for closed-loop hydronic systems:
 - 1. Manual chemical-feed equipment.
 - 2. Chemicals for cleaning the system of oils, fouling and corrosion.
 - 3. Chemicals for corrosion inhibition, passivation and stabilization of pipe material.

1.3 DEFINITIONS

- A. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- B. RO: Reverse osmosis.
- C. TSS: Total suspended solids are solid materials, including organic and inorganic, that are suspended in the water. These solids may include silt, plankton, and industrial wastes.

1.4 ACTION SUBMITTALS

- A. Product Data: Include rated capacities, operating characteristics, and furnished specialties and accessories for the following products:
 - 1. Bypass feeders.
 - 2. Water meters.
 - 3. pH meters and controllers.
 - 4. TSS controllers.
 - 5. Chemical solution tanks.
 - 6. Chemical test equipment.
 - 7. Chemical material safety data sheets.

- B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to hydronic systems.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include diagrams for power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.
- C. Field quality-control reports.
- D. Other Informational Submittals:
 - 1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
 - 2. Water Analysis: Illustrate water quality available at Project site.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

1.8 MAINTENANCE SERVICE

- A. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one year from date of Substantial Completion and shall include the following:
 - 1. Initial water analysis and HVAC water-treatment recommendations.
 - 2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.

3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Ampion Corp.
 2. Anderson Chemical Company.
 3. Aqua-Chem, Inc.
 4. Barclay Water Management, Inc.
 5. Boland.
 6. Cascade Water Services, Inc.
 7. Chem-Treat, Inc.
 8. Earthwise Environmental Inc.
 9. General Electric Company; GE Water & Process Technologies.
 10. H-O-H Water Technology, Inc.
 11. Metro Group, Inc. (The); Metropolitan Refining Div.
 12. Nalco; an Ecolab company.
 13. Neptune
 14. New England Systems and Supply, Inc.
 15. Rhomar Water
 16. Watcon, Inc.
 17. Water Services Inc.

2.2 PERFORMANCE REQUIREMENTS

- A. Water quality for hydronic systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of hydronic equipment without creating a hazard to operating personnel or the environment.
- B. Base HVAC water treatment on quality of water available at Project site, hydronic system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
- C. Closed hydronic systems, including hot-water heating water, shall have the following water qualities:
1. pH: Maintain a value within 8.5 to 10.5.
 2. "P" Alkalinity: Maintain a value within 100 to 500 ppm.
 3. Boron: Maintain a value within 100 to 200 ppm.
 4. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
 5. Soluble Copper: Maintain a maximum value of 0.20 ppm.
 6. TSS: Maintain a maximum value of 10 ppm.
 7. Ammonia: Maintain a maximum value of 20 ppm.
 8. Free Caustic Alkalinity: Maintain a maximum value of 20 ppm.
 9. Microbiological Limits:
 - a. Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/mL.

- b. Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/mL.
 - c. Nitrate Reducers: Maintain a maximum value of 100 organisms/mL.
 - d. Sulfate Reducers: Maintain a maximum value of zero organisms/mL.
 - e. Iron Bacteria: Maintain a maximum value of zero organisms/mL.
10. The above criteria shall be superseded by specific manufacturer equipment requirements including boilers, tanks and heat exchangers.

2.3 MANUAL FILTER CHEMICAL-FEED EQUIPMENT

- A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel. A stainless steel perforated basket shall fit within and seat upon the neck of the vessel. A selection of polyester fabric filters in 50, 20 and 5 micron ratings. Furnish each filter feeder with five (5) filters of each rating.
- 1. Capacity: 5 gal.
 - 2. Minimum Working Pressure: 300 psig at 200 deg. F.
 - 3. Carbon steel support stand and bracket with bolt holes.

2.4 CHEMICALS

- A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment and that can attain water quality specified in "Performance Requirements" Article.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

- A. Delete this article if water analysis has been or will be performed by Owner.
- B. Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

- A. Install chemical application equipment on concrete bases or bracketed on suitable walls, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
- B. Bypass Feeders: Install in closed hydronic systems, including hot-water heating and condenser water, and equipped with the following:
- 1. Install bypass feeder in a bypass circuit around circulating pumps unless otherwise indicated on Drawings.
 - 2. Install test-coupon assembly in bypass circuit around circulating pumps unless otherwise indicated on Drawings.

3. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below the feeder inlet.
4. Install a swing check on the inlet after the isolation valve.

3.3 CONNECTIONS

- A. Where installing piping adjacent to equipment, allow space for service and maintenance.
- B. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Comply with requirements in Section 15179 "HYDRONIC PIPING SPECIALTIES."
- C. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Section 15112 "GENERAL-DUTY VALVES FOR HVAC PIPING."
- D. Comply with requirements in Section 15145 "DOMESTIC WATER PIPING SPECIALTIES" for backflow preventers required in makeup-water connections to potable-water systems.
- E. Provide each filter feeder with isolation, drain and vent valves. Demonstrate pressure relief prior to opening. Place signage requiring venting upon isolation for the feeder.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform the following tests and inspections:
 1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
 2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
 3. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
 4. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
 5. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
 6. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
 7. Repair leaks and defects with new materials and retest piping until no leaks exist.
- C. Equipment will be considered defective if it does not pass tests and inspections.

- D. Prepare test and inspection reports.
- E. Comply with ASTM D 3370 and with the following standards:
 - 1. Silica: ASTM D 859.
 - 2. Acidity and Alkalinity: ASTM D 1067.
 - 3. Iron: ASTM D 1068.
 - 4. Water Hardness: ASTM D 1126.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to Train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15195
FACILITY NATURAL-GAS PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 02300 – EARTHWORK
 - 2. Section 09900 – PAINTING
 - 3. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 4. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 5. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 6. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 7. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 8. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 9. Section 15127 – METERS AND GAGES FOR PIPING
 - 10. Section 16630 – EMERGENCY GENERATOR.

1.2 SUMMARY

- A. Section Includes:
 - 1. Pipes, tubes, and fittings.
 - 2. Piping specialties.
 - 3. Joining materials.
 - 4. Valves.
 - 5. Pressure regulators.

1.3 DEFINITIONS

- A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
- B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
- C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

1.4 PERFORMANCE REQUIREMENTS

- A. Minimum Operating-Pressure Ratings:
 - 1. Piping and Valves: 100 psig minimum unless otherwise indicated.
 - 2. Service Regulators: 100 psig minimum unless otherwise indicated.
 - 3. Minimum Operating Pressure of Service Meter: 5 psig.

- B. Delegated Design: Design restraints and anchors for natural-gas piping and equipment, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of the following:
 - 1. Piping specialties.
 - 2. Corrugated, stainless-steel tubing with associated components.
 - 3. Valves. Include pressure rating, capacity, settings, and electrical connection data of selected models.
 - 4. Pressure regulators. Indicate pressure ratings and capacities.
 - 5. Dielectric fittings.

- B. Shop Drawings: For facility natural-gas piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion joints and loops.
 - 1. Shop Drawing Scale: 3/8 inch per foot.
 - 2. Detail mounting, supports, and valve arrangements for service meter assembly and pressure regulator assembly.

- C. Delegated-Design Submittal: For natural-gas piping and equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 - 1. Detail fabrication and assembly of seismic restraints.
 - 2. Design Calculations: Calculate requirements for selecting seismic restraints.

1.6 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans and details, drawn to scale, on which natural-gas piping is shown and coordinated with other installations, using input from installers of the items involved.

- B. Site Survey: Plans, drawn to scale, on which natural-gas piping is shown and coordinated with other services and utilities.

- C. Qualification Data: For qualified professional engineer.

- D. Welding certificates.

- E. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For pressure regulators and service meters to include in emergency, operation, and maintenance manuals.
- B. Inspection reports and signatures of Authorities Having Jurisdiction.

1.8 QUALITY ASSURANCE

- A. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Pipe Welding Qualifications: Qualify procedures and operators per ASME Boiler and Pressure Vessel Code.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Handling Flammable Liquids: Remove and dispose of liquids from existing natural-gas piping per requirements of authorities having jurisdiction.
- B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
- C. Store and handle pipes and tubes having factory-applied protective coatings to avoid damaging coating, and protect from direct sunlight.

1.10 PROJECT CONDITIONS

- A. Perform site survey, research public utility records, and verify existing utility locations. Contact utility-locating service for area where Project is located.
- B. Interruption of Existing Natural-Gas Service: Do not interrupt natural-gas service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide purging and startup of natural-gas supply per requirements indicated:
 - 1. Notify Construction Manager no fewer than 14 days in advance of proposed interruption of natural-gas service.
 - 2. Do not proceed with interruption of natural-gas service without Construction Manager's written permission.

1.11 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

- B. Coordinate requirements for access panels and doors for valves installed concealed behind finished surfaces.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
 - 1. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
 - 2. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
 - 3. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
 - 4. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
 - a. Material Group: 1.1.
 - b. End Connections: Threaded or butt welding to match pipe.
 - c. Lapped Face: Not permitted underground.
 - d. Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
 - e. Bolts and Nuts: ASME B18.2.1, carbon steel aboveground and stainless steel underground.
 - 5. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.
 - a. Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.

2.2 PIPING SPECIALTIES

- A. Y-Pattern Strainers:
 - 1. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
 - 2. End Connections: Threaded ends for NPS 2 and smaller; flanged ends for NPS 2-1/2 and larger.
 - 3. Strainer Screen: 40-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
 - 4. CWP Rating: 125 psig.
- B. Flexible Piping Terminal Equipment Connectors:
 - 1. Conform to ANSI LC 1 "Fuel Gas Piping Systems Using CSST" and listed with CSA® , ICC and IAPMO.

2. Material: ASTM A240 type 300 corrugated stainless steel tubing with a minimum wall thickness of .010", jacketing of UV resistant polyethylene meeting the requirements of ASTM E84 for flame spread and smoke density.
3. Mechanical tube fittings: SAE CA360 brass with double wall flare sealing and jacket capturing for steel tubing protection.
4. Maximum assembly length: 30 inches.
5. Maximum size: 1" NPS.

2.3 JOINING MATERIALS

- A. Joint Compound: Suitable for natural gas. No PTFE or similar tape will be acceptable. Only brush-on thread compounds suitable for natural gas shall be acceptable.
- B. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.4 MANUAL GAS SHUTOFF VALVES

- A. General Requirements for Metallic Valves, NPS 2 and Smaller: Comply with ASME B16.33.
 1. CWP Rating: 125 psig.
 2. Threaded Ends: Comply with ASME B1.20.1.
 3. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
 4. Tamperproof Feature: Locking feature for valves indicated "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 5. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch and smaller.
 6. Service Mark: Valves 1-1/4 inches to NPS 2 shall have initials "WOG" permanently marked on valve body.
 7. "Tee" handle for individual appliance shut-off.
- B. General Requirements for Metallic Valves, NPS 2-1/2 and Larger: Comply with ASME B16.38.
 1. CWP Rating: 125 psig.
 2. Flanged Ends: Comply with ASME B16.5 for steel flanges.
 3. Tamperproof Feature: Locking feature for valves indicated in "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
 4. Service Mark: Initials "WOG" shall be permanently marked on valve body.
- C. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. BrassCraft Manufacturing Company; a Masco company.
 - b. Conbraco Industries, Inc.; Apollo Div.
 - c. Lyall, R. W. & Company, Inc.
 - d. McDonald, A. Y. Mfg. Co.
 - e. Perfection Corporation; a subsidiary of American Meter Company.

2. Body: Bronze, complying with ASTM B 584.
3. Ball: Chrome-plated bronze.
4. Stem: Bronze; blowout proof.
5. Seats: Reinforced TFE; blowout proof.
6. Packing: Threaded-body packnut design with adjustable-stem packing.
7. Ends: Threaded, flared, or socket.
8. CWP Rating: 600 psig.
9. Listing: Valves NPS 1 and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
10. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

2.5 PRESSURE REGULATORS

A. General Requirements:

1. Single stage and suitable for natural gas.
2. Steel jacket and corrosion-resistant components.
3. Elevation compensator.
4. End Connections: Threaded for regulators NPS 2 and smaller; flanged for regulators NPS 2-1/2 and larger.

B. Line Pressure Regulators: Comply with ANSI Z21.80.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Actaris.
 - b. American Meter Company.
 - c. Eclipse Combustion, Inc.
 - d. Fisher Control Valves and Regulators; Division of Emerson Process Management.
 - e. Invensys.
 - f. Maxitrol Company.
 - g. Richards Industries; Jordan Valve Div.
2. Body and Diaphragm Case: Cast iron or die-cast aluminum.
3. Springs: Zinc-plated steel; interchangeable.
4. Diaphragm Plate: Zinc-plated steel.
5. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
6. Orifice: Aluminum; interchangeable.
7. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
8. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
9. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
10. Overpressure Protection Device: Factory mounted on pressure regulator.
11. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
12. Maximum Inlet Pressure: 5 psig.

2.6 LABELING AND IDENTIFYING

- A. Detectable Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches wide and 4 mils thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches deep; colored yellow.
- B. Exposed facility gas piping shall be labeled after painting. Label per Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for natural-gas piping system to verify actual locations of piping connections before equipment installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Close equipment shutoff valves before turning off natural gas to premises or piping section.
- B. Inspect natural-gas piping per the International Fuel Gas Code, MA 248 CMR, to determine that natural-gas utilization devices are turned off in piping section affected.
- C. Comply with the International Fuel Gas Code, and MA 248 CMR, requirements for prevention of accidental ignition.

3.3 OUTDOOR PIPING INSTALLATION

- A. Comply with the International Fuel Gas Code, MA 248 CMR, for installation and purging of natural- gas piping.
- B. Install underground, natural-gas piping buried at least 48 inches below finished grade. Comply with requirements in Section 02300 "EARTHWORK" for excavating, trenching, and backfilling.
 - 1. If natural-gas piping is installed less than 36 inches below finished grade, install it in containment conduit.
- C. Install underground, PE, natural-gas piping per ASTM D 2774.
- D. Steel Piping with Protective Coating:
 - 1. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.

2. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
- E. Install fittings for changes in direction and branch connections.
- F. Install capped pressure gage connections upstream and downstream from each service regulator.

3.4 PIPING INSTALLATION

- A. Comply with the International Fuel Gas Code, and MA 248 CMR, for installation and purging of natural-gas piping.
- B. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems.

Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

- C. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
- D. Locate valves for easy access.
- E. Install natural-gas piping at uniform grade of 2 percent down toward drip and sediment traps.
- F. Install piping free of sags and bends.
- G. Install fittings for changes in direction and branch connections.
- H. Verify final equipment locations for roughing-in.
- I. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.
- J. Drips and Sediment Traps: Install drips at points where condensate may collect, including service- meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
 1. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.
- K. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.
- L. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
- M. Connect branch piping from top or side of horizontal piping.

- N. Install unions in pipes NPS 2 and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.
- O. Do not use natural-gas piping as grounding electrode.
- P. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.
- Q. Install pressure gage upstream and downstream from each line regulator.
- R. Install sleeves for piping penetrations of walls, ceilings, and floors.
- S. Install sleeve seals for piping penetrations of concrete walls and slabs.
- T. Install escutcheons for piping penetrations of walls, ceilings, and floors.

3.5 VALVE INSTALLATION

- A. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing connector.
- B. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.

3.6 PIPING JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly. Apply gas-compatible brush-on joint compound to male threads only.
- C. Welded Joints:
 1. Construct joints per AWS D10.12/D10.12M, using qualified processes and welding operators.
 2. Bevel plain ends of steel pipe.
 3. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.
- D. Flanged Joints: Install gasket material, size, type, and thickness appropriate for natural-gas service.
- E. Install gasket concentrically positioned.
 1. Plain-End Pipe and Fittings: Use butt fusion.
 2. Plain-End Pipe and Socket Fittings: Use socket fusion.

3.7 HANGER AND SUPPORT INSTALLATION

- A. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT"
- B. Comply with requirements for pipe hangers and supports specified in Section 15062 "HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT."
- C. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
 - 1. NPS 1 and Smaller: Maximum span, 96 inches; minimum rod size, 3/8 inch.
 - 2. NPS 1-1/4: Maximum span, 108 inches; minimum rod size, 3/8 inch.
 - 3. NPS 1-1/2 and NPS 2: Maximum span, 108 inches; minimum rod size, 3/8 inch.
 - 4. NPS 2-1/2 to NPS 3-1/2: Maximum span, 10 feet; minimum rod size, 1/2 inch.
 - 5. NPS 4 and Larger: Maximum span, 10 feet; minimum rod size, 5/8 inch.

3.8 CONNECTIONS

- A. Install natural-gas piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance per NFPA 70.
- B. Install piping adjacent to appliances to allow service and maintenance of appliances.
- C. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches of each gas-fired appliance and equipment. Install union between valve and appliances or equipment and of a T-handle type operable without tools.
- D. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.
- E. Pressure Test Ports: Install a tee and minimum line x 1/8" NPT plug and test port for pressure testing at each connected appliance.
- F. Limit use of CSST to terminal connections not exceeding 1" NPS size and not exceeding 30 inches length in exposed accessible locations not subject to mechanical abuse. All terminal connections shall otherwise be hard-piped with unions.

3.9 LABELING AND IDENTIFYING

- A. Comply with requirements in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT" for piping and valve identification.
- B. Install detectable warning tape directly above gas piping, 12 inches below finished grade, except 6 inches below subgrade under pavements and slabs.

3.10 PAINTING

- A. Comply with requirements in Section 09900 "PAINTING" for painting interior and exterior natural- gas piping.
- B. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.
 - 1. Alkyd System: MPI EXT 5.1D.
 - a. Prime Coat: Alkyd anticorrosive metal primer.
 - b. Intermediate Coat: Exterior alkyd enamel matching topcoat.
 - c. Topcoat: Exterior alkyd enamel (semigloss).
 - d. Color: Grey for general locations, safety yellow for piping within 10 feet of grade.
- C. Piping mounted on roofs shall additionally be provided with exterior grade reflective tape to minimize trip hazards.
- D. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

3.11 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
 - 1. Test, inspect, and purge natural gas per the International Fuel Gas Code, MA 248 CMR, and authorities having jurisdiction.
- C. Natural-gas piping will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.12 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain earthquake valves.

3.13 OUTDOOR PIPING SCHEDULE

- A. Underground natural-gas piping shall be the following:
 - 1. Steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
- B. Aboveground natural-gas piping shall be the following:
 - 1. Steel pipe with wrought-steel fittings and welded joints.

- C. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

3.14 PIPING SCHEDULE FOR SYSTEM PRESSURES LESS THAN 1.0 PSIG

- A. Aboveground, distribution piping shall be the following:
 - 1. General Distribution Mains, All Sizes: Steel pipe with wrought-steel fittings and welded joints.
 - 2. Connectors to Equipment 2.5 NPS and larger: Steel pipe with wrought-steel fittings and welded joints.
 - 3. Connectors to Equipment up to 2" NPS: Steel pipe with malleable iron fittings and screwed joints.
 - 4. Connectors to Equipment downstream of shut-off valve: CSST, not to exceed 1" NPS and not to exceed 30 inches in length and with integral unions Installations shall accessible, visible, exposed and not in areas subject to mechanical abuse.
 - 5. All other connections to equipment shall be hard-piped with appropriate unions.
- B. Prohibited Gas Piping: Corrugated Stainless Steel Tubing (CSST) shall not be acceptable for distribution piping with the exception of final connections to equipment per 3.14. A. 4.

3.15 ABOVEGROUND MANUAL GAS SHUTOFF VALVE SCHEDULE

- A. Valves for pipe sizes NPS 2 and smaller at service meter shall be the following:
 - 1. Two-piece, full-port, bronze ball valves with bronze trim.
- B. Valves for pipe sizes NPS 2-1/2 and larger at service meter shall be the following:
 - 1. Bronze plug valve.
- C. Distribution piping valves for pipe sizes NPS 2 and smaller shall be the following:
 - 1. Bronze plug valve.
- D. Distribution piping valves for pipe sizes NPS 2-1/2 and larger shall be the following:
 - 1. Bronze plug valve.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15211

GENERAL-SERVICE COMPRESSED-AIR PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes piping and related specialties for general-service compressed-air systems operating at 200 psig or less.
- B. Related Sections include the following:
 - 1. Section 15251– GENERAL-SERVICE PACKAGED AIR COMPRESSORS AND RECEIVERS
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 7. Section 15127 – METERS AND GAGES FOR PIPING

1.3 DEFINITIONS

- A. CR: Chlorosulfonated polyethylene synthetic rubber.
- B. EPDM: Ethylene-propylene-diene terpolymer rubber.
- C. NBR: Acrylonitrile-butadiene rubber.
- D. High-Pressure Compressed-Air Piping: System of compressed-air piping and specialties operating at pressures between 150 and 200 psig.
- E. Low-Pressure Compressed-Air Piping: System of compressed-air piping and specialties operating at pressures of 150 psig or less.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Compressed-air piping and support and installation shall withstand effects of seismic events determined per SEI/ASCE 7, "Minimum Design Loads for Buildings and Other Structures."

- B. Only metallic piping, fittings and valves shall be acceptable for all stationary compressed air piping systems. Flexible metallic or composite tubing shall be permissible only for portable terminal hoses direct to pneumatic tools. Flexible braided metallic connectors shall be used at compressors and dryers. The use of plastic piping in any form for compressed air is prohibited.

1.5 ACTION SUBMITTALS

- A. Product Data: For the following:
 - 1. Metallic pipe, fittings, and valves.
 - 2. Dielectric fittings.
 - 3. Flexible pipe connectors.
 - 4. Safety valves.
 - 5. Pressure regulators. Include rated capacities and operating characteristics.
 - 6. Automatic drain valves.
 - 7. Filters. Include rated capacities and operating characteristics.
 - 8. Lubricators. Include rated capacities and operating characteristics.
 - 9. Quick couplings.
 - 10. Hose assemblies.

1.6 INFORMATIONAL SUBMITTALS

- A. Brazing and welding certificates.
- B. Qualification Data: For Installers.
- C. Field quality-control test reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For general-service compressed-air piping specialties to include in emergency, operation, and maintenance manuals.

1.8 QUALITY ASSURANCE

- A. Installer Qualifications:
 - 1. Licensed plumbers and pipefitters qualified to work on compressed air systems.
- B. Brazing: Qualify processes and operators per ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications," or to AWS B2.2, "Standard for Brazing Procedure and Performance Qualification."
- C. Welding: Qualify processes and operators per ASME Boiler and Pressure Vessel Code: Section IX.
- D. ASME Compliance:
 - 1. Comply with ASME B31.1, "Power Piping," for high-pressure compressed-air piping.
 - 2. Comply with ASME B31.9, "Building Services Piping," for low-pressure compressed-air piping.

PART 2 - PRODUCTS

2.1 PIPES, TUBES, AND FITTINGS

- A. Schedule 40, Steel Pipe: ASTM A 53/A 53M, Type E or S, Grade B, black or hot-dip zinc coated with ends threaded per ASME B1.20.1.
 - 1. Steel Nipples: ASTM A 733, made of ASTM A 53/A 53M or ASTM A 106, Schedule 40, galvanized seamless steel pipe. Include ends matching joining method.
 - 2. Malleable-Iron Fittings: ASME B16.3, Class 150 or 300, threaded.
 - 3. Malleable-Iron Unions: ASME B16.39, Class 150 or 300, threaded.
 - 4. Steel Flanges: ASME B16.5, Class 150 or 300, carbon steel, threaded.
 - 5. Wrought-Steel Butt-Welding Fittings: ASME B16.9, Schedule 40.
 - 6. Steel Flanges: ASME B16.5, Class 150 or 300, carbon steel.
- B. Copper Tube: ASTM B 88, Type K seamless, drawn-temper, water tube.
 - 1. Wrought-Copper Fittings: ASME B16.22, solder-joint pressure type or MSS SP-73, wrought copper with dimensions for brazed joints.
 - 2. Cast-Copper-Alloy Flanges: ASME B16.24, Class 150 or 300.
 - 3. Copper Unions: ASME B16.22 or MSS SP-123.
- C. Transition Couplings for Metal Piping: Metal coupling or other manufactured fitting same size as, with pressure rating at least equal to and ends compatible with, piping to be joined.
- D. Plastic piping in any form will not be acceptable for the compressed air system.

2.2 JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: Suitable for compressed-air piping system contents.
 - 1. ASME B16.21, nonmetallic, flat, asbestos free, 1/8-inch maximum thickness unless thickness or specific material is indicated.
 - a. Full-Face Type: For flat-face, Class 125, cast-iron and cast-bronze flanges.
 - b. Narrow-Face Type: For raised-face, Class 250, cast-iron and steel flanges.
- B. Flange Bolts and Nuts: ASME B18.2.1, carbon steel, unless otherwise indicated.
- C. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux per ASTM B 813.
- D. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for general-duty brazing, unless otherwise indicated.
- E. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.3 VALVES

- A. Metal Ball, Butterfly, Check, Gate, and Globe Valves: Comply with requirements in Section 15112 "GENERAL-DUTY VALVES FOR PIPING."

2.4 DIELECTRIC FITTINGS

- A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

- B. Dielectric Unions:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Capitol Manufacturing Company.
 - b. Hart Industries International, Inc.
 - c. Jomar International Ltd.
 - d. Matco-Norca, Inc.
 - e. McDonald, A. Y. Mfg. Co.
 - f. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
 - g. Wilkins; a Zurn company.
- 2. Description:
 - a. Standard: ASSE 1079.
 - b. Pressure Rating: 250 psig.
 - c. End Connections: Solder-joint copper alloy and threaded ferrous.

- C. Dielectric Flanges:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Capitol Manufacturing Company.
 - b. Matco-Norca, Inc.
 - c. Watts Regulator Co.; a division of Watts Water Technologies, Inc.
 - d. Wilkins; a Zurn company.
- 2. Description:
 - a. Standard: ASSE 1079.
 - b. Factory-fabricated, bolted, companion-flange assembly.
 - c. Pressure Rating: 300 psig.
 - d. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.

- D. Dielectric-Flange Insulating Kits:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. Advance Products & Systems, Inc.
 - b. Calpico, Inc.
 - c. Pipeline Seal and Insulator, Inc.
2. Description:
- a. Nonconducting materials for field assembly of companion flanges.
 - b. Pressure Rating: 300 psig.
 - c. Gasket: Neoprene or phenolic.
 - d. Bolt Sleeves: Phenolic or polyethylene.
 - e. Washers: Phenolic with steel backing washers.

2.5 FLEXIBLE PIPE CONNECTORS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Flex-Hose Co., Inc.
 - 2. Flexicraft Industries.
 - 3. Hyspan Precision Products, Inc.
 - 4. Mercer Rubber Co.
 - 5. Metraflex, Inc.
 - 6. Proco Products, Inc.
 - 7. Unaflex, Inc.
 - 8. Universal Metal Hose; a Hyspan Company
- C. Bronze-Hose Flexible Pipe Connectors: Corrugated-bronze tubing with bronze wire-braid covering and ends brazed to inner tubing.
 - 1. Working-Pressure Rating: 250 psig minimum.
 - 2. End Connections, NPS 2 and Smaller: Threaded copper pipe or plain-end copper tube.
 - 3. End Connections, NPS 2-1/2 and Larger: Flanged copper alloy.
- D. Stainless-Steel-Hose Flexible Pipe Connectors: Corrugated-stainless-steel tubing with stainless-steel wire-braid covering and ends welded to inner tubing.
 - 1. Working-Pressure Rating: 250 psig minimum.
 - 2. End Connections, NPS 2 and Smaller: Threaded steel pipe nipple.
 - 3. End Connections, NPS 2-1/2 and Larger: Flanged steel nipple.

2.6 SPECIALTIES

- A. Safety Valves: ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," construction; National Board certified, labeled, and factory sealed; constructed of bronze body with poppet-type safety valve for compressed-air service.
 - 1. Pressure Settings: Higher than discharge pressure and same or lower than receiver pressure rating.

- B. Air-Main Pressure Regulators: Bronze body, direct acting, spring-loaded manual pressure-setting adjustment, and rated for 250-psig inlet pressure, unless otherwise indicated.
 - 1. Type: Pilot operated.
- C. Air-Line Pressure Regulators: Diaphragm or pilot operated, bronze body, direct acting, spring-loaded manual pressure-setting adjustment, and rated for 300-psig minimum inlet pressure, unless otherwise indicated.
- D. Coalescing Filters: Coalescing type with activated carbon capable of removing water and oil aerosols; with color-change dye to indicate when carbon is saturated and warning light to indicate when selected maximum pressure drop has been exceeded. Include mounting bracket if wall mounting is indicated.
- E. Mechanical Filters: Two-stage, mechanical-separation-type, air-line filters. Equip with deflector plates, resin-impregnated-ribbon-type filters with edge filtration, and drain cock. Include mounting bracket if wall mounting is indicated.
- F. Air-Line Lubricators: With drip chamber and sight dome for observing oil drop entering air stream; with oil-feed adjustment screw and quick-release collar for easy bowl removal. Include mounting bracket if wall mounting is indicated.
 - 1. Provide with automatic feed device for supplying oil to lubricator.

2.7 QUICK COUPLINGS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Aeroquip Corporation; Eaton Corp.
 - 2. Bowes Manufacturing Inc.
 - 3. Foster Manufacturing, Inc.
 - 4. Milton Industries, Inc.
 - 5. Parker Hannifin Corp.; Fluid Connectors Group; Quick Coupling Div.
 - 6. Rectus Corp.
 - 7. Schrader-Bridgeport; Amflo Div.Schrader-Bridgeport/Standard Thomson.
 - 8. Snap-Tite, Inc.; Quick Disconnect & Valve Division.
 - 9. TOMCO Products Inc.
 - 10. Tuthill Corporation; Hansen Coupling Div.
- C. General Requirements for Quick Couplings: Assembly with locking-mechanism feature for quick connection and disconnection of compressed-air hose.
- D. Automatic-Shutoff Quick Couplings: Straight-through brass body with O-ring or gasket seal and stainless-steel or nickel-plated-steel operating parts.
 - 1. Socket End: With one-way valve and threaded inlet for connection to piping or threaded hose fitting.
 - 2. Plug End: Flow-sensor-bleeder, check-valve Straight-through type with barbed outlet for attaching hose.

- E. Valveless Quick Couplings: Straight-through brass body with stainless-steel or nickel-plated-steel operating parts.
 - 1. Socket End: With O-ring or gasket seal, without valve, and with barbed inlet for attaching hose.
 - 2. Plug End: With barbed outlet for attaching hose.
 - 3. Coordinate connection types with MBTA's tool inventory.

2.8 HOSE ASSEMBLIES

- A. Description: Compatible hose, clamps, couplings, and splicers suitable for compressed-air service, of nominal diameter indicated, and rated for 300-psig minimum working pressure, unless otherwise indicated.
 - 1. Hose: Reinforced double-wire-braid, CR-covered hose for compressed-air service.
 - 2. Hose Clamps: Stainless-steel clamps or bands.
 - 3. Hose Couplings: Two-piece, straight-through, threaded brass or stainless-steel O-ring or gasket-seal swivel coupling with barbed ends for connecting two sections of hose.
 - 4. Hose Splicers: One-piece, straight-through brass or stainless-steel fitting with barbed ends for connecting two sections of hose.

PART 3 - EXECUTION

3.1 PIPING APPLICATIONS

- A. Compressed-Air Piping between Air Compressors and Receivers: Use the following piping materials for each size range and application:
 - 1. **NPS 2** and Smaller: Schedule 40, black steel pipe; threaded, malleable-iron fittings; and threaded joints, except where welded piping is indicated.
 - 2. **NPS 2** and Smaller, compressor and receiver manifolds: Schedule 40, black-steel pipe; wrought-steel fittings; and welded joints. Compressor and receiver branch connections from this manifolds shall be threaded with unions or flanges.
 - 3. **NPS 2** and Smaller: Type L hard-drawn copper tube; wrought-copper fittings; and brazed joints.
- B. High and Low-Pressure Compressed-Air Distribution Piping: Use the following piping materials for each size range:
 - 1. **NPS 2** and Smaller: Schedule 40, black steel pipe; threaded, malleable-iron fittings; and threaded joints.
 - 2. **NPS 2** and Smaller: Hard-Drawn Type L, copper tube; wrought-copper fittings; and brazed joints.
- C. Drain Piping: Use the following piping materials:

1. NPS 2 and Smaller: Type L copper tube; wrought-copper fittings; and brazed or soldered joints.

3.2 VALVE APPLICATIONS

- A. General-Duty Valves: Comply with requirements in Section 15112 "GENERAL-DUTY VALVES FOR PIPING" for metal general-duty valves. Use metal valves, unless otherwise indicated.
 1. Metal General-Duty Valves: Use valve types specified in "Valve Applications" Article in Section 15112 "GENERAL-DUTY VALVES FOR PIPING" per the following:
 - a. Low-Pressure Compressed Air: Valve types specified for low-pressure compressed air.
 - b. High-Pressure Compressed Air: Valve types specified for medium-pressure compressed air.
 - c. Equipment Isolation NPS 2 and Smaller: Safety-exhaust, copper-alloy ball valve with exhaust vent and pressure rating at least as great as piping system operating pressure.

3.3 PIPING INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of compressed-air piping. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, air-compressor sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
- B. Install piping concealed from view and protected from physical contact by building occupants, unless otherwise indicated and except in equipment rooms and service areas.
- C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited, unless otherwise indicated.
- D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal and to coordinate with other services occupying that space.
- E. Install piping adjacent to equipment and machines to allow service and maintenance.
- F. Install air and drain piping with 1 percent slope downward in direction of flow.
- G. Install piping to promote drainage of condensibles to low points. Branches in general shall rise off the top of mains and shall include swing joints in three directions before dropping.
- H. Pipe layout shall promote flexibility to meet varying user loads with the use of loop and bridge layouts.
- I. Install nipples, flanges, unions, transition and special fittings, and valves with pressure ratings same as or higher than system pressure rating, unless otherwise indicated.
- J. Equipment and Specialty Flanged Connections:
 1. Use steel companion flange with gasket for connection to steel pipe.

2. Use cast-copper-alloy companion flange with gasket and brazed joint for connection to copper tube. Do not use soldered joints for connection to air compressors or to equipment or machines producing shock or vibration.
 3. Piping shall be all-rigid and secured at points of user connection.
- K. Flanged joints may be used instead of specified joint for any piping or tubing system.
 - L. Install eccentric reducers where compressed-air piping is reduced in direction of flow, with bottoms of both pipes and reducer fitting flush.
 - M. Install branch connections to compressed-air mains from top of main. Provide drain leg and drain trap at end of each main and branch and at low points.
 - N. Install thermometer and pressure gage on discharge piping from each air compressor and on each receiver. Comply with requirements in Section 15127 "METERS AND GAGES FOR PIPING."
 - O. Install piping to permit valve servicing.
 - P. Install piping free of sags and bends.
 - Q. Install fittings for changes in direction and branch connections.
 - R. Install seismic restraints on piping. Seismic-restraint devices are specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PLUMBING PIPING AND EQUIPMENT."
 - S. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
 - T. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
 - U. Install one-piece escutcheons for piping penetrations of walls, ceilings, and floors.

3.4 JOINT CONSTRUCTION

- A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- B. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
- C. Threaded Joints: Thread pipe with tapered pipe threads per ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
- D. Welded Joints for Steel Piping: Join per AWS D10.12/D10.12M.

- E. Brazed Joints for Copper Tubing: Join per AWS's "Brazing Handbook," "Pipe and Tube" Chapter, including continuous dry nitrogen purge.
- F. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Join per ASTM B 828 or CDA's "Copper Tube Handbook."
- G. Flanged Joints: Use asbestos-free, nonmetallic gasket suitable for compressed air. Join flanges with gasket and bolts per ASME B31.9 for bolting procedure.
- H. Dissimilar Metal Piping Material Joints: Use an NPT pattern bronze ball valve of line size.

3.5 VALVE INSTALLATION

- A. General-Duty Valves: Comply with requirements in Section 15112 "GENERAL-DUTY VALVES FOR PIPING."
- B. Install shutoff valves and unions or flanged joints at compressed-air piping to air compressors.
- C. Install shutoff valve at inlet to each automatic drain valve, filter, lubricator, and pressure regulator.
- D. Install check valves to maintain correct direction of compressed-air flow to and from compressed-air piping specialties and equipment.
- E. Install bypass lines with normally closed valves around serviceable items. Several items in-series which are part of a dedicated circuit which must be entirely shut down, may share a bypass valve across all devices to be serviced. This arrangement will be allowable provided there is a redundant assembly in parallel to the out-of-service device train.

3.6 FLEXIBLE PIPE CONNECTOR INSTALLATION

- A. Install flexible pipe connectors in discharge piping and in inlet air piping from remote air-inlet filter of each air compressor.
- B. Install bronze-hose flexible pipe connectors in copper compressed-air tubing.
- C. Install stainless-steel-hose flexible pipe connectors in steel compressed-air piping.

3.7 SPECIALTY INSTALLATION

- A. Install safety valves on receivers in quantity and size to relieve at least the capacity of connected air compressors.
- B. Install air-main pressure regulators in compressed-air piping at or near air compressors.
- C. Install air-line pressure regulators in branch piping to equipment and tools.
- D. Install automatic drain valves on aftercoolers, receivers, and dryers. Discharge condensate onto nearest floor drain.

- E. Install coalescing filters in compressed-air piping at or near air compressors and upstream from mechanical filters.
- F. Install mechanical filters in compressed-air piping at or near air compressors and downstream from coalescing filters.
- G. Install air-line lubricators in branch piping to machine tools.
- H. Install quick couplings at piping terminals for hose connections.
- I. Install hose assemblies at hose connections.

3.8 CONNECTIONS

- A. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment and machine.
- B. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment and machine.

3.9 HANGER AND SUPPORT INSTALLATION

- A. Comply with requirements in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT" for seismic-restraint devices.
- B. Comply with requirements in Section 150621 "HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT" for pipe hanger and support devices.
- C. Vertical Piping: MSS Type 8 or 42, clamps.
- D. Individual, Straight, Horizontal Piping Runs:
 - 1. 100 Feet or Less: MSS Type 1, adjustable, steel clevis hangers.
 - 2. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
- E. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
- F. Base of Vertical Piping: MSS Type 52, spring hangers.
- G. Support horizontal piping within 12 inches of each fitting and coupling.
- H. Rod diameter may be reduced 1 size for double-rod hangers, with 3/8-inch minimum rods.
- I. Install hangers for Schedule 40, steel piping with the following maximum horizontal spacing and minimum rod diameters:
 - 1. NPS 1/4 to NPS 1/2: 96 inches with 3/8-inch rod.
 - 2. NPS 3/4 to NPS 1-1/4: 84 inches with 3/8-inch rod.
 - 3. NPS 1-1/2: 12 feet with 3/8-inch rod.
 - 4. NPS 2: 13 feet with 3/8-inch rod.

5. NPS 2-1/2: 14 feet with 1/2-inch rod.
- J. Install supports for vertical, Schedule 40, steel piping every 15 feet.
1. NPS 2: 11 feet with 3/8-inch rod.
- K. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:
1. NPS 1/4: 60 inches with 3/8-inch rod.
 2. NPS 3/8 and NPS 1/2: 72 inches with 3/8-inch rod.
 3. NPS 3/4: 84 inches with 3/8-inch rod.
 4. NPS 1: 96 inches with 3/8-inch rod.
 5. NPS 1-1/4: 108 inches with 3/8-inch rod.
 6. NPS 1-1/2: 10 feet with 3/8-inch rod.
 7. NPS 2: 11 feet with 3/8-inch rod.
 8. NPS 2-1/2: 13 feet with 1/2-inch rod.
- L. Install supports for vertical copper tubing every 10 feet.

3.10 LABELING AND IDENTIFICATION

- A. Install identifying labels and devices for general-service compressed-air piping, valves, and specialties. Comply with requirements in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

3.11 FIELD QUALITY CONTROL

- A. Perform field tests and inspections.
- B. Tests and Inspections:
1. Piping Leak Tests for Metal Compressed-Air Piping: Test new and modified parts of existing piping. Cap and fill general-service compressed-air piping with oil-free dry air or gaseous nitrogen to pressure of 50 psig above system operating pressure, but not less than 200 psig. Isolate test source and let stand for four hours to equalize temperature. Refill system, if required, to test pressure; hold for two hours with no drop in pressure. Space temperature shall be monitored and thermal expansion or contraction shall be taken into account.
 2. Repair leaks and retest until no leaks exist.
 3. Inspect filters, lubricators and pressure regulators for proper operation.
- C. Prepare test reports.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15251

GENERAL-SERVICE PACKAGED AIR COMPRESSORS AND RECEIVERS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Furnish and install as required all equipment, as specified, complete and ready for operation. Provide any necessary accessories, mechanical, electrical and structural items, whether specified or not in order to deliver properly installed and functional equipment.
- C. Equipment shall be suitable for installation in the space allocated and operate on the available building utilities. Any modification or redesign to the building structure or utilities because of an alternate equipment selection by the Contractor shall be provided at no additional cost to the Agency and shall be as approved by the Contracting Officer.
- D. Furnish and install the equipment items listed below by their identifier:
 - 1. Compressor, screw, rotary, 40 HP (EQ ID: 2196)
- E. The work specified in this Section shall be performed and coordinated with the work of other trades including, but not limited to, those listed in 1.2, Related Work.

1.2 RELATED WORK

- A. Carefully examine all of the contract documents for requirements which affect the work of this section.
- B. The Contractor shall coordinate all disciplines indicated herein and as required to ensure that the equipment is tested, inspected and fully operational prior to use. Specification divisions which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Division 2 - Site Work
 - 2. Division 3 - Concrete
 - 3. Division 5 - Metals
 - 4. Division 15 - Mechanical
 - 5. Division 16 - Electrical

1.3 SUBMITTALS

- A. Product Data - Submit Product Data in accordance with Volume 2 Technical Provisions Subsection 2.7 "Design Submittal Review Management" and Subsection 2.8 "Construction Submittal Requirements".
- B.
- C. Operations and Maintenance Manual - Provide a complete parts, operating and maintenance manual covering the equipment when the item is shipped.

1.4 QUALITY ASSURANCE

- A. Equipment shall be produced by a manufacturer of established reputation with a minimum of five (5) years' experience supplying the specified equipment.

1.5 PRODUCT SUBSTITUTIONS

- A. Follow the requirements specified in Division 1 - General Requirements.
- B. Additional costs resulting from product substitutions other than those specified, including drawing changes and construction will be at the expense of the Contractor.
- C. Substitution Approval: Prior to delivery or installation, submittals for each item by Equipment Identifier shall be provided in accordance with Division 1 - General Requirements. Acceptance will be based on the technical requirements herein as determined by the Owner and Architect.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Deliver equipment in the manufacturer's containers, appropriately packaged and/or crated for protection during domestic shipment and storage in humid and/or dusty conditions.
- B. Permanently label all containers, including those contained in others, on the outside with item description(s) per title and the Equipment Identifier listed in this specification.
- C. Provide the equipment and materials specified complete in one shipment for each item. Split or partial shipments are not permissible.

1.7 WARRANTY

- A. Warrant work specified herein for one (1) year from substantial completion against defects in materials, functions, and workmanship.
- B. Warranty shall include all materials and labor necessary to correct defects.
- C. Defects shall include, but not be limited to, rough or substandard operation; loose, damaged, and missing parts; and abnormal deterioration of finish. Defects shall not include damage due to neglect, misuse, or situations resulting from non-performance of a manufacturer's recommended preventive maintenance schedule.
- D. All parts shall be readily available locally in the United States.
- E. Submit warranties in accordance with Division 1 - General Requirements.

PART 2 – PRODUCTS

1.8 COMPRESSORS AND ACCESSORIES

- A. Manufacturer's Reference:
 - 1. Prime manufacturer: Specifications are based on equipment identified by manufacturer's name and model to establish acceptable standard of quality, performance, features and construction.

- a. Ingersoll-Rand, Baltimore, MD, (410)-238-0542
 - 1) Model: Nirvana, IRN40H-TAS or approved equal.
 2. Alternate manufacturers: Contingent upon compliance with this specification and documentation requirements set forth in SUBMITTALS, equipment produced by other manufacturers, including the following, may be considered as an equal:
 - a. Champion, Princeton, IL (815) 875-3321
 - b. Gardner Denver Compressor Division, Quincy, IL, (217) 222-5400
 - c. Quincy Compressor, Bay Minette, AL (877) 784-6292
- B. Capacities/Dimensions:
1. Motor: 40 HP
 2. Main motor efficiency at full speed/power: 94%
 3. Target rated pressure: 65 – 150 PSIG
 4. Capacity: 41 - 161 CFM
 5. Compression stages: two
 6. Overall compressor dimensions (approximate):
 - a. Length: 64 inches
 - b. Width: 56 inches
 - c. Height: 29 inches
 - d. Weight: 1350 pounds
- C. Features/Performance/Construction
1. The air end shall have a five to six lobe combination with both male and female rotors being identical in diameter. Minimum rotor diameter shall be 85 mm.
 2. The discharge end of the rotors shall be supported by tapered roller bearings. The suction end of the rotors shall be supported by a single row of cylindrical roller bearings.
 3. The area adjacent the bearings shall be free of any obstruction to the free flow of compressor fluid. Pockets or reservoirs where fluid might collect in the bearing area shall have a magnetic drain plug to trap metallic contamination. This drain plug shall be of sufficient size and conveniently located to allow the regular cleaning of pockets of reservoirs in the bearing area.
 4. The drive rotor shall have a redundant shaft sealing arrangement. Should the primary shaft seal fail, a secondary seal shall be capable of preventing fluid from leaking out of the airend. A method of detecting a primary shaft seal failure while the machine is in operation shall be provided.
 5. The air end shall be totally enclosed by, but removable as a unit from, the air/fluid separator reservoir.
 6. Sound levels (free field conditions) 73 dB(A) when receiver mounted
 7. Operates with variable speed inverter using a hybrid permanent magnet.
 8. Conserves energy by shutting off rather than running unloaded
 9. Controller with easily adjustable operating parameters, onboard diagnostics, multiple language interface and built in energy savings calculator

10. Higher efficiency and durability through low compression ratios in each stage and reduced bearing thrust load Coolant curtain reduces energy consumption by injecting atomized oil into the compressed air stream, significantly lowering the energy required for compression
11. Blower speed adaptable to ambient temperature
12. Voltage and frequency fluctuation protection
13. Removable hinged doors allow easy access to internal components
14. Electronic drain valve (refer to part 2.3)
15. Integral dryer and filter
16. Dryer, Refrigerated
 - a. Air cooled design
 - b. Pressure dew point ISO class 5: lower than 5 degrees C (41 degrees F)
 - c. Refrigerant: R-134a
17. Filter, Air Compressor
 - a. Filter is designed with primary and final filters to remove oil and water liquid/mists and solid particles from compressed air
 - b. Filters must be capable of removing oil and water liquid/mist, when at 21 degrees C: 0.5 ppm
 - c. Filters must be capable of removing particulate matter to: 0.01 microns
 - d. Both coalescing and particle filters are employed.
 - e. Pressure gage shall be supplied to measure pressure drop across the filter.
18. Accessories:
 - a. Drive motor:
 - 1) The main drive motor shall be 40 HP rated for 460 VAC, 60 cycle, 3-phase operation with not more than a 1.15 service factor.
 - 2) The main drive motor shall have a TEFC enclosure.
 - b. Cooling system:
 - 1) The compressor shall be air-cooled.
 - 2) The cooling system shall be capable of maintaining proper compressor temperatures in ambient conditions up to 130 degrees Fahrenheit.
 - 3) Compressor fluid circulation shall be by pressure differential or positive displacement pump.
 - c. Receiver: 120 gallon
 - d. After-cooler:

- 1) An air-cooled after-cooler shall be included as an integral part of the compressor package.
 - 2) The after-cooler shall be sized to have an approach temperature of not more than 15 degrees Fahrenheit.
 - 3) A moisture separator and trap shall be included with the after-cooler.
- e. Air Dryer: 460/3/60...

19. Controls:

- a. Controls should come with a minimum 3.5” high resolution color display.
- b. Controls shall be web-enabled for remote compressor monitoring and control.
- c. Controls shall provide email notification for any alarms activated.
- d. Controls shall be able to sequence at least 2 compressors operating in lead-lag without any additional hardware or software.
- e. Controls shall be customizable.
- f. All electrical controls shall be designed and constructed in accordance with National Electrical Code (NEC) guidelines.
- g. The main control box shall be NEMA 4 design and contain starters for the drive and fan motors.
- h. All components within the main control box shall be UL and/or CSA approved or listed.
- i. The main control box shall be UL and/or CSA approved or listed.
- j. Remote mounted control panel boxes will not be accepted.
- k. Controls shall operate compressors under the following minimum conditions:
 - 1) If system demand shall fall below 20 percent of compressor capacity, the compressor shall go into an unloaded condition.
 - 2) An adjustable timer shall be provided to shut down the compressor if it runs in the unloaded mode for a predetermined length of time.
- l. The compressor shall automatically restart if the system pressure falls below the set point.
- m. Controls should display the following conditions:
 - 1) Discharge air pressure
 - 2) Discharge air temperature
 - 3) Air/fluid separator condition
 - 4) Fluid filter condition
 - 5) High temperature shut down
 - 6) Power on
 - 7) Running hours
 - 8) Compressor loaded hours
 - 9) Operating mode
 - 10) Operational alerts
 - 11) Dryer status (optional for integrated Dryer systems)

20. Utility – Connection Requirements:

- a. Electrical: 460 VAC, 3-phase, 60 Hz, 60 H.P. Provide a disconnect switch near equipment.
- b. Compressed air: 1.5” NPT outlet
- c. Provide drain near equipment.
- d. All equipment utility requirements shall be verified by the Contractor per the actual item/model procured

- D. Finish: Durable enamel using the Owner's choice from the manufacturer's standard colors.

PART 3 – EXECUTION

3.1 INSPECTION

- A. Coordinate the location of rough-in work and utility stub-outs to assure that they match with the equipment to be installed.
- B. Inspect delivered equipment for damage from shipping and exposure to weather. Compare the delivered equipment with packing lists and specifications to assure receipt of all items and specified accessories.

3.2 INSTALLATION

- A. Perform work under the direct supervision of the Foreman or Construction Superintendent who has the authority to coordinate the installation of scheduled equipment with the Architect or designated representative.
- B. Comply with requirements of Section 15211 GENERAL SERVICE COMPRESSED AIR PIPING.
- C. Install equipment in accordance with the plans, shop drawings, and manufacturer's instructions:
 - 1. Positioning: Place equipment in accordance with any noted special positioning requirements generally level (or slight slope as required by instructions), plumb, and at right angles to adjacent work.
 - 2. Fitting: Where field cutting or trimming is necessary, perform in a neat, accurate, and professional manner without damaging equipment or adjacent work.
 - 3. Anchorage: Attach equipment as directed by the Architect or designated representative. Installation fasteners shall be installed to avoid scratching or damaging adjacent surfaces.
- D. Upon completion of the work, finish surfaces shall be free of tool marks, scratches, blemishes, and stains.

3.3 TESTING

- A. After final installation is complete, and prior to authorizing payment, specified equipment shall be checked against the specifications in the presence of the Architect or designated representative using acceptance procedures provided by the manufacturer.

3.4 CLEANUP

- A. Touch-up damage to painted finishes.
- B. Wipe and clean equipment of any oil, grease, and solvents, and make ready for use.
- C. Clean the area around equipment installation and remove packing and installation debris from the job site.

- D. Notify the Architect or designated representative for acceptance inspection.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 15260

GAS BOOSTER SYSTEM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This section specifies the packaged gas booster system and installation. The Design-Builder shall assign unit responsibility to the booster system manufacturer for the equipment specified in this section
- B. Related Sections:
 - 1. Section 03300 – CAST IN PLACE CONCRETE
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15195 – FACILITY NATURAL GAS PIPING
 - 7. Section 16265 – UNINTERRUPTIBLE POWER SUPPLY (UPS)

1.3 TYPE

- A. The packaged gas booster system shall be a complete assembled unit designed for on demand operation to deliver natural gas as scheduled on the drawings
 - 1. It shall operate at ambient temperatures at the performance levels scheduled on the drawings.
 - 2. The gas booster pump shall be U.L. listed and be of the hermetically sealed, single stage, centrifugal type.
 - 3. The design of the booster shall completely enclose the impeller and explosion proof motor in an airtight housing without the requirement for external shaft seals.
- B. The system shall include, but not be limited to, a hermetically sealed centrifugal type gas booster blower, check valve, high and low gas pressure switch, isolating valves, cooling, inlet and outlet piping and flange connectors, pressure gauges, inlet low pressure switch and control system all mounted to a single structural mounting base, assembled, wired, and tested.

1.4 SUBMITTALS

Design-Builder shall submit documentation to show conformance to the specifications and material shall include but not be limited to pressure and flow performance, dimensions, weight, electrical ratings, sound data, and environmental conditions.

1.5 QUALITY ASSURANCE

A. Performance and design responsibility:

1. The packaged gas booster system shall be designed and supplied by a single manufacturer who shall assume responsibility for the adequacy of all components.
2. Electrical components and devices shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction.

1.6 PERFORMANCE REQUIREMENTS

- ### **A.**
- The booster blower system shall be designed to allow continuous operation with the specified gas over the specified flow, ambient temperature, and humidity ranges

1.7 QUALITY SYSTEM

- ### **A.**
- The manufacturer shall have an active and documented quality assurance program and the employees shall be qualified to perform their assigned manufacturing tasks.

1.8 WARRANTY

- ### **A.**
- Manufacturer shall provide a warranty for all system components for one year following acceptance by the MBTA.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- #### **A.**
- Subject to compliance with requirements, provide products by one of the following:
1. Spencer
 2. Eclipse
 3. Etter Engineering Co.
 4. Hydratron

2.2 EQUIPMENT

- #### **A.**
- Furnish and install one Natural Gas Booster System as shown on the drawings. The booster System specified herein shall be a Pre-packaged/Skid-Mounted Hermetic Natural Gas Boosting

System. The booster system shall operate in an automatic fashion and without surge or undue vibration.

B. Booster:

1. The UL-listed hermetic gas booster shall be a single stage variable speed centrifugal design built in overhung construction where the impellers are mounted on a standard motor shaft. It shall compress the design connected load in cfh of natural gas at differential (boost) pressure to produce an adjustable controlled discharge pressure range of 9.0 to 13.0 inches w.c. with inlet conditions of 70° F and 14.82 psia. The specific gravity of the gas is 0.6. Discharge pressure shall not exceed 14.0" w.c.
2. The pressure shall remain constant within 5 percent of setpoint from the surge limit to the full volume rating while the power consumption shall increase in direct proportion to the volume of gas handled at operating speed. The gas booster performance and design shall be approved and listed by Underwriters Laboratories.
3. The booster operation shall be governed by an inlet pressure sensor and transducer to prevent drawing down inlet street pressure to satisfy building requirements.

C. Motor:

1. The motor shall be capable of operating continuously in the natural gas environment. The motor shall be rated at 1/2-HP and suitable for operation on scheduled electrical characteristics at 3,500 RPM. The motor enclosure shall be explosion proof per NEMA Class- I, Division- I, Group-D classification with thermal overload protection.

D. Casing:

1. The casing shall be cylindrical fabricated steel construction. The enclosing heads shall be of similar metal, properly braced for strength. The inlet and outlet connections shall be 3-inch diameter flanged. The casing shall be leak tight to 1 0-3 cc/sec. with drive fans and motor contained within the casing shell, requiring no shaft seals.

E. Impellers:

1. The impeller peripheral speed shall not exceed 25,000 FPM. There shall be at least 1/8-inch clearance between the impeller and all stationary parts. The impeller shall be fabricated from high strength aluminum alloy, and shall be attached to the shaft by a clamped or tapered bushing hub.

F. Shaft and Bearings:

1. The motor shaft shall be supported by anti-friction grease lubricated bearings designed to absorb both thrust and radial loads. Each shaft shall be sized so that the rotating assembly shall operate at a minimum of 20% below the first critical speed.

G. Vibration Pneumatic and Performance Test:

1. Each motor and booster assembly shall be balanced for minimum vibration (1.5 mils or less for 3,500 RPM units) and shall be capable of operation throughout its design range without the need for hold down or mounting bolts. Each unit shall be given a complete

factory performance test over its full range. The results of this test shall be comparable to ASME Code Test requirements. A multiple orifice plate shall be installed on the end of a fabricated steel pipe section. For this test the pipe section will be at least one and one-half pipe diameters long and the same diameter as the blower outlet on which it will be installed. The outlet sections shall be sized for maximum velocity of 4,600 FPM and 100% rated flow.

2. Pressure taps flush with the inside diameter of the test section shall be installed at least one-half pipe diameter before the orifice plate. Sharp-edged orifices shall be opened to atmosphere; a few at a time and pressure, temperature, speed, voltage, amperage, and kilowatt readings shall be recorded for each test point.
3. The air volume at a particular discharge pressure shall then be read from a calibrated orifice chart and the number of open orifices shall multiply this volume. On request, certified performance curves shall then be supplied showing the exact performance and efficiencies of each specific machine. Prior tests on similar or identical machines shall not be acceptable. The skid shall be pneumatically leak tested at 5 psig.

H. Flexible Joints:

1. Expansion joints will be supplied for the inlet and discharge of the gas booster and suitable for natural gas service. Flexible joints will be of the same diameter as the gas booster's inlet and discharge and shall serve as vibration isolation between the gas booster and the gas train piping.

I. Booster Isolation Valves:

1. Lubricated plug valves will be supplied on the inlet and discharge of each gas booster. Valves shall be gas tight and approved for natural gas service. Valves will be of the same diameter as the gas booster inlet and discharge and shall serve to isolate gas flow to and from each gas booster.

J. Low Pressure Gauges:

1. One UL Listed, manual reset type low inlet pressure switch will be supplied. The switch will be used to shut down the on-line booster in the event of below normal supply pressure. The switch will be housed in a NEMA 4 enclosure, and preset at 3.0 W.C.

K. Booster Pressure Gauges:

1. Pressure gauges will be supplied on the inlet main to the gas booster and at the discharge of the gas booster. Gauges shall be suitably scaled and shall be suitable by the manufacturer for natural gas service. Gauges will include shut-off cocks.

L. Booster Recirculation Loop:

1. A recirculation loop from the gas booster discharge to the inlet will be supplied. The recirculation loop will include a manual adjustment valve designed for natural gas service. The loop shall serve to insure a minimum/adequate gas flow is maintained through the gas booster and that slight heat rise of gas is dissipated during low or no flow operation of the gas booster skid.

M. Control Panel:

1. NEMA 4 – Indoor Rated Control Panel for the operation of one (1) Natural Gas Gas Booster. The Control Panel will be UL Stamped and built in accordance with UL508A Standards for Industrial Control Panels and shall include:
 - a. One (1) OSHA type lock-out/tag-out circuit breaker disconnect switch
 - b. One (1) ATL magnetic, non-reversing motor starter
 - c. One (1) Control Transformer
 - d. Four (4) Pilot Lights
 - 1) Power "ON"
 - 2) Gas Booster "ON"
 - 3) Low Inlet Pressure
 - 4) High Motor Temperature
 - e. One (1) Hand-Off-AUTO Selector Switch for Gas Booster control.
 - 1) HAND - Allows Manual Start/Stop of Gas Booster via Local Start/Stop Push Button.
 - 2) OFF - Off
 - 3) AUTO - Allows Automatic Start/Stop of Gas Booster via remote signal (dry contact)
 - f. Loss of Power Sequencing - In the event of supply power loss to the Control, the Control Panel shall "power up" automatically upon restoration of power.
 - 1) HAND - Gas Booster has to be "Manually" Restarted
 - 2) AUTO - Gas Booster shall "Automatically" Start if the remote dry contact from the process controls is maintained in the "closed" position (i.e.: calling for the Gas Booster to run).
 - g. Three (3)-Push Buttons
 - 1) START - Manual Start of Gas Booster (Hand)
 - 2) STOP - Manual Stop of Gas Booster (Hand)
 - 3) RESET - Alarm Reset.
 - h. One (1)-Elapsed "Run Time" Hour Meter.
 - i. Provisions (dry contact) for remote start/shutdown of Gas Booster via a signal from BMS or process controls.
 - j. Provisions for a Low Inlet Gas Pressure Switch to shutdown the Gas Booster, energize an Alarm Light on the Control Panel, and energize a Common Alarm Relay.
 - k. Provision for a N.C. Motor High Temperature Switch to shutdown the Gas Booster, energize an Alarm Light on the Control Panel, and energize a Common Alarm Relay

- 1. Provisions for a Motor Starter Overload Relay to shutdown the Gas Booster. Provision (dry contact) to activate a remote alarm when panel common alarm is activated. Provision to Automatically Re-Set Alarms upon restoration of power.
 - m. Miscellaneous components and hardware to assure proper functioning.
- N. Uninterruptible Power System:
- 1. Refer to Specification section 16265 – UNINTERRUPTIBLE POWER SUPPLY (UPS)
- O. Skid:
- 1. All above items shall be factory assembled, pre-wired, pre-piped and factory mounted on a common factory furnished steel skid. The overall skid footprint dimensions shall not exceed 36 inches wide x 50 inches in length.
- P. Auxiliary Gas Components:
- 1. The auxiliary non-Booster gas components shall be selected and supplied by the gas booster manufacturer and field installed by Design-Builder upstream and downstream of the Skid Assembly.
- Q. Full Booster System Bypass:
- 1. Design-Builder shall field install a full booster system by-pass line from a point in the supply main, upstream of the booster system to a point in the main downstream of the booster system PRV. The bypass shall include a 2-inch diameter NPT check valve and a 2-inch diameter full-open area NPT lubricated plug valve approved for natural gas service. The by- pass shall serve as a means to enable full gas flow at available un-boosted gas pressure should the booster system be out of service.
- R. Upstream Check Valve:
- 1. Design-Builder shall field install a 2-inch diameter NPT disc type check valve in the in let supply main, upstream of the gas booster system inlet. The valve shall be installed in a horizontal position. The valve shall be FM-Approved for natural gas service and shall have a maximum rated pressure drop not to exceed 0.5 inch W.C. at full gas demand being served by the gas booster system
- S. Downstream Gas Pressure Regulator:
- 1. The Design-Builder shall field install a Pressure Regulator (PRV) to be supplied by the gas booster manufacturer in a per manufacturer's instructions in straight sections of piping just downstream of the gas booster system common gas discharge. The PRVs shall be a direct- acting type with lock-up feature and approved for natural gas service and installed with two (2) 2" NPT full open area type lubricated plug isolation valves and a discharge pressure gauge. The PRV shall serve to provide constant controlled delivery pressure range of 9.0 to 13.0 inches W.C.
- T. Start-Up:
- 1. Design-Builder shall provide start-up service of the system by an authorized factory-trained manufacturer's representative. Start-up service shall include inspection of overall

installation, initial start-up and running of the system, confirmation of all automated and alarm functions, and operational and maintenance instructions to facility personnel.

2. Design-Builder shall provide written report on start-up test sequence of UPS Electrical Power Supply prior to gas booster skid.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Coordinate concrete pad dimensions and equipment bolt down pattern prior to the start of work.
- B. All gas compressor booster pumps shall be installed and maintained according to the manufacturer's instructions.

3.2 INSTALLATION

- A. General Installation Requirements:
 1. Equipment Mounting: Install packaged gas boosters on concrete bases using elastomeric pads. Comply with requirements in Section 03300 - CAST IN PLACE CONCRETE. Comply with requirements for vibration isolation devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
 2. Minimum Deflection: 1/4 inch
 3. Bolts to elevations required for proper attachment to equipment.
- B. Arrange equipment so controls and devices are accessible for servicing.
- C. Maintain manufacturer's recommended clearances for service and maintenance
- D. A gas~air check valve must always be installed ahead of the booster pump, between the pump and the meter, to prevent an accidental flow toward the meter.
- E. If several appliances are not on the same fuel line as an appliance being supplied gas at an elevated pressure from a booster pump, a bypass is recommended around the booster pump provided that the appliances can operate on low pressure.
- F. The method of connection between the inlet valve and the booster pump and the outlet of the booster pump and the fuel line shall be made as shown on the drawings. The Gas company field representative must approve the method of connection.
- G. A booster pump will be interlocked with the appliances the booster supplies. It is recommended that the booster pump be wired through the control panel interlocked with the equipment that needs to operate at elevated pressure.
- H. The acceptable pressure switch with manual reset must be installed between the utility company meter and the pump to shut down the booster in the event of low inlet pressure.

1. Normally open, break on a fall in inlet pressure, setpoint: 3.5" W.C.

3.3 CONNECTIONS

- A. Comply with requirements for piping specified in Section 15195 - FACILITY NATURAL-GAS PIPING. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Comply with requirements for piping specified in Section 15195 - FACILITY NATURAL-GAS PIPING. Drawings indicate general arrangement of piping, fittings, and specialties.

3.4 IDENTIFICATION

- A. Identify gas booster and components. Comply with requirements for identification specified in Section 15077- IDENTIFICATION FOR PIPING AND EQUIPMENT.

3.5 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform the following startup service.
 1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Check for lubricating oil in lubricated-type equipment.
 3. Test start-up checks using UPS electrical power according to manufacturer's written instructions.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain the gas booster.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15400

PLUMBING FIXTURES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15084 – PLUMBING EQUIPMENT INSULATION
 - 6. Section 15085 – PLUMBING PIPING INSULATION
 - 7. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 8. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 9. Section 15127 – METERS AND GAGES FOR PIPING
 - 10. Section 15140 – DOMESTIC WATER PIPING
 - 11. Section 15145 – DOMESTIC WATER PIPING SPECIALTIES
 - 12. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 13. Section 15155 – SANITARY WASTE PIPING SPECIALTIES

1.2 SUMMARY

- A. This Section includes the following conventional plumbing fixtures and related components:
 - 1. Faucets for lavatories.
 - 2. Kitchen Sink Faucets
 - 3. Mop Receptor Faucets
 - 4. Flushometers.
 - 5. Toilet seats.
 - 6. Protective shielding guards.
 - 7. Fixture supports.
 - 8. Water closets.
 - 9. Urinals.
 - 10. Lavatories.
 - 11. Commercial Sink
 - 12. Mop Receptors
 - 13. Kitchen Sinks
 - 14. Hose Stations

1.3 DEFINITIONS

- A. ABS: Acrylonitrile-butadiene-styrene plastic.

- B. Accessible Fixture: Plumbing fixture that can be approached, entered, and used by people with disabilities.
- C. Fitting: Device that controls the flow of water into or out of the plumbing fixture. Fittings specified in this Section include supplies and stops, faucets and spouts, shower heads and tub spouts, drains and tailpieces, and traps and waste pipes. Piping and general-duty valves are included where indicated.
- D. Solid Surface: Nonporous, homogeneous, cast-polymer-plastic material with heat-, impact-, scratch-, and stain-resistance qualities.

1.4 SUBMITTALS

- A. Product Data: For each type of plumbing fixture indicated. Include selected fixture and trim, fittings, accessories, appliances, appurtenances, equipment, and supports. Indicate materials and finishes, dimensions, construction details, and flow-control rates.
- B. Shop Drawings: Diagram power, signal, and control wiring.
- C. Operation and Maintenance Data: For plumbing fixtures to include in, operation, and maintenance manuals.
- D. Warranty: Special warranty specified in this Section.

1.5 QUALITY ASSURANCE

- A. Source Limitations: Obtain plumbing fixtures, faucets, and other components of each category through one source from a single manufacturer.
 - 1. Exception: If fixtures, faucets, or other components are not available from a single manufacturer, obtain similar products from other manufacturers specified for that category.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Regulatory Requirements: Comply with requirements in ICC A117.1, "Accessible and Usable Buildings and Facilities"; Public Law 90-480, "Architectural Barriers Act"; and Public Law 101-336, "Americans with Disabilities Act"; for plumbing fixtures for people with disabilities.
- D. Regulatory Requirements: Comply with requirements in Public Law 102-486, "Energy Policy Act," about water flow and consumption rates for plumbing fixtures.
- E. Regulatory Requirements: All fixtures and trim shall be approved by the Commonwealth of Massachusetts Board of State Examiners of Plumbers and Gas Fitters, including provision of the current approval number for each item. This applies to all items to be furnished and installed, whether specified herein or not. All specification listings are intended to establish a standard of quality for each application and does not imply that any specific fixture has obtained or has a current Massachusetts Plumbing Board approval.
- F. NSF Standard: Comply with NSF 61, "Drinking Water System Components--Health Effects," for fixture materials that will be in contact with potable water.

- G. Select combinations of fixtures and trim, faucets, fittings, and other components that are compatible.
- H. Comply with the following applicable standards and other requirements specified for plumbing fixtures:
 - 1. Vitreous-China Fixtures: ASME A112.19.2M.
 - 2. Water-Closet, Flush Valve, Tank Trim: ASME A112.19.5.
 - 3. Water-Closet, Flushometer Tank Trim: ASSE 1037.
- I. Comply with the following applicable standards and other requirements specified for lavatory faucets:
 - 1. Faucets: ASME A112.18.1.
 - 2. NSF Potable-Water Materials: NSF 61.
 - 3. Supply Fittings: ASME A112.18.1.

1.6 WARRANTY

- A. Special Warranties: Manufacturer's standard form in which manufacturer agrees to repair or replace components of whirlpools that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures of unit shell.
 - b. Faulty operation of controls, blowers, pumps, heaters, and timers.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal use.
 - 2. Warranty Period for Commercial Applications: One year(s) from date of Substantial Completion.

1.7 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Faucet Cartridges and O-Rings: Equal to 3 of each type used.
 - 2. Flushometer Valve, Repair Kits: Equal to 2 of each type used.

PART 2 - PRODUCTS

2.1 LAVATORY FAUCETS

- A. Lavatory Faucets, LAV-1:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Chicago Faucets
 - b. Delta Faucet company
 - c. Moen Incorporated
 - d. Speakman company
 - e. T & S Brass and Bronze Works Inc.

2. Description: Metering Faucet – Refer to Plumbing Fixture Schedule on Drawings.

2.2 KITCHEN SINK FAUCETS

A. Kitchen Sink Faucets

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Chicago Faucets
 - b. Delta Faucet company
 - c. Moen Incorporated
 - d. Speakman company
 - e. T & S Brass and Bronze Works Inc.
2. Description: Kitchen faucet, three-hole fixture. Include hot- and cold-water indicators; coordinate faucet inlets with supplies and fixture holes; coordinate outlet with spout and fixture receptor.
 - a. Body Material: Commercial, chrome plated solid brass
 - b. Finish: Polished chrome plate
 - c. Maximum Flow Rate: 2.2 gpm.
 - d. Mixing Valve: Two-lever handle.
 - e. Backflow Protection Device for Hose Outlet: None
 - f. Centers: 8 inches
 - g. Mounting: Deck.
 - h. Handles: Wing Lever
 - i. Inlets: NPS 1/2female shank.
 - j. Spout Type: Swivel, chrome plated solid brass.
 - k. Spout Outlet: Hose thread.
 - l. Vacuum Breaker: No.
 - m. Operation: Compression, manual.
 - n. Tempering Device: Thermostatic.

2.3 MOP RECEPTOR FAUCET

A. Mop Receptor Faucets:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Chicago Faucets
 - b. Delta Faucet company
 - c. Moen Incorporated
 - d. Speakman company
 - e. T & S Brass and Bronze Works Inc.
2. Description: Service sink faucet with stops in shanks, vacuum breaker, hose-thread outlet, and pail hook. Include hot and cold-water indicators; coordinate faucet inlets with supplies and fixture holes; coordinate outlet with spout and fixture receptor.
 - a. Body Material: Commercial, solid brass

- b. Finish: Polished chrome plate
- c. Maximum Flow Rate: 2.5 gpm.
- d. Mixing Valve: Two-lever handle.
- e. Backflow Protection Device for Hose Outlet: Required
- f. Centers: 8 inches
- g. Mounting: Back/wall, concealed.
- h. Handles: Lever
- i. Inlets: NPS 1/2female shank.
- j. Spout Type: Rigid, solid brass with wall brace.
- k. Spout Outlet: Hose thread.
- l. Vacuum Breaker: Required.
- m. Operation: Compression, manual.
- n. Drain: Grid.

2.4 FLUSHOMETERS

A. Flushometers:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Sloan Valve Company.
 - b. Toto
- 2. Description: Manual Flushometer – Refer to Plumbing Fixture Schedule on Drawings.
- 3. Ultra low-flow, 0.50 gpf.

2.5 TOILET SEATS

A. Toilet Seats:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bemis Manufacturing Company.
 - b. Church Seats.
 - c. Kohler Co.
- 2. Description: Toilet seat for water-closet-type fixture.
 - a. Material: Molded, solid plastic with antimicrobial agent.
 - b. Configuration: Open front without cover.
 - c. Size: Elongated
 - d. Hinge Type: SC, self-sustaining, check.
 - e. Class: Standard commercial.
 - f. Color: White.

2.6 PROTECTIVE SHIELDING GUARDS

A. Protective Shielding Pipe Covers:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

- a. McGuire Manufacturing Co., Inc.
 - b. TRUEBRO, Inc.
 - c. Zurn Plumbing Products Group; Tubular Brass Plumbing Products Operation.
2. Description: Manufactured plastic wraps for covering plumbing fixture hot- and cold-water supplies and trap and drain piping. Comply with Americans with Disabilities Act (ADA) requirements.

2.7 FIXTURE SUPPORTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Josam Company.
2. Smith, Jay R. Mfg. Co.
3. Tyler Pipe; Wade Div.
4. Watts Drainage Products Inc.; a div. of Watts Industries, Inc.
5. Zurn Plumbing Products Group; Specification Drainage Operation.

B. Water-Closet Supports:

1. Description: Combination carrier designed for accessible mounting height of wall-mounting, water-closet-type fixture. Include single or double, vertical or horizontal, hub-and-spigot or hubless waste fitting as required for piping arrangement; faceplates; couplings with gaskets; feet; and fixture bolts and hardware matching fixture. Include additional extension coupling, faceplate, and feet for installation in wide pipe space.

C. Urinal Supports:

1. Description: Type I, urinal carrier with fixture support plates and coupling with seal and fixture bolts and hardware matching fixture for wall-mounting, urinal-type fixture. Include steel uprights with feet.
2. Accessible-Fixture Support: Include rectangular steel uprights.

2.8 WATER CLOSETS

A. Water Closets:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. American Standard.
 - b. Kohler Co.
 - c. Sloan
 - d. Toto
2. Description: Accessible, floor mounting, floor-outlet, vitreous-china fixture designed for flushometer valve operation.
 - a. Style: One piece.

- 1) Bowl Type: Elongated floor mounted with siphon-jet design. Include bolt caps matching fixture.
 - 2) Height: Accessible.
 - 3) Design Consumption: 1.6 gal./flush.
 - 4) Trip Mechanism: Lever-handle actuator.
 - 5) Color: White.
- b. Supply: 1½" chrome-plated brass or copper with screwdriver stop.
- c. Style: Flushometer valve.
- 1) Bowl Type: Elongated with siphon-jet design. Include bolt caps matching fixture.
 - 2) Height: Accessible.
 - 3) Design Consumption: 1.28 gal./flush.
 - 4) Color: White.
- d. Flushometer: WC-1.
- e. Toilet Seat: WC-1.

2.9 URINALS

A. Urinals:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. American Standard.
 - b. Kohler Co.
 - c. Sloan
2. Description: Accessible, wall mounting, back-outlet, vitreous-china fixture designed for flushometer valve operation.
 - a. Type: Siphon jet.
 - b. Strainer or Trapway: Open trapway with integral trap.
 - c. Design Consumption: 0.5 gal./flush.
 - d. Color: White.
 - e. Supply Spud Size: NPS 3/4
 - f. Outlet Size: NPS 2.
 - g. Flushometer: UR-1.
 - h. Fixture Support: Urinal UR-1 chair carrier.

2.10 LAVATORIES

A. Lavatories, LAV-1:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. American Standard.
 - b. Kohler Co.
 - c. Sloan
 - d. Toto

2. Description: Description: Under counter-mounting, stainless-steel fixture.
 - a. Type: Wall Mount or Counter Mount to suit installation.
 - b. Refer to Schedule on Drawings for Description and Trim

2.11 COMMERCIAL SINKS

A. Commercial Sinks:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Elkay Manufacturing Co.
 - b. Just Manufacturing Company.
2. Description: One-compartment, counter-mounting, stainless-steel commercial sink with backsplash.
 - a. Overall Dimensions: Refer to drawings
 - b. Metal Thickness: 0.050 inch.
 - c. Compartment:
 - 1) Dimensions: Provide sink that will fit into existing countertop opening.
 - 2) Drain: NPS 1-1/2 tailpiece with stopper and flap for garbage disposal.
 - a) Location: Centered in compartment.
 - d. Faucet(s): Sink KS
 - 1) Number Required: One.
 - 2) Mounting: Deck.
 - e. Supplies: NPS 1/2 chrome-plated copper with stops or shutoff valves.
 - f. Drain Piping: NPS 1-1/2 chrome-plated, cast-brass P-trap; 0.045-inch-thick tubular brass waste to wall; and wall escutcheon(s).

2.12 MOP RECEPTORS

A. Mop Receptor:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Crane Plumbing, L.L.C./Fiat Products.
 - b. Eljer
 - c. Serviceceptor
2. Description: Flush-to-wall, floor-mounting, terrazzo fixture with rim guard.
 - a. Shape: Rectangular.
 - b. Size: 24 by 36 inches.
 - c. Height: 12 inches.

- d. Tiling Flange: Coordinate with GC
- e. Rim Guard: On all top surfaces.
- f. Color: Not applicable.
- g. Refer to drawings for additional information.
- h. Drain Grid with NPS 3 Outlet

2.13 HOSE STATIONS

A. Hose station:

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Straham Valves, Inc.
- 2. Description: Wall mounted hose station
 - a. Stainless steel hose rack
 - b. Single control valve
 - c. Mounting attachments

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in of water supply and sanitary drainage and vent piping systems to verify actual locations of piping connections before plumbing fixture installation.
- B. Examine cabinets, counters, floors, and walls for suitable conditions where fixtures will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Assemble plumbing fixtures, trim, fittings, and other components according to manufacturers' written instructions.
- B. Install off-floor supports, affixed to building substrate, for wall-mounting fixtures.
 - 1. Use carrier supports with waste fitting and seal for back-outlet fixtures.
 - 2. Use carrier supports without waste fitting for fixtures with tubular waste piping.
 - 3. Use chair-type carrier supports with rectangular steel uprights for accessible fixtures.
- C. Install back-outlet, wall-mounting fixtures onto waste fitting seals and attach to supports.
- D. Install floor-mounting fixtures on closet flanges or other attachments to piping or building substrate.
- E. Install wall-mounting fixtures with tubular waste piping attached to supports.
- F. Install fixtures level and plumb according to roughing-in drawings.

- G. Install water-supply piping with stop on each supply to each fixture to be connected to water distribution piping. Attach supplies to supports or substrate within pipe spaces behind fixtures. Install stops in locations where they can be easily reached for operation.
- H. Install trap and tubular waste piping on drain outlet of each fixture to be directly connected to sanitary drainage system.
- I. Install tubular waste piping on drain outlet of each fixture to be indirectly connected to drainage system.
- J. Install flushometer valves for accessible water closets and urinals with handle mounted on wide side of compartment. Install other actuators in locations that are easy for people with disabilities to reach.
- K. Install toilet seats on water closets.
- L. Install traps on fixture outlets.
 - 1. Exception: Omit trap on fixtures with integral traps.
- M. Install escutcheons at piping wall ceiling penetrations in exposed, finished locations and within cabinets and millwork. Use deep-pattern escutcheons if required to conceal protruding fittings. Escutcheons are specified in Division 15 Section 15051 "BASIC MATERIALS AND METHODS FOR PLUMBING WORK."
- N. Seal joints between fixtures and walls, floors, and countertops using sanitary-type, one-part, mildew-resistant silicone sealant. Match sealant color to fixture color. Sealants are specified in Division 7 Section "Joint Sealants."
- O. Install hose stations four feet above finished floor located as indicated on drawings. Install hose stations in accordance with manufacturer's instructions.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Division 15 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect fixtures with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.

3.4 FIELD QUALITY CONTROL

- A. Verify that installed plumbing fixtures are categories and types specified for locations where installed.
- B. Check that plumbing fixtures are complete with trim, faucets, fittings, and other specified components.
- C. Inspect installed plumbing fixtures for damage. Replace damaged fixtures and components.
- D. Test installed fixtures after water systems are pressurized for proper operation. Replace malfunctioning fixtures and components, then retest. Repeat procedure until units operate properly.

3.5 ADJUSTING

- A. Operate and adjust faucets and controls. Replace damaged and malfunctioning fixtures, fittings, and controls.
- B. Adjust water pressure at faucets and flushometer valves to produce proper flow and stream.
- C. Replace washers and seals of leaking and dripping faucets and stops.

3.6 CLEANING

- A. Clean fixtures, faucets, and other fittings with manufacturers' recommended cleaning methods and materials. Do the following:
 - 1. Remove faucet spouts and strainers, remove sediment and debris, and reinstall strainers and spouts.
 - 2. Remove sediment and debris from drains.
- B. After completing installation of exposed, factory-finished fixtures, faucets, and fittings, inspect exposed finishes and repair damaged finishes.

3.7 PROTECTION

- A. Provide protective covering for installed fixtures and fittings.
- B. Do not allow use of plumbing fixtures for temporary facilities unless approved in writing by MBTA.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15412

EMERGENCY PLUMBING FIXTURES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Eyewash equipment.
 - 2. Water-tempering equipment.

1.3 DEFINITIONS

- A. Accessible Fixture: Emergency plumbing fixture that can be approached, entered, and used by people with disabilities.
- B. Plumbed Emergency Plumbing Fixture: Fixture with fixed, potable-water supply.
- C. Tepid: Moderately warm; temperature between 95 degrees F. and 100 degrees F.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include flow rates and capacities, furnished specialties, and accessories.
- B. Shop Drawings: Diagram power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Product Certificates: Submit certificates of performance testing specified in "Source Quality Control" Article.
- B. Field quality-control test reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For emergency plumbing fixtures to include in operation and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ANSI Standard: Comply with ANSI Z358.1, "Emergency Eyewash and Shower Equipment."
- C. NSF Standard: Comply with NSF 61, "Drinking Water System Components - Health Effects," for fixture materials that will be in contact with potable water.
- D. Regulatory Requirements: Comply with requirements in ICC/ANSI A117.1, "Accessible and Usable Buildings and Facilities " Public Law 101-336, "Americans with Disabilities Act"; for plumbing fixtures for people with disabilities.

PART 2 - PRODUCTS

2.1 EYEWASH EQUIPMENT

- A. Standard, Wall-Mounted, Plumbed Eyewash Units, EEW.
 - 1. Manufacturers: Subject to compliance with requirements, provide comparable product by one of the following:
 - a. Acorn Safety; a division of Acorn Engineering Company.
 - b. Bradley Corporation.
 - c. Haws Corporation.
 - d. Speakman Company.
 - 2. Capacity: Not less than 0.4 gpm for at least 15 minutes.
 - 3. Supply Piping: NPS 1/2 chrome-plated brass or stainless steel with flow regulator and stay-open control valve.
 - 4. Control-Valve Actuator: Paddle
 - 5. Spray-Head Assembly: Two receptor-mounted spray heads.
 - 6. Receptor: Plastic bowl.
 - 7. Drain Piping: NPS 1-1/4 minimum, chrome-plated brass, receptor drain, P-trap, waste to wall, and wall flange complying with ASME A112.18.2/CSA B125.2.
 - 8. Mounting: Wall bracket.

2.2 WATER-TEMPERING EQUIPMENT

- A. Hot- and Cold-Water, Water-Tempering Equipment,
 - 1. Basis-of-Design Product: Subject to compliance with requirements, provide comparable product by one of the following:
 - a. Acorn Safety; a division of Acorn Engineering Company.
 - b. Bradley Corporation.
 - c. Haws Corporation.
 - d. Lawler Manufacturing Co., Inc.
 - e. Leonard Valve Company.
 - f. Powers; a division of Watts Water Technologies, Inc.

- g. Speakman Company.
- 2. Description: Factory-fabricated equipment with thermostatic mixing valve.
 - a. Thermostatic Mixing Valve: Designed to provide 85 deg F tepid, potable water at emergency plumbing fixtures, to maintain temperature at plus or minus 5 deg F throughout required 15-minute test period, and in case of unit failure to continue cold-water flow, with union connections, controls, metal piping, and corrosion-resistant enclosure.
 - b. Supply Connections: For hot and cold water.
- B. Electric Water-Tempering Equipment,:
 - 1. Basis-of-Design Product: Subject to compliance with requirements, provide comparable product by one of the following:
 - a. Chronomite Laboratories, Inc.; a division of Acorn Engineering Company.
 - 2. Description: Factory-fabricated equipment with electric heating.
 - a. Heating System: Electric, designed to provide 85 deg F tepid, potable water at emergency plumbing fixtures, to maintain temperature at plus or minus 5 deg F throughout required 15-minute test period, and in case of unit failure to continue cold-water flow, with union connections, controls, heating coils, high-temperature-limit device, metal piping, and corrosion-resistant enclosure.
 - 1) Electrical Characteristics: 208-V ac, 277-V ac, single phase, 60 Hz.

2.3 SOURCE QUALITY CONTROL

- A. Certify performance of emergency plumbing fixtures by independent testing organization acceptable to authorities having jurisdiction.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine roughing-in for water and waste piping systems to verify actual locations of piping connections before plumbed emergency plumbing fixture installation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EMERGENCY PLUMBING FIXTURE INSTALLATION

- A. Assemble emergency plumbing fixture piping, fittings, control valves, and other components.
- B. Install fixtures level and plumb.

- C. Fasten fixtures to substrate.
- D. Install shutoff valves in water-supply piping to fixtures. Use ball, gate, or globe valve if specific type valve is not indicated. Install valves chained or locked in open position if permitted. Install valves in locations where they can easily be reached for operation. Comply with requirements for valves specified in Section 15111 "General-Duty Valves for Plumbing Piping."
 - 1. Exception: Omit shutoff valve on supply to group of plumbing fixtures that includes emergency equipment.
 - 2. Exception: Omit shutoff valve on supply to emergency equipment if prohibited by authorities having jurisdiction.
- E. Install dielectric fitting in supply piping to emergency equipment if piping and equipment connections are made of different metals. Comply with requirements for dielectric fittings specified in Section 15140 "DOMESTIC WATER PIPING."
- F. Install thermometers in supply and outlet piping connections to water-tempering equipment. Comply with requirements for thermometers specified in Section 15126 "METERS AND GAGES FOR PIPING."
- G. Install trap and waste piping on drain outlet of emergency equipment receptors that are indicated to be directly connected to drainage system. Comply with requirements for waste piping specified in Section 15150 "SANITARY WASTE AND VENT PIPING."
- H. Install indirect waste piping on drain outlet of emergency equipment receptors that are indicated to be indirectly connected to drainage system. Comply with requirements for waste piping specified in Section 15150 "SANITARY WASTE AND VENT PIPING."
- I. Install escutcheons on piping wall and ceiling penetrations in exposed, finished locations. Comply with requirements for escutcheons specified in Section 15051 "GENERAL MATERIALS AND METHODS FOR PLUMBING WORK."
- J. Fill self-contained fixtures with flushing fluid.

3.3 CONNECTIONS

- A. Connect cold-water-supply piping to plumbed emergency plumbing fixtures not having water-tempering equipment. Comply with requirements for cold-water piping specified in Section 15140 "DOMESTIC WATER PIPING."
- B. Connect hot- and cold-water-supply piping to hot- and cold-water, water-tempering equipment. Connect output from water-tempering equipment to emergency plumbing fixtures. Comply with requirements for hot- and cold-water piping specified in Section 15140 "DOMESTIC WATER PIPING."
- C. Connect cold water and electrical power to electric heating water-tempering equipment. Comply with requirements for cold-water piping specified in Section 15140 "DOMESTIC WATER PIPING."
- D. Directly connect emergency plumbing fixture receptors with trapped drain outlet to sanitary waste and vent piping. Comply with requirements for waste piping specified in Section 15150 "SANITARY WASTE AND VENT PIPING."

- E. Indirectly connect emergency plumbing fixture receptors without trapped drain outlet to sanitary waste or storm drainage piping.
- F. Where installing piping adjacent to emergency plumbing fixtures, allow space for service and maintenance of fixtures.

3.4 IDENTIFICATION

- A. Install equipment nameplates or equipment markers on emergency plumbing fixtures and equipment and equipment signs on water-tempering equipment. Comply with requirements for identification materials specified in Section 15076 "IDENTIFICATION FOR PLUMBING PIPING AND EQUIPMENT."

3.5 FIELD QUALITY CONTROL

- A. Mechanical-Component Testing: After plumbing connections have been made, test for compliance with requirements. Verify ability to achieve indicated capacities.
- B. Tests and Inspections:
 - 1. Perform each visual and mechanical inspection.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Emergency plumbing fixtures and water-tempering equipment will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Adjust or replace fixture flow regulators for proper flow.
- B. Adjust equipment temperature settings.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15485

ELECTRIC WATER HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 03300 - CAST IN PLACE CONCRETE
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15062 – HANGER AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15084 – PLUMBING EQUIPMENT INSULATION
 - 7. Section 15085 – PLUMBING PIPING INSULATION
 - 8. Section 15093 – SLEEVES AND SLEEVES SEALS FOR PIPING
 - 9. Section 15012 – GENERAL-DUTY VALVES FOR PIPING
 - 10. Section 15127 – METERS AND GAGES FOR PIPING
 - 11. Section 15140 – DOMESTIC WATER PIPING
 - 12. Section 15145 – DOMESTIC WATER PIPING SPECIALTIES

1.2 SUMMARY

- A. Section Includes:
 - 1. Commercial, electric, storage, domestic-water heaters.
 - 2. Domestic-water heater accessories.
 - 3. Thermostat-control, electric, tankless, domestic water heaters.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Commercial domestic-water heaters shall withstand the effects of earthquake motions determined per ASCE/SEI 7.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and size of domestic-water heater indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Shop Drawings:
 - 1. Wiring Diagrams: For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For commercial domestic-water heaters, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Product Certificates: For each type of commercial, electric, domestic-water heater, from manufacturer.
- C. Domestic-Water Heater Labeling: Certified and labeled by testing agency acceptable to authorities having jurisdiction.
- D. Source quality-control reports.
- E. Field quality-control reports.
- F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electric, domestic-water heaters to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
- C. ASME Compliance: Where ASME-code construction is indicated, fabricate and label commercial, domestic-water heater storage tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
- D. NSF Compliance: Fabricate and label equipment components that will be in contact with potable water to comply with NSF 61, "Drinking Water System Components - Health Effects."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.9 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of electric, domestic-water heaters that fail in materials or workmanship within specified warranty period.
1. Failures include, but are not limited to, the following:
 - a. Structural failures including storage tank and supports.
 - b. Faulty operation of controls.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal use.
 2. Warranty Periods: From date of Substantial Completion.
 - a. Electric, Tankless, Domestic-Water Heater and Commercial, Electric, Storage, Domestic-Water Heaters:
 - 1) Storage Tank: Five years.
 - 2) Controls and Other Components: Five years.
 - b. Compression Tanks: Five years.

PART 2 - PRODUCTS

2.1 COMMERCIAL, ELECTRIC, DOMESTIC-WATER HEATERS

- A. Commercial, Electric, Storage, Domestic-Water Heaters:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Bradford White Corporation.
 - b. Rheem Manufacturing Company.
 - c. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 2. Standard: UL 1453.
 3. Storage-Tank Construction: Non-ASME-code, steel vertical arrangement.
 - a. Tappings: Factory fabricated of materials compatible with tank and piping connections. Attach tappings to tank before testing.
 - 1) NPS 2 and Smaller: Threaded ends per ASME B1.20.1.
 - 2) NPS 2-1/2 and Larger: Flanged ends per ASME B16.5 for steel and stainless-steel flanges, and per ASME B16.24 for copper and copper-alloy flanges.
 - b. Pressure Rating: 150 psig.
 - c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending lining material into tappings.
 4. Factory-Installed Storage-Tank Appurtenances:

- a. Anode Rod: Replaceable magnesium.
 - b. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
 - c. Insulation: Comply with ASHRAE/IESNA 90.1.
 - d. Jacket: Steel with enameled finish.
 - e. Heating Elements: Electric, screw-in or bolt-on immersion type arranged in multiples of three.
 - f. Temperature Control: Adjustable thermostat.
 - g. Safety Controls: High-temperature-limit and low-water cutoff devices or systems.
 - h. Relief Valves: ASME rated and stamped for combination temperature-and-pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
5. Special Requirements: NSF 5 construction.

2.2 ELECTRIC, TANKLESS, DOMESTIC-WATER HEATER

A. Thermostat-Control, Electric, Tankless, Domestic-Water Heaters.

- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eemax, Inc.
 - b. Bradford White, Inc.
 - c. Rheem
 - d. Keltech, Inc. Smith, A.O. Water Products CO.; a division of A.O. Smith Corporation
- 2. Standard: UL 499 for electric, tankless (domestic-water heater) heating appliance.
- 3. Construction: Copper piping or tubing complying with NSF 61 barrier materials for portable water, without storage capacity.
 - a. Connection: ASME B1.20.1 pipe thread.
 - b. Pressure Rating: 150 psig.
 - c. Heating Element: Resistance heating system.
 - d. Temperature Control: Thermostat
 - e. Safety Control: High –temperature-limit cutoff device or system.
 - f. Jacket: Aluminum or steel with enameled finish or plastic.

B. Support: Bracket for wall mounting.

2.3 DOMESTIC-WATER HEATER ACCESSORIES

A. Domestic-Water Compression Tanks:

- 1. Manufacturers: Subject to compliance with requirements:
 - a. AMTROL Inc.
 - b. Flexcon Industries.
 - c. Honeywell International Inc.
 - d. Pentair Pump Group (The); Myers.

- e. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - f. State Industries.
 - g. Taco, Inc.
2. Description: Steel pressure-rated tank constructed with welded joints and factory-installed butyl-rubber diaphragm. Include air precharge to minimum system-operating pressure at tank.
 3. Construction:
 - a. Tappings: Factory-fabricated steel, welded to tank before testing and labeling. Include ASME B1.20.1 pipe thread.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.
 - c. Air-Charging Valve: Factory installed.
- B. Drain Pans: Corrosion-resistant metal with raised edge. Comply with ANSI/CSA LC 3. Include dimensions not less than base of domestic-water heater, and include drain outlet not less than NPS 3/4 with ASME B1.20.1 pipe threads or with ASME B1.20.7 garden-hose threads.
 - C. Piping-Type Heat Traps: Field-fabricated piping arrangement per ASHRAE/IESNA 90.1.
 - D. Heat-Trap Fittings: Comply with ASHRAE 90.2.
 - E. Pressure-Reducing Valves: ASSE 1003 for water. Set at 25-psig-maximum outlet pressure unless otherwise indicated.
 - F. Combination Temperature-and-Pressure Relief Valves: ASME rated and stamped. Include relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select relief valves with sensing element that extends into storage tank.
 - G. Vacuum Relief Valves: ANSI Z21.22/CSA 4.4.
 - H. Shock Absorbers: ASSE 1010 or PDI-WH 201, Size A water hammer arrester.
 - I. Domestic-Water Heater Stands: Manufacturer's factory-fabricated steel stand for floor mounting, capable of supporting domestic-water heater and water. Include dimension that will support bottom of domestic-water heater a minimum of 18 inches above the floor.
 - J. Domestic-Water Heater Mounting Brackets: Manufacturer's factory-fabricated steel bracket for wall mounting, capable of supporting drain pan, domestic-water heater and water.

2.4 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect domestic-water heaters specified to be ASME-code construction, per ASME Boiler and Pressure Vessel Code.
- B. Hydrostatically test commercial domestic-water heaters to minimum of one and one-half times pressure rating before shipment.
- C. Electric, domestic-water heaters will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 DOMESTIC-WATER HEATER INSTALLATION

- A. Install electric, domestic-water heaters level and plumb, per layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.
 - 1. Install shutoff valves on domestic-water-supply piping to domestic-water heaters and on domestic-hot-water outlet piping. Comply with requirements for shutoff valves specified in Section 15112 "GENERAL-DUTY VALVES FOR PIPING."
- B. Install commercial, electric, domestic-water heaters with seismic-restraint devices. Comply with requirements for seismic-restraint devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- C. Install combination temperature-and-pressure relief valves in top portion of storage tanks. Use relief valves with sensing elements that extend into tanks. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- D. Install thermometers on outlet piping of electric, domestic-water heaters. Comply with requirements for thermometers specified in Section 15127 "METERS AND GAGES FOR PIPING."
- E. Assemble and install inlet and outlet piping manifold kits for multiple electric, domestic-water heaters.

Fabricate, modify, or arrange manifolds for balanced water flow through each electric, domestic-water heater. Include shutoff valve and thermometer in each domestic-water heater inlet and outlet, and throttling valve in each electric, domestic-water heater outlet. Comply with requirements for valves specified in Section 15112 "GENERAL-DUTY VALVES FOR PIPING," and comply with requirements for thermometers specified in Section 15127 "METERS AND GAGES FOR PIPING."
- F. Install piping-type heat traps on inlet and outlet piping of electric, domestic-water heater storage tanks without integral or fitting-type heat traps.
- G. Fill electric domestic-water heaters with water.
- H. Charge domestic-water compression tanks with air to system cold-fill static pressure prior to filling system with water.

3.2 CONNECTIONS

- A. Comply with requirements for piping specified in Section 15140 "Domestic Water Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to electric, domestic-water heaters, allow space for service and maintenance of water heaters. Arrange piping for easy removal of domestic-water heaters.

3.3 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Electric, domestic-water heaters will be considered defective if they do not pass tests and inspections.
 - 1. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain commercial, electric, domestic-water heaters.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15486

FUEL-FIRED WATER HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Commercial, gas-fired, high-efficiency, storage, domestic-water heaters.
 - 2. Domestic-water heater accessories.

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Commercial domestic-water heaters shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.4 ACTION SUBMITTALS

- A. Product Data: For each type and size of domestic-water heater indicated.
- B. Shop Drawings:
 - 1. Wiring Diagrams: For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For fuel-fired, domestic-water heaters, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Product Certificates: For each type of commercial, gas-fired, gas-fired tankless, domestic-water heater, from manufacturer.

- C. Domestic-Water Heater Labeling: Certified and labeled by testing agency acceptable to authorities having jurisdiction.
- D. Source quality-control reports.
- E. Field quality-control reports.
- F. Warranty: Sample of special warranty.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fuel-fired, domestic-water heaters to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE/IESNA Compliance: Fabricate and label fuel-fired, domestic-water heaters to comply with ASHRAE/IESNA 90.1.
- C. ASME Compliance:
 - 1. Where ASME-code construction is indicated, fabricate and label commercial, domestic-water heater storage tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
 - 2. Where ASME-code construction is indicated, fabricate and label commercial, finned-tube, domestic-water heaters to comply with ASME Boiler and Pressure Vessel Code: Section IV.
- D. NSF Compliance: Fabricate and label equipment components that will be in contact with potable water to comply with NSF 61, "Drinking Water System Components - Health Effects."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

1.9 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of fuel-fired, domestic-water heaters that fail in materials or workmanship within specified warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Structural failures including storage tank and supports.
 - b. Faulty operation of controls.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal use.

2. Warranty Periods: From date of Substantial Completion.
 - a. Commercial, Gas-Fired, Storage, Domestic-Water Heaters:
 - 1) Storage Tank: Ten years.
 - 2) Controls and Other Components: 5 year(s).
 - b. Compression Tanks: Five years.

PART 2 - PRODUCTS

2.1 COMMERCIAL, GAS-FIRED, STORAGE, DOMESTIC-WATER HEATERS

A. Commercial, Gas-Fired, High-Efficiency, Storage, Domestic-Water Heaters:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AERCO International, Inc.
 - b. Ajax Boiler Inc.
 - c. American Water Heaters.
 - d. Bradford White Corporation.
 - e. Heat Transfer Products, Inc.
 - f. Lochinvar Corporation.
 - g. PVI Industries, LLC.
 - h. RBI Water Heaters; a Mestek company.
 - i. Rheem Manufacturing Company.
 - j. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - k. State Industries.
 - l. Weben-Jarco, Inc.
2. Standard: ANSI Z21.10.3/CSA 4.3.
3. Description: Manufacturer's proprietary design to provide at least 95 percent combustion efficiency at optimum operating conditions.
4. Storage-Tank Construction: ASME-code steel with 150-psig minimum working-pressure rating.
 - a. Tappings: Factory fabricated of materials compatible with tank. Attach tappings to tank before testing.
 - 1) NPS 2 and Smaller: Threaded ends according to ASME B1.20.1.
 - 2) NPS 2-1/2 and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges and according to ASME B16.24 for copper and copper-alloy flanges.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.

- c. Lining: Cement Glass Nickel plate Stainless Steel complying with NSF 61 barrier materials for potable-water tank linings, including extending lining into and through tank fittings and outlets.
5. Factory-Installed Storage-Tank Appurtenances:
- a. Anode Rod: Replaceable magnesium.
 - b. Dip Tube: Required unless cold-water inlet is near bottom of tank.
 - c. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
 - d. Insulation: Comply with ASHRAE/IESNA 90.1. Surround entire storage tank except connections and controls.
 - e. Jacket: Steel with enameled finish.
 - f. Burner or Heat Exchanger: Comply with UL 795 or approved testing agency requirements for gas-fired, high-efficiency, domestic-water heaters and natural-gas fuel.
 - g. Temperature Control: Adjustable thermostat.
 - h. Safety Controls: Automatic, high-temperature-limit and low-water cutoff devices or systems.
 - i. Combination Temperature-and-Pressure Relief Valves: ANSI Z21.22/CSA 4.4-M. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.
6. Draft Hood: Draft connections arrangement per manufacturer's standard device consistent with the product listing. This shall include combustion air connections, combustion condensate drain points, termination fittings and connectors. .

2.2 DOMESTIC-WATER HEATER ACCESSORIES

A. Domestic-Water Compression Tanks:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. AMTROL Inc.
 - b. Flexcon Industries.
 - c. Honeywell International Inc.
 - d. Pentair Pump Group (The); Myers.
 - e. Smith, A. O. Water Products Co.; a division of A. O. Smith Corporation.
 - f. State Industries.
 - g. Taco, Inc.
2. Description: Steel, pressure-rated tank constructed with welded joints and factory-installed butyl-rubber diaphragm. Include air precharge to minimum system-operating pressure at tank.
3. Construction:
 - a. Tappings: Factory-fabricated steel, welded to tank before testing and labeling. Include ASME B1.20.1 pipe thread.
 - b. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending finish into and through tank fittings and outlets.

- c. Air-Charging Valve: Factory installed.
4. Capacity and Characteristics:
- a. Working-Pressure Rating: 150 psig.
 - b. Capacity Acceptable: Sized for volume of potable water protected but not less than 2 gallons minimum.
 - c. Air Precharge Pressure: Equal to the cold-fill static pressure. Adjust pressure before connecting to the system and before the system is first filled.
- B. Drain Pans: Corrosion-resistant metal with raised edge. Comply with ANSI/CSA LC 3. Include dimensions not less than base of domestic-water heater, and include drain outlet not less than NPS 3/4 with ASME B1.20.1 pipe threads or with ASME B1.20.7 garden-hose threads.
- C. Piping-Type Heat Traps: Field-fabricated piping arrangement according to ASHRAE/IESNA 90.1.
- D. Heat-Trap Fittings: ASHRAE 90.2.
- E. Manifold Kits: Domestic-water heater manufacturer's factory-fabricated inlet and outlet piping for field installation, for multiple domestic-water heater installation. Include ball-, butterfly-, or gate-type shutoff valves to isolate each domestic-water heater and calibrated balancing valves to provide balanced flow through each domestic-water heater.
- 1. Comply with requirements for ball-, butterfly-, or gate-type shutoff valves specified in Section 15111 "General-Duty Valves for Plumbing Piping."
 - 2. Comply with requirements for balancing valves specified in Section 15145 "Domestic Water Piping Specialties."
- F. Gas Shutoff Valves: ANSI Z21.15/CSA 9.1-M, manually operated. Furnish for installation in piping.
- G. Gas Pressure Regulators: ANSI Z21.18/CSA 6.3, appliance type. Include pressure rating as required to match gas supply.
- H. Automatic Gas Valves: ANSI Z21.21/CSA 6.5, appliance, electrically operated, on-off automatic valve.
- I. Combination Temperature-and-Pressure Relief Valves: Include relieving capacity at least as great as heat input, and include pressure setting less than domestic-water heater working-pressure rating. Select relief valves with sensing element that extends into storage tank.
- 1. Gas-Fired, Domestic-Water Heaters: ANSI Z21.22/CSA 4.4-M.
- J. Pressure Relief Valves: Include pressure setting less than domestic-water heater working-pressure rating.
- 1. Gas-Fired, Domestic-Water Heaters: ANSI Z21.22/CSA 4.4-M.

- K. Vacuum Relief Valves: ANSI Z21.22/CSA 4.4-M.
- L. Domestic-Water Heater Stands: Manufacturer's factory-fabricated steel stand for floor mounting, capable of supporting domestic-water heater and water. Provide dimension that will support bottom of domestic-water heater a minimum of 18 inches above the floor.
- M. Domestic-Water Heater Mounting Brackets: Manufacturer's factory-fabricated steel bracket for wall mounting, capable of supporting domestic-water heater and water.

2.3 SOURCE QUALITY CONTROL

- A. Factory Tests: Test and inspect assembled domestic-water heaters and storage tanks specified to be ASME-code construction, according to ASME Boiler and Pressure Vessel Code.
- B. Hydrostatically test commercial domestic-water heaters and storage tanks to minimum of one and one-half times pressure rating before shipment.
- C. Domestic-water heaters will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 01400 "Quality Requirements" for retesting and reinspecting requirements and Section 01700 "Execution Requirements" for requirements for correcting the Work.
- D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 DOMESTIC-WATER HEATER INSTALLATION

- A. Commercial, Domestic-Water Heater Mounting: Install commercial domestic-water heaters on concrete base. Comply with requirements for concrete base specified in Section 03300 "Cast-in-Place Concrete."
 1. Exception: Omit concrete bases for commercial domestic-water heaters if installation on stand, bracket, suspended platform, or directly on floor is indicated.
 2. Maintain manufacturer's recommended clearances.
 3. Arrange units so controls and devices that require servicing are accessible.
 4. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
 5. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 6. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 7. Install anchor bolts to elevations required for proper attachment to supported equipment.

8. Anchor domestic-water heaters to substrate.
- B. Install domestic-water heaters level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.
1. Install shutoff valves on domestic-water-supply piping to domestic-water heaters and on domestic-hot-water outlet piping. Comply with requirements for shutoff valves specified in Section 15111 "General-Duty Valves for Plumbing Piping."
- C. Install gas-fired, domestic-water heaters according to NFPA 54-2012 as amended by, 248 CMR 5.00 including:
1. Install gas shutoff valves on gas supply piping to gas-fired, domestic-water heaters which are provided without shutoff valves.
 2. Install gas pressure regulators on gas supplies to gas-fired, domestic-water heaters without gas pressure regulators if gas pressure regulators are required to reduce gas pressure at burner.
 3. Install automatic gas valves on gas supplies to gas-fired, domestic-water heaters if required for operation of safety control.
 4. Comply with requirements for gas shutoff valves, gas pressure regulators, and automatic gas valves specified in Section 15195 "Facility Natural-Gas Piping." Furnish and install all venting and combustion air systems as approved by the appliance manufacturer, in accordance with the appliance listing and approved published literature. Notwithstanding anything to the contrary, the use of plastic and non-metallic combustion vent systems shall not be acceptable.
- D. Install commercial domestic-water heaters with seismic-restraint devices. Comply with requirements for seismic-restraint devices specified in Section 15073 "Vibration and Seismic Controls for Plumbing Piping and Equipment."
- E. Install combination temperature-and-pressure relief valves in top portion of storage tanks. Use relief valves with sensing elements that extend into tanks. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- F. Install combination temperature-and-pressure relief valves in water piping for domestic-water heaters without storage. Extend commercial-water-heater relief-valve outlet, with drain piping same as domestic-water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.
- G. Install water-heater drain piping as indirect waste to spill by positive air gap into open drains or over floor drains. Install hose-end drain valves at low points in water piping for domestic-water heaters that do not have tank drains. Comply with requirements for hose-end drain valves specified in Section 15145 "Domestic Water Piping Specialties."
- H. Install thermometer on outlet piping of domestic-water heaters. Comply with requirements for thermometers specified in Section 15126 "Meters and Gages for Piping."
- I. Assemble and install inlet and outlet piping manifold kits for multiple domestic-water heaters.

Fabricate, modify, or arrange manifolds for balanced water flow through each domestic-water heater. Include shutoff valve and thermometer in each domestic-water heater inlet and outlet, and throttling valve in each domestic-water heater outlet. Comply with requirements for valves specified in Section 15111 "General-Duty Valves for Plumbing Piping," and comply with requirements for thermometers specified in Section 15126 "Meters and Gages for Piping."

- J. Install piping-type heat traps on inlet and outlet piping of domestic-water heater storage tanks without integral or fitting-type heat traps.
- K. Fill domestic-water heaters with water.
- L. Charge domestic-water compression tanks with air.

3.2 CONNECTIONS

- A. Comply with requirements for domestic-water piping specified in Section 15140 "Domestic Water Piping."
- B. Comply with requirements for gas piping specified in Section 15195 "Facility Natural-Gas Piping."
- C. Drawings indicate general arrangement of piping, fittings, and specialties.
- D. Where installing piping adjacent to fuel-fired, domestic-water heaters, allow space for service and maintenance of water heaters. Arrange piping for easy removal of domestic-water heaters.

3.3 IDENTIFICATION

- A. Identify system components. Comply with requirements for identification specified in Section 15076 "Identification for Plumbing Piping and Equipment."

3.4 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - 2. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Domestic-water heaters will be considered defective if they do not pass tests and inspections. Comply with requirements in Section 01400 "Quality Requirements" for retesting and reinspecting requirements and Section 01700 "Execution Requirements" for requirements for correcting the Work.

- C. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain commercial, gas-fired, storage, gas-fired, tankless domestic-water heaters.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15513

CONDENSING BOILERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes packaged, factory-fabricated, gas-fired, condensing boilers, trim, and accessories for generating heating hot water.
- B. Related Sections:
 - 1. Section 03300 - CAST IN PLACE CONCRETE
 - 2. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15179 – HYDRONIC PIPING SPECIALTIES
 - 7. Section 15181 – HYDRONIC PIPING
 - 8. Section 15185 – HYDRONIC PUMPS
 - 9. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 10. Section 15127 – METERS AND GAGES FOR PIPING
 - 11. Section 15195 – FACILITIES NATURAL GAS PIPING
 - 12. Section 15550 – BREECHINGS, CHIMNEYS AND STACKS

1.3 ACTION SUBMITTALS

- A. Product Data: Include performance data, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Source quality-control reports.
- B. Field quality-control reports.
- C. Warranty: Special warranty specified in this Section.
- D. Other Informational Submittals:

1. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For boilers to include in emergency, operation, and maintenance manuals.

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- B. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
- C. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
- D. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N, "Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers."
- E. UL Compliance: Test boilers for compliance with UL 795, "Commercial-Industrial Gas Heating Equipment." Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

1.7 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.8 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of boilers that fail in materials or workmanship within specified warranty period.
 1. Warranty Period for Fire-Tube Condensing Boilers: 10 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 FIRE-TUBE CONDENSING BOILERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Heat Transfer Products, Inc.
 2. Lochinvar Corporation.
 3. NYT
 4. Triangle Tube
 5. Viessmann
- B. Description: Factory-fabricated, -assembled, and -tested, fire-tube condensing boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls. Water heating service only.
- C. The fire tube arrangement shall consist of a vertical water vessel with vertical combustion heat transfer tubes passing through the water volume to promote lower water-side pressure drops than water-tube designs.
- D. Heat Exchanger: Stainless steel primary heat exchangers. Acceptable stainless steel alloys: 316L, 316 Ti, 430 series. Aluminum and cast iron heat exchangers will not be acceptable. Designs using primary and secondary heat exchangers will not be acceptable.
- E. Combustion Chamber: Stainless steel, sealed.
- F. Burner: Natural gas, forced draft drawing from gas premixing valve. Minimum 5:1 turn-down to 199 MBH, 10:1 turndown above 199 MBH.
- G. Blower: Centrifugal fan to operate during each burner firing sequence and to prepurge and postpurge the combustion chamber.
- H. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- I. Gas Train: Combination gas valve with manual shutoff and pressure regulator. Negative pressure gas valves shall be provided to allow repeatable full turndown operation at or below 4.0 inches w.g. gas pressure.
- J. Ignition: Silicone carbide hot-surface ignition that includes flame safety supervision and 100 percent main-valve shutoff.
- K. Integral Circulator: Cast-iron body and stainless-steel impeller sized for minimum flow required in heat exchanger.
- L. Casing:
1. Jacket: Sheet metal, with snap-in or interlocking closures.
 2. Control Compartment Enclosures: NEMA 250, Type 1A.
 3. Finish: Textured epoxy.
 4. Insulation: Minimum 1-inch-thick, mineral-fiber insulation surrounding the heat exchanger.

5. Combustion-Air Connections: Inlet and vent duct collars.
6. Mounting base to secure boiler.

M. Characteristics and Capacities:

1. Heating Medium: Hot water.
2. Design Water Pressure Rating: 160 psig.
3. Safety Relief Valve Setting: 100 psig.
4. Minimum Efficiency AFUE: 95 percent.
5. Minimum Thermal Efficiency: 92 percent.
6. Minimum Combustion Efficiency: 95 percent.
7. Blower:
 - a. Modulates between minimum scheduled fire to 100% of full fire.
8. Electrical Characteristics:
 - a. Volts: 115 V.
 - b. Phase: Single.
 - c. Hertz: 60.
 - d. Full-Load Amperes: As indicated on drawings.
 - e. Minimum Circuit Ampacity: As indicated on drawings.
 - f. Maximum Overcurrent Protection: As indicated on drawings.

2.2 TRIM

- A. Include devices sized to comply with ANSI B31.9, "Building Services Piping."
- B. Aquastat Controllers: Operating and high limit.
- C. Safety Relief Valve: ASME rated.
- D. Boiler Air Vent: Automatic.
- E. Drain Valve: Minimum NPS 3/4 hose-end gate valve.
- F. Low Water Cut-Out
- G. Massachusetts Board of Plumbing Examiners approval requirements.

2.3 ACCESSORIES

- A. Low-Loss Header type combination dirt/air/hydraulic separator by boiler manufacturer where offered. Where no boiler manufacturer separator is offered, furnish and install a separator equal to Taco 5900 Flex-Balance Plus, Bell and Gossett, Caleffi, Spirovent, or John Wood Co.
- B. Condensate Neutralizer, as standard offering by boiler manufacturer, to adjust acidic boiler condensate to a pH of 8.0 minimum prior to disposal.

2.4 CONTROLS

- A. Boiler operating controls shall include the following devices and features:
 1. Set-Point Adjust: Set points shall be adjustable.
 2. Sequence of Operation: factory-programmed and field-adjustable outdoor reset to control burner firing rate to reset supply-water temperature inversely with outside-air temperature.

- a. Include automatic, alternating-firing sequence for multiple boilers to ensure maximum plant efficiency and even run-hours on each boiler.
 - b. Boiler shall have a modulating output to control the boiler circuit pump and secondary circuit pump(s).
- B. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
- 1. Hardwired Points:
 - a. Monitoring: On/off status, common trouble alarm, low water level alarm.
 - b. Control: On/off operation.
 - 2. Controls shall be BACNET compliant.

2.5 ELECTRICAL POWER

- A. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in electrical Sections.
- B. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
- 1. House in NEMA 250, Type 1 enclosure.
 - 2. Wiring shall be numbered and color-coded to match wiring diagram.
 - 3. Field power interface shall be to fused disconnect switch.
 - 4. Provide each motor with overcurrent protection.

2.6 VENTING KITS

- A. Kit: Complete system, ASTM A 959, Type 29-4C stainless steel, pipe, vent terminal, thimble, indoor plate, vent adapter, condensate trap, neutralizer dilution vessel and sealant.
- B. Combustion-Air Intake: Complete system, stainless steel, pipe, vent terminal with screen, inlet air coupling, and sealant.

2.7 SOURCE QUALITY CONTROL

- A. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
- B. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Before boiler installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting boiler performance, maintenance, and operations.
 - 1. Final boiler locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
- B. Examine mechanical spaces for suitable conditions where boilers will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 BOILER INSTALLATION

- A. Equipment Mounting:
 - 1. Install boilers on wall where indicated on drawings according to manufacturer's written instructions.
- B. Install gas-fired boilers according to NFPA 54, 248 CMR.
- C. Assemble and install boiler trim.
- D. Install electrical devices furnished with boiler but not specified to be factory mounted.
- E. Install control wiring to field-mounted electrical devices.
- F. Arrange and be present for State Department of Public Safety boiler inspection and insurance inspections. Obtain and present certificates to the MBTA.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to boiler to allow service and maintenance.
- C. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
- D. Connect piping to boilers, except safety relief valve connections, with flexible connectors of materials suitable for service. Flexible connectors and their installation are specified in Section 15179 "HYDRONIC PIPING SPECIALTIES."
- E. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
- F. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
- G. Install piping from safety relief valves to nearest floor drain.

- H. Install combustion condensate neutralizer vessel and charge with pH adjustment chemicals. Make CPVC or polypropylene drain connections from boiler condensate trap to neutralizer and from neutralizer to floor drain all with pipe unions. Demonstrate clearances and removal of neutralizer and replacement of neutralizer chemicals in-place.
- I. Boiler Venting:
 - 1. Install flue venting kit and combustion-air intake.
 - 2. Connect full size to boiler connections. Comply with requirements in Section 15550 "BREECHINGS, CHIMNEYS, AND STACKS."
- J. Ground equipment according to Section 16060 "GROUNDING AND BONDING."
- K. Connect wiring according to Section 16120 "CONDUCTORS AND CABLES."

3.4 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections:
 - 1. Perform installation and startup checks according to manufacturer's written instructions.
 - 2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - a. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level and water temperature.
 - b. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Prepare test and inspection reports.
- F. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.
- G. Performance Tests:

1. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment to comply.
3. Perform field performance tests to determine capacity and efficiency of boilers.
 - a. Test for full capacity.
 - b. Test for boiler efficiency at minimum low fire 20, 40, 60, 80, 100 percent of full capacity. Determine efficiency at each test point.
4. Repeat tests until results comply with requirements indicated.
5. Provide analysis equipment required to determine performance.
6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
7. Document test results in a report and submit to Engineer.

3.5 DEMONSTRATION

- A. Train MBTA's maintenance personnel to adjust, operate, and maintain boilers. Video training sessions. Refer to Section 01820 "DEMONSTRATION AND TRAINING."

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15523

LOW-INTENSITY GAS-FIRED RADIANT TUBE HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections
 - 1. Section 15050 - BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15051 - BASIC MATERIALS AND METHODS FOR PLUMBING WORK
 - 3. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 4. Section 15086 - DUCT INSULATION
 - 5. Section 15195 – FACILITY NATURAL GAS PIPING
 - 6. Section 15550 – BREECHINGS, CHIMNEYS AND STACKS
 - 7. Section 15815 – METAL DUCTS
 - 8. Section 15940 – SEQUENCE OF OPERATION FOR HVAC SYSTEMS
 - 9. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.2 SUMMARY

- A. Section Includes:
 - 1. Gas-fired low intensity tubular radiant heaters. (Multiple-Burner Engineered Vacuum System Type).
 - 2. Vacuum Blower.
 - 3. Controls.
 - 4. Related work includes venting of combustion products, insulated combustion air ductwork

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of gas-fired radiant heater indicated. Included rated capacities at high and low firing ranges, operating characteristics and accessories, tubing, burner and reflector materials. Gas burner loads in cfh, Btu/H, minimum and maximum gas inlet pressures in inches w.g.
- B. Vacuum blower, burners, weights, controls and electrical characteristics. Include a listing of all equipment to be wired with the maximum electrical overcurrent protection, wiring size Amperes, wiring diagrams for both power and controls.
- C. Shop Drawings: Minimum 3/8" scale electronic format drawings indicating elevations, sections, details, connections, all coordinated with other work. Drawings shall indicate reflector rotation. Shop drawing format shall be suitable for import into the Design-Build Contractors BIM program for overall system coordination.

- D. Vent, combustion air and gas piping connections, including capacities and connection sizes. Details of combustion air intake, pre-filtering, sizing and pressure drop limitations.
- E. Operations and Maintenance Data including consumable parts, recommended spare parts including burners, igniters, control boards.
- F. Warranty including special warranty per Paragraph 1.5.

1.4 QUALITY ASSURANCE

- A. Electrical components, devices, and accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- B. Equipment shall be certified to the ANSI Z83.20 Standard and bear the CSA certification label.

1.5 WARRANTY

- A. Warranty Period: (One year parts and labor on all internal components), (five years parts on tube exchangers), and (ten years parts on burner) from date of substantial completion.

PART 2 - PRODUCTS

2.1 TUBULAR INFRA-RED HEATERS

- A. Manufacturers
 - 1. Detroit Radiant Re-Verber-Ray HLV Series
 - 2. Roberts Gordon Co-Ray-Vac
 - 3. Superior Radiant Products Premier VS-VH Vacuum Series
- B. Fuel type: burner shall be designed for utility natural gas having characteristics as follows: Specific gravity 0.60, BTU content: 950 to 1,050 BTUs per Cubic Foot.
- C. Gas control: operation shall include a defined input differential. Heater must be CSA Design Certified to operate at an input differential of at least 20% between the low and nominal rated input modes.
- D. Combustion chamber: shall be 4 inch O.D. 16ga. Titanium stabilized aluminized steel to allow for the operating temperature to exceed the 1030F as set forth in the ANSI Z83.20 standard, finished with a high emissivity rated, corrosion resistant, black coating with an emissivity level documented at .92 or higher.
- E. Emitter tube: shall be 4 inch O.D. 16ga. aluminized steel finished with a high emissivity rated, corrosion resistant, black coating with an emissivity level documented at .92 or higher
- F. Condensate tail pipe: shall be 4 inch O.D. 16ga. 304, 316 or 316L stainless steel. Pipe shall be able to be cut to any length without having raw carbon steel exposed at the edges. Glass lined, porcelain lined, or other material prone to chipping and cracking shall not be acceptable.

- G. Burner type: units shall operate under a negative pressure with exhaust gasses pulled through the exchanger pipe to a common exhauster pump. Each burner shall receive its combustion air independently. Burners shall be fired in parallel to the main tube. Burners that have exhaust gases from upstream burners passing over them shall not be acceptable. Burners shall operate at a minimum of 3.5" W.C. manifold pressure to achieve proper air-gas mixing. Burners that require air filters shall not be acceptable.
- H. Burner: stainless-steel Venturi burner. The flame anchoring screen shall have a minimum temperature rating equivalent to 304 grade stainless steel. Non-stainless steel burners shall not be acceptable.
- I. Tube connections: the heater's combustion chamber and radiant emitter tube shall incorporate a 4 inch slip-fit, interlocking connection in which the upstream tube slides into the next tube and is held by a bolted clamp. A butted tube connection system shall not be acceptable.
- J. Vacuum Exhauster Blowers/Pumps:
 - 1. Housings shall pressure-cast aluminum, welded stainless steel housing for corrosion resistance. Cast iron housings shall not be acceptable.
 - 2. Motors ½ hp and higher shall be TEFC type standard efficiency. Motors shall be equipped with thermal protection and capacitor starters.
- K. Ignition system: Hot surface silicon carbide composition. Igniter shall be readily accessible and serviceable without having to remove the burner. Spark ignition systems shall not be acceptable.
- L. Reflectors: Shall be .025 polished aluminum with a multi-faceted design which includes reflector end caps. Reflector shall have a polished bright finish with clear visual reflection ability. (A sample will be required at time of submittal). Reflector shall have a minimum of 7 sheet metal bends in its fabrication to optimize downward radiation. Reflectors shall be rotatable from 0 to 45 degrees when required. The heater's reflector hanging system shall be designed to permit expansion while minimizing noise and/or rattles.
- M. Control box: Heater's exterior control chassis shall be constructed of corrosion resistant enameled steel.
- N. Air intake: An air intake collar shall be supplied as part of the burner control assembly to accept a 4 inch O.D. supply duct.
- O. Heaters shall be equipped with a sight glass allowing a visual inspection of igniter and burner operation from the floor. Sight glass visible only at an appliance level shall not be acceptable.
- P. Heater shall be supplied with a stainless steel flexible gas connector.
- Q. System Operation and Safety Controls:
 - 1. Each burner assembly shall include a safety differential pressure switch to monitor combustion air flow, as to provide complete burner shutdown due to insufficient combustion air or flue blockage. A single differential pressure switch at the exhauster assembly shall not be acceptable.
 - 2. In event of a failure of the vacuum blower to operate, a pressure switch shall shut down all burners connected to that vacuum blower and an alarm contactor shall be closed to alert the BMS.

3. The system exhauster shall have a minimum of a 90-second post purge to aid in the removal of exhaust gases and condensate in the exchanger pipes.
 4. The heater shall incorporate a self-diagnostic ignition module, and recycle the heater after an inadvertent shutdown.
 5. The heater's control system shall be designed to shut off the gas flow to the main burner in the event either a gas supply or power supply interruption occurs.
 6. Heater control assembly shall include three indicator lights that define the unit's operating input ranges. One indicator shall validate air flow. Two indicator lights shall indicate low and high stages.
 7. Thermostat control shall be two-stage operating on 24 volts.
- R. Venting: shall be per manufacturer approval and specifications.
- S. Thermostat: devices and wiring are specified in Division 23 Section "Instrumentation and Control for HVAC."
- T. Thermostat: 2-stage, digital programmable wall-mounting type with 50 to 90 deg F (10 to 32 deg C) operating range.
- U. Control Transformer: Integrally mounted.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install and connect gas-fired radiant heaters, associated fuel and vent features and systems per 248 CMR 5.00, NFPA 54, applicable local codes and regulations, and manufacturer's written installation instructions.
- B. Suspended units: suspend from substrate using chain hanger kits and building attachments.
- C. Maintain manufacturers' published clearances to combustibles.
- D. Adhere to manufacturers' installation instructions.

3.2 CONNECTIONS

- A. Piping installation requirements are specified in other Division 15 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to gas-fired radiant heaters to allow service and maintenance. Refer to manufacturers' instructions for proper gas connection details.
- C. Gas Piping: Comply with 248 CMR 5.00, NFPA 54 and manufacturer's installation instructions, per Section 15195 – FACILITY NATURAL GAS PIPING.

- D. Vent Connections: adhere to manufacturers' installation instructions and Section 15550 – BREECHINGS, CHIMNEYS AND STACKS.
- E. Combustion Air Connections: Provide insulated ducted combustion air including filters, insulation and fittings, per Sections 15815 – METAL DUCTS and 15086 - DUCT INSULATION.
- F. Electrical Connections: Comply with applicable requirements in Division 16 Sections.
- G. Install electrical devices furnished with heaters but not specified to be factory mounted.

3.3 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Replace damaged and malfunctioning controls and equipment.

3.4 ADJUSTING

- A. Obtain adjustment instructions from gas-fired radiant heater manufacturer before making any adjustments to burners or other heating components.
- B. Angle reflectors for appropriate coverage.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain gas-fired radiant heaters.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15550

BREECHINGS, CHIMNEYS, AND STACKS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 4. Section 15486 – FUEL-FIRED WATER HEATERS
 - 5. Section 15513 – CONDENSING BOILERS
 - 6. Section 15523 – LOW INTENSITY GAS-FIRED RADIANT HEATERS
 - 7. Section 15940 – SEQUENCE OF OPERATION FOR THE HVAC SYSTEMS
 - 8. Section 15950 – TESTING, ADJUSTING, AND BALANCING

1.2 SUMMARY

- A. This Section includes the following:
 - 1. Listed double-wall vent systems suitable for use with gas-fired appliances furnished and installed on this project. This includes appliances as may be specified by the Design-Build Contractor team and not listed in this Section.
 - 2. Each venting system shall be of the appropriate Category (I, II, III or IV), specifically listed for use with each gas-fired appliance or system by the appliance or system manufacturer.
 - 3. Notwithstanding any information to the contrary, all gas vent systems shall be metallic construction. Plastic materials shall not be acceptable for venting, even when specifically allowed by the appliance or equipment manufacturer. All gas vent systems shall first be of a manufacturer recommended by the appliance or equipment manufacturer. Where there is no recommendation, the appropriate category of venting shall apply, using a metallic construction.
 - 4. All combustion venting systems shall include capped test ports for combustion products testing and draft testing.

1.3 ACTION SUBMITTALS

- A. Product Data: For the following:
 - 1. Type B and BW vents.
 - 2. Type L vents.
 - 3. Special gas vents.
 - 4. Guy wires and connectors.

5. Terminations including combustion air intake and vent exhaust discharge
- B. Shop Drawings: For vents, breechings, chimneys, and stacks. Include plans, elevations, sections, details, and attachments to other work.
1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, methods of field assembly, components, hangers and seismic restraints, and location and size of each field connection.
 2. For installed products indicated to comply with design loads, include calculations required for selecting seismic restraints and structural analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1.4 INFORMATIONAL SUBMITTALS

- A. Welding certificates.
- B. Warranty: Special warranty specified in this Section.

1.5 QUALITY ASSURANCE

- A. Source Limitations: Obtain listed system components through one source from a single manufacturer.
- B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code--Steel," for hangers and supports and AWS D9.1/D9.1M, "Sheet Metal Welding Code," for shop and field welding of joints and seams in vents, breechings, and stacks.
- C. Certified Sizing Calculations: Manufacturer shall certify venting system sizing calculations.

1.6 COORDINATION

- A. Coordinate size and location of concrete bases, mass pads and supports. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete, Section 03300 "CAST-IN-PLACE CONCRETE".
- B. Coordinate installation of roof curbs, equipment supports, wall penetrations and roof penetrations, membranes and finishes, all as specified in DIVISION 7.
- C. Coordinate routing of vent piping and combustion air ductwork with all other services and building structure. Routing shall be perpendicular/parallel to building walls and plumb where vertical. Termination points shall use the least distant path to the exterior approved locations.

1.7 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of venting system that fail in materials or workmanship within specified warranty period. Failures include, but are not limited to, structural failures caused by expansion and contraction.
 1. Warranty Period: 10 years from date of Substantial Completion or the manufacturer's standard Warranty Period, whichever is greater.

PART 2 - PRODUCTS

2.1 LISTED TYPE B AND BW VENTS

- A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
- B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. American Metal Products; MASCO Corporation.
 - 2. Cleaver-Brooks; Div. of Aqua-Chem Inc.
 - 3. FAMCO.
 - 4. Hart & Cooley, Inc.
 - 5. Heat-Fab, Inc.
 - 6. Industrial Chimney Company.
 - 7. LSP Products Group, Inc.
 - 8. Metal-Fab, Inc.
 - 9. Schebler Co. (The).
 - 10. Selkirk Inc.; Selkirk Metalbestos and Air Mate.
 - 11. Simpson Dura-Vent Co., Inc.; Subsidiary of Simpson Manufacturing Co.
 - 12. Tru-Flex Metal Hose Corp.
 - 13. Van-Packer Company, Inc.
- C. Description: Double-wall metal vents tested according to UL 441 and rated for 480 deg F continuously for Type B, or 550 deg F continuously for Type BW; with neutral or negative flue pressure complying with NFPA 211.
- D. Construction: Inner shell and outer jacket separated by at least a 1/4-inch airspace.
- E. Inner Shell: ASTM A 666, Type 430 stainless steel.
- F. Outer Jacket: Aluminized steel.
- G. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
 - 1. Termination: Round chimney top designed to exclude minimum 98 percent of rainfall.

2.2 LISTED TYPE L VENTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. American Metal Products; MASCO Corporation.
 - 2. FAMCO.
 - 3. Heat-Fab, Inc.
 - 4. Industrial Chimney Company.
 - 5. LSP Products Group, Inc.
 - 6. Metal-Fab, Inc.
 - 7. Schebler Co. (The).
 - 8. Selkirk Inc.; Selkirk Metalbestos and Air Mate.

9. Simpson Dura-Vent Co., Inc.; Subsidiary of Simpson Manufacturing Co.
 10. Tru-Flex Metal Hose Corp.
 11. Van-Packer Company, Inc.
- B. Description: Double-wall metal vents tested according to UL 641 and rated for 570 deg F continuously, or 1700 deg F for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
 - C. Construction: Inner shell and outer jacket separated by at least a 1-inch airspace filled with high-temperature, mineral-wool insulation.
 - D. Inner Shell: ASTM A 666, Type 304 stainless steel.
 - E. Outer Jacket: Aluminized steel.
 - F. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
 1. Termination: Round chimney top designed to exclude 98 percent of rainfall.

2.3 LISTED SPECIAL GAS VENTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Heat-Fab, Inc.
 2. Metal-Fab, Inc.
 3. Selkirk Inc.; Selkirk Metalbestos and Air Mate.
 4. Z-Flex; Flexmaster Canada Limited.
 5. Schebler Co. (The).
- B. Description: Double-wall metal vents tested according to UL 1738 and for 480 deg F continuously, with positive or negative flue pressure complying with NFPA 211.
- C. Construction: Inner shell and outer jacket separated by at least a 1/2-inch airspace.
- D. Inner Shell: ASTM A 959, Type AL29-4C stainless steel.
- E. Outer Jacket: Aluminized steel, Type AL29-4C stainless steel, 316L stainless steel, 304 stainless steel.
- F. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
 1. Termination: Listed round chimney top designed to exclude minimum 98 percent of rainfall. Shanty caps shall not be acceptable.

2.4 GUYING AND BRACING MATERIALS

- A. Cable: Three galvanized, stranded wires of the following thickness:

1. Minimum Size: 1/4 inch in diameter.
 2. For ID Sizes 4 to 15 Inches: 5/16 inch.
 3. For ID Sizes 18 to 24 Inches: 3/8 inch.
 4. For ID Sizes 27 to 30 Inches: 7/16 inch.
 5. For ID Sizes 33 to 36 Inches: 1/2 inch.
 6. For ID Sizes 39 to 48 Inches: 9/16 inch.
 7. For ID Sizes 51 to 60 Inches: 5/8 inch.
- B. Pipe: Three galvanized steel, NPS 1-1/4.
- C. Angle Iron: Three galvanized steel, 2 by 2 by 0.25 inch.
- D. Structural attachments to roof sufficient to withstand wind loads.

2.5 VENT TERMINATIONS

- A. Vent terminations shall be furnished by the vent system manufacturer conforming to each application, including vertical discharge, discharge and combustion air intake, sidewall discharge, sidewall combination discharge and combustion air intake.
- B. Combination combustion air intake and exhaust terminations shall include concentric fitting assemblies and special fittings to make connections to the termination device.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of work.
1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATION

- A. Listed Type B and BW Vents: Vents for certified gas appliances, Typically Category I.
- B. Listed Type L Vent: Vents for low-heat appliances.
- C. Listed Special Gas Vent: Condensing gas appliances, typically Category IV and II in limited circumstances.

3.3 INSTALLATION OF LISTED VENTS AND CHIMNEYS

- A. Locate to comply with minimum clearances from combustibles and minimum termination heights according to product listing or NFPA 211, whichever is most stringent.
- B. Seal between sections of positive-pressure vents and grease exhaust ducts according to manufacturer's written installation instructions, using sealants recommended by manufacturer.

- C. Support vents at intervals recommended by manufacturer to support weight of vents and all accessories, without exceeding appliance loading.
- D. Slope breechings down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain. Provide a condensate neutralizer at all combustion drains with a minimum discharge pH of 8.0.
- E. Lap joints in direction of flow.
- F. Connect base section to foundation using anchor lugs of size and number recommended by manufacturer.
- G. Join sections with approved sealants, gaskets and joint system to provide continuous joint and smooth interior finish.
- H. Erect stacks plumb to finished tolerance of no more than 0.25 inches per 10 feet out of plumb and in total from top to bottom.

3.4 CLEANING

- A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes. Test drain ports and piping and demonstrate that water runs clear and that the volume entered equals the volume drained.
- B. Clean breechings internally, during and after installation, to remove dust and debris. Clean external surfaces to remove welding slag and mill film. Grind welds smooth and apply touchup finish to match factory or shop finish.
- C. Provide temporary closures at ends of breechings, chimneys, and stacks that are not completed or connected to equipment.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15725

MODULAR INDOOR CENTRAL-STATION AIR-HANDLING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Variable-air-volume, single-zone or multiple zone air-handling units.
 - 2. Actual configurations including fan types, arrangements, cooling, heating and application, shall be as determined by the Design-Builder most appropriate for each application.

1.3 ACTION SUBMITTALS

- A. Product Data: For each air-handling unit indicated.
 - 1. Unit dimensions and weight.
 - 2. Cabinet material, metal thickness, finishes, insulation, and accessories.
 - 3. Fans:
 - a. Certified fan-performance curves with system operating conditions indicated.
 - b. Certified fan-sound power ratings.
 - c. Fan construction and accessories.
 - d. Motor ratings, electrical characteristics, and motor accessories.
 - 4. Certified coil-performance ratings with system operating conditions indicated.
 - 5. Dampers, including housings, linkages, and operators.
 - 6. Filters with performance characteristics.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.
 - 2. Support location, type, and weight.
 - 3. Field measurements.
- B. Source quality-control reports.

- C. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-handling units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: One set(s) for each air-handling unit.
 - 2. Gaskets: One set(s) for each access door.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
- C. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.
- D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND STARTUP."
- E. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "HEATING, VENTILATING, AND AIR-CONDITIONING."
- F. Comply with NFPA 70.

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.
- B. Coordinate sizes and locations of structural-steel support members, if any, with actual equipment provided.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Carrier Corporation; a member of the United Technologies Corporation Family.

2. Cambridgeport Air Systems Inc.
3. Johnson Controls, Inc. York Division.
4. Daikin-McQuay International
5. Trane, Inc.

B. General Description

1. Air handling units shall include DX evaporator coils, filters, supply fan, hot water preheat coil, return fan, economizer section, and unit controls.
2. Unit shall be factory assembled (shipped as individual modules) and tested including leak testing of the coils, pressure testing of the refrigeration circuit, and run testing of the completed unit. Run test report shall be supplied with the unit in the controls compartment's literature pocket.
3. Unit components shall be labeled, including pipe stub outs, refrigeration system components and electrical and controls components.
4. Unit nameplate shall be provided in two locations on the unit, affixed to the exterior of the unit and affixed to the interior of the control compartment's access door.

2.2 UNIT CASINGS

A. General Fabrication Requirements for Casings:

1. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
2. Casing Joints: Sheet metal screws or pop rivets.
3. Sealing: Seal all joints with water-resistant sealant.
4. Factory Finish for Steel and Galvanized Steel Casings: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked on enamel finish consisting of prime coat and thermosetting topcoat.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Casing Insulation:

1. Materials: Injected Polyurethane foam with density of 2 lb/cu.ft. for R value of 13.
2. Thickness: 2 inches
3. Location and Application: Encased between outside and inside casing.

C. Inspection and Access Doors:

1. Panel and Door Fabrication: Formed and reinforced, double-wall and insulated panels of same materials, construction and thicknesses as casing.
2. Access Doors:
 - a. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.

- b. Gasket: Neoprene, applied around entire perimeters of panel frames.
 - c. Size: At least 18 inches wide by full height of unit casing up to a maximum height of 60 inches.
 - d. Features: Each door shall have:
 - 1) Integral gasketed screw-cap pressure and temperature ports.
 - 2) Tempered insulated glass viewport, minimum 10x10 inches, in fan sections, coil sections, filter sections, any sections with light fixtures.
3. Locations and Applications:
- a. Fan Section: Doors.
 - b. Access Section: Doors.
 - c. Coil Section: Doors.
 - d. Damper Section: Doors.
 - e. Filter Section: Doors large enough to allow periodic removal and installation of filters.
 - f. Mixing Section: Doors.
4. Service Light: vapor-proof 100W incandescent equivalent output LED-lamped fixture with switched junction box located outside adjacent to fan compartment door for the entire unit. Switch to have a red LED lamp to indicate lights are on.
- a. Locations: Each section accessed with door.

D. Condensate Drain Pans:

- 1. Fabricated with one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) to direct water toward drain connection.
 - a. Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
 - b. Depth: A minimum of 2 inches deep.
 - c. Formed sections.
 - d. Double-wall R-8 minimum insulated, pitched and formed stainless-steel sheet.
- 2. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan as a primary drain and a higher secondary drain for overflow detection. Minimum Primary Connection Size: NPS 1.5. Minimum Secondary Connection Size: NPS 1.5.
- 3. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil and conduct each pan's drainage express to the main section drain pan. Units with cascading coil drainage shall not be acceptable.

E. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.

2.3 FAN, DRIVE, AND MOTOR SECTION

- A. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.
 - 1. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower.

- B. Plenum Fan Housings: Steel frame and panel; fabricated without fan scroll and volute housing.
- C. Fan Shaft Bearings:
 - 1. Grease-Lubricated Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing with grease lines extended to outside unit. AMCA Air Handling Duty rated.
 - 2. All bearings shall have L10-200,000 hour bearing life per American Bearing Manufacturer's Association (ABMA).
- D. Discharge Dampers: Heavy-duty steel assembly with channel frame and sealed ball bearings, and opposed blades constructed of two plates formed around and welded to shaft, with blades linked out of air stream to single control lever.
- E. Internal Vibration Isolation: Fans shall be factory mounted with manufacturer's standard vibration isolation mounting devices having a minimum static deflection of 2 inches.
- F. Motor: Motor shall be a premium high efficiency inverter-compatible and with a unit-mounted VFD for each fan.

2.4 COIL SECTION

- A. General Requirements for Coil Section:
 - 1. Comply with ARI 410.
 - 2. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
 - 3. Coils shall not act as structural component of unit.
 - 4. Coil section floor in its entirety shall be a stainless steel positively pitched drain pan.

2.5 AIR FILTRATION SECTION

- A. General Requirements for Air Filtration Section:
 - 1. Comply with NFPA 90A.
 - 2. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
 - 3. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
- B. Extended-Surface, Disposable Panel Filters:
 - 1. Factory-fabricated, dry, extended-surface type.
 - 2. Thickness: 2 inches.
 - 3. Initial Resistance: 0.25 inches wg.
 - 4. Recommended Final Resistance: 0.5 inches wg.
 - 5. MERV (ASHRAE 52.2): 8.
 - 6. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent and held by self-supporting wire grid.
 - 7. Media-Grid Frame: Nonflammable cardboard.
 - 8. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks.

C. Extended-Surface, Disposable Panel:

1. Factory-fabricated, dry, extended-surface type.
2. Thickness: 4 inches.
3. Initial Resistance: 0.25 inches wg.
4. Recommended Final Resistance: 0.5 inches wg.
5. MERV (ASHRAE 52.2): 13.
6. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.
7. Filter-Media Frame: Galvanized steel.
8. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks.

D. Filter Gage:

1. 2-inch-diameter, diaphragm-actuated dial in metal case.
2. Vent valves.
3. Black figures on white background.
4. Front recalibration adjustment.
5. 3 percent of full-scale accuracy.
6. Range: 0 to 0.5 inch wg 0- to 1.0-inch wg
7. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch aluminum tubing, and 2- or 3-way vent valves.

2.6 DAMPERS

A. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpmface velocity through damper and 4-inch wg pressure differential.

B. Damper Operators: Comply with requirements in Section 15900 "HVAC Instrumentation and Controls."

C. Electronic Damper Operators:

1. Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
2. Electronic damper position indicator shall have visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
3. Operator Motors:
 - a. Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
4. Coupling: V-bolt and V-shaped, toothed cradle.
5. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
6. Fail-Safe Operation: Mechanical, spring-return mechanism with external, manual gear release on nonspring-return actuators.
7. Power Requirements (Two-Position Spring Return): 24-V ac.
8. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
9. Temperature Rating: Minus 22 to plus 122 deg F.
10. Run Time: 60 seconds.

- D. Outdoor- and Return-Air Dampers: Low-leakage, double-skin, airfoil-blade, dampers with compressible jamb seals and extruded-vinyl blade edge seals in opposed-blade arrangement with steel operating rods rotating in sintered bronze or nylon bearings mounted in a single extruded-aluminum frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed 5 cfm/sq. ft. at 1-inch wg and 9 cfm/sq. ft. at 4-inch wg.
- E. Combination Filter Section:
 - 1. Cabinet support members shall hold 2-inch-thick, pleated, and 4 inch thick pleated throwaway filters.

2.7 CAPACITIES AND CHARACTERISTICS

- A. General:
 - 1. Component pressure drops, velocities and characteristics shall be designed to limit system brake horsepower (BHP) to the maximum allowed by ASHRAE 90.1 for each system. These criteria apply notwithstanding performance criteria limits for each component.
 - 2. Thermal performance characteristics shall be as scheduled by the Design-Builder.
 - 3. Construction criteria shall conform to or exceed the following criteria.
- B. Casing:
 - 1. Outside Casing: Galvanized steel, minimum 16 gauge.
 - 2. Inside Casing: Galvanized steel, solid, minimum 16 gauge..
 - 3. Floor Plate: Stainless steel, minimum 16 gauge..
 - 4. Insulation Thickness: 2 inches.
 - 5. Static-Pressure Classifications for Unit Sections before Fans: 3-inch wg.
 - 6. Static-Pressure Classifications for Unit Sections after Fans: 3-inch wg.
 - 7. Static-Pressure Classifications for Unit Fan and Septum Wall Sections: 6-inch wg.
 - 8. Casing deflection not to exceed 1/270 span at 4" WG SP.
- C. Supply Fan:
 - 1. Class II: AMCA 99-2408. Use Class III construction if design performance RPM exceeds 80% of maximum Class II RPM.
 - 2. Drive: Direct.
 - 3. Type: Fabricated-aluminum plenum airfoil SWSI.
 - 4. Number of Fan Wheels: One per fan.
 - 5. VFD Motor controls for each fan.
 - 6. Electrical Characteristics:
 - a. Volts: 460.
 - b. Phase: Three.
 - c. Hertz: 60.
 - d. Full-Load Amperes: As indicated on drawings.
 - e. Minimum Circuit Ampacity: As indicated on drawings.
 - f. Maximum Overcurrent Protection: As indicated on drawings.

D. Return Fan:

1. Class II: AMCA 99-2408. Use Class III construction if design performance RPM exceeds 80% of maximum Class II RPM.
2. Drive: Direct.
3. Type: Fabricated-aluminum plenum airfoil SWSI.
4. Number of Fan Wheels: One per fan.
5. VFD Motor controls for each fan.
6. Electrical Characteristics:
 - a. Volts: 460.
 - b. Phase: Three.
 - c. Hertz: 60.
 - d. Full-Load Amperes: As indicated on drawings.
 - e. Minimum Circuit Ampacity: As indicated on drawings.
 - f. Maximum Overcurrent Protection: As indicated on drawings.

E. Preheat Coil:

1. Maximum Face Velocity: 600 fpm.
2. Coil Type: Continuous circuit Cleanable.
3. Piping Connections: Threaded, same end of coil.
4. Tube Material: Copper.
5. Tube Thickness: 0.020 inches tube, 0.035 inches tube bends
6. Fin Type: Plate.
7. Fin Material: Aluminum, 0.01" minimum.
8. Fin Spacing: 80 fins per foot maximum
9. Fin and Tube Joint: Mechanical bond.
10. Frames: Channel frame, 16 gauge. galvanized steel.
11. Number of Rows: As indicated on drawings.
12. Coil Working-Pressure Ratings: 200 psig, 325 deg F.
13. Fluid: Hot Water or Glycol Hot Water 40% PG by weight to suit design. Select coils for final fluid and concentration, 140 degrees F. maximum entering fluid temperature with a 40 degree F. temperature drop.

F. Cooling Coil:

1. Maximum Face Velocity: 450 fpm.
2. Coil Type: Continuous full-face split circuit.
3. Piping Connections: Same end of coil.
4. Tube Material: Copper.
5. Tube Thickness: 0.020 inches tube, 0.035 inches tube bends
6. Fin Type: Plate.
7. Fin Material: Aluminum, 0.01" minimum.
8. Fin Spacing: 96 fins per foot, maximum
9. Fin and Tube Joint: Mechanical bond.
10. Frames: Channel frame, 16 gauge 304 stainless steel.
11. Number of Rows: As indicated on drawings.
12. Coil Working-Pressure Ratings: 200 psig, 325 deg F.
13. Refrigerant Type: R-410a.

2.8 SOURCE QUALITY CONTROL

- A. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.
- B. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."
- C. Water Coils: Factory tested to 300 psig according to ARI 410 and ASHRAE 33.
- D. Refrigerant Coils: Factory tested to 450 psig according to ARI 410 and ASHRAE 33.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine casing insulation materials and filter media before air-handling unit installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for steam, hydronic, and condensate drainage piping systems and electrical services to verify actual locations of connections before installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Equipment Mounting:
 - 1. Install air-handling units on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 03300 "CAST-IN-PLACE CONCRETE."
- B. Arrange installation of units to provide access space around air-handling units for service and maintenance.
- C. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.
- D. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

3.3 CONNECTIONS

- A. Comply with requirements for piping specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to air-handling unit to allow service and maintenance.
- C. Install drain pipes from unit drain pans to storm drain, not sanitary disposal.
 - 1. Drain Piping: Drawn-temper copper water tubing complying with ASTM B 88, Type L, with soldered joints.
 - 2. Pipe Size: Same size as condensate drain pan connection with P-Trap with depth one inch greater than total unit static pressure. Drain trap assemblies shall have pipe unions for seasonal removal and cleanouts for cleaning and drainage.
 - 3. Pipe secondary drain in same manner as primary, except secondary drain shall be instrumented with a high-level water detector to shut down the cooling process.
 - 4. Indirect storm-water receptor with backwater valve to be furnished and installed by Plumbing Subcontractor Design-Builder.
- D. Hot-Water Piping: Comply with applicable requirements in Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES." Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.
- E. Refrigerant Piping: Comply with applicable requirements in Section 15183 "REFRIGERANT PIPING." Install shutoff valve and union or flange at each supply and return connection.
- F. Connect duct to air-handling units with flexible connections. Comply with requirements in Section 15820 "DUCT ACCESSORIES."

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 - 1. Leak Test: After installation, fill water coils with water, and test coils and connections for leaks.
 - 2. Charge refrigerant coils with refrigerant and test for leaks.
 - 3. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 STARTUP SERVICE

- A. Perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Verify that shipping, blocking, and bracing are removed.
 3. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
 4. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations.
 5. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
 6. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
 7. Comb coil fins for parallel orientation.
 8. Install new, clean filters.
 9. Verify that automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.
- B. Starting procedures for air-handling units include the following:
1. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.
 2. Measure and record motor electrical values for voltage and amperage.
 3. Manually operate dampers from fully closed to fully open position and record fan performance.

3.6 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Comply with requirements in Section 15950 "TESTING, ADJUSTING, AND BALANCING" for air-handling system testing, adjusting, and balancing.

3.7 CLEANING

- A. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

3.8 DEMONSTRATION

- A. Train MBTA's maintenance personnel to adjust, operate, and maintain air-handling units.
- B. Testing, Adjusting and Balancing (TAB) reports shall be furnished including fan curves for each AHU fan section, plotting actual versus design performance at specifically tested 100% capacity final operating RPM.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15733

DEDICATED OUTDOOR-AIR UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15745 WATER-TO-AIR HEAT PUMPS
 - 2. Section 15785 AIR-TO-AIR ENERGY RECOVERY EQUIPMENT
 - 3. Section 15181 HYDRONIC PIPING
 - 4. Section 15195 FACILITY GAS PIPING

1.2 SUMMARY

- A. Section includes factory-packaged units capable of supplying up to 100 percent outdoor air and providing cooling and heating.
- B. Unit type specified is for electric DX refrigerant cooling, where cooling is required and with heating by either hot water or indirect-fired gas.
- C. The actual type and configuration shall be as determined by the Design-Builder most suitable and appropriate for each application, including indoor suspended or floor-mounted, roof curb mounted, grade-mounted or mounted on dunnage steel.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include rated capacities, operating characteristics, and furnished specialties and accessories.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Roof-curb mounting details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Size and location of unit-mounted rails and anchor points and methods for anchoring units to roof curb.
 - 2. Required roof penetrations for ducts, pipes, and electrical raceways, including size and location of each penetration.
- B. Startup service reports.
- C. Sample Warranty: For special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: One set for each unit.

1.7 WARRANTY

- A. Special Warranty: Manufacturer agrees to replace components of units that fail in materials or workmanship within specified warranty period.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products equal to one of the following:
 - 1. AnnexAire
 - 2. Munters Corporation, Dehumidification Division; Des Champs Products.
 - 3. Thomas & Betts Corporation; Reznor HVAC Division.
 - 4. Trane, Inc.
 - 5. SEMCO, Flakt Woods Group

2.2 PERFORMANCE REQUIREMENTS

- A. General Fabrication Requirements: Comply with requirements in ASHRAE 62.1, SECTION 5 - "SYSTEMS AND EQUIPMENT," and Section 7 - "CONSTRUCTION AND SYSTEM START-UP."
- B. Cabinet Thermal Performance:
 - 1. Maximum Overall U-Value: Comply with requirements in ASHRAE/IESNA 90.1 but not less than R12 center of panel and R11 overall.
 - 2. Include effects of metal-to-metal contact and thermal bridges in the calculations.
- C. Cabinet Surface Condensation:
 - 1. Cabinet shall have additional insulation and vapor seals if required to prevent condensation on the interior and exterior of the cabinet.
 - 2. Portions of cabinet located downstream from the cooling coil shall have a thermal break at each thermal bridge between the exterior and interior casing to prevent condensation from occurring

on the interior and exterior surfaces. The thermal break shall not compromise the structural integrity of the cabinet.

- D. Maximum Cabinet Leakage: 1 percent of the total supply-air flow at a pressure rating equal to the fan shut-off pressure.
- E. Cabinet Deflection Performance:
 - 1. Walls and roof deflection shall be within 1/240 of the span at the design working pressure equal to the fan shut-off pressure. Deflection limits shall be measured at any point on the surface.
 - 2. Floor deflections shall be within 1/240 of the span considering the worst-case condition caused by the following:
 - a. Service personnel.
 - b. Internal components.
 - c. Design working pressure defined for the walls and roof.
- F. Electrical components, devices, and accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- G. Capacities and Characteristics: Refer to drawings.

2.3 CABINET

- A. Construction: double wall.
- B. Exterior Casing Material: Galvanized steel with paint finish baked enamel finish in manufacturer's standard color.
- C. Interior Casing Material: Galvanized steel.
- D. Lifting and Handling Provisions: Factory-installed shipping skids and lifting lugs.
- E. Base Rails: Galvanized-steel rails for mounting on roof curb or pad as indicated.
- F. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
 - 1. Service Doors: Hinged access doors with gaskets. Material and construction of doors shall match material and construction of cabinet in which doors are installed.
- G. Roof: Standing seam or membrane; sloped to drain water.
- H. Floor: Reinforced, metal surface; reinforced to limit deflection when walked on by service personnel. Insulation shall be below metal walking surface.
- I. Cabinet Insulation:
 - 1. Type: Polyurethane injected foam, R Value minimum 6.0 per inch, aged value.
 - 2. Thickness: 2 inches.
- J. Condensate Drain Pans:

1. Shape: Rectangular, with 1 percent slope in at least two planes to direct water toward drain connection.
 2. Size: Large enough to collect condensate from cooling coils including coil piping connections, coil headers, and return bends.
 - a. Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
 - b. Depth: A minimum of 3 inches deep.
 3. Configuration: Double wall, with space between walls filled with foam insulation and moisture-tight seal.
 4. Material: Minimum 16 gauge 304 Stainless-steel sheet.
 5. Drain Connection:
 - a. Located on one end of pan, primary drain at lowest point of pan and secondary drain one diameter above the primary drain.
 - b. Terminated with threaded nipple.
 - c. Minimum Connection Sizes: NPS 1.5 primary and NPS 1.5 secondary overflow.
 6. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil conducted express to the main drain pan. Cascading of condensate from coil pan to coil pan will not be acceptable.
- K. Surfaces in Contact with Airstream: Comply with requirements in ASHRAE 62.1 for resistance to mold and erosion.

2.4 SUPPLY AND EXHAUST FANS

- A. Plenum Fan Type: Single width, non-overloading, with backward-inclined or airfoil blades.
1. Fan Wheel Material: Fabricated, welded aluminum; attached directly to motor shaft.
 2. Fan Wheel Drive and Arrangement: Direct drive, AMCA Arrangement 4.
 3. Fan panel and frame Material: Powder-coated steel, stainless steel, or aluminum.
 4. Fan Enclosure: Easily removable enclosure around rotating parts.
 5. Fan Balance: Precision balance fan below 0.08 inch/s at design speed with filter in.
- B. Motors:
1. Variable speed, permanently lubricated, electronically commutated motor with integrated power electronics or inverter-duty with one VFD per fan.
- C. Mounting: Fan wheel, motor, and drives shall be mounted to fan casing with elastomeric isolators.

2.5 COOLING COILS

- A. Capacity Ratings: Comply with ASHRAE 33 and ARI 410.
- B. Coil Casing Material: 304 Stainless Steel, min. 16 gauge.
- C. Tube Material: Copper, 0.02” wall tubing, 0.035” tube bends.

- D. Tube Header Material: Copper, Type L equivalent weight.
- E. Fin Material: Aluminum, 0.01” thickness minimum.
- F. Fin and Tube Joints: Mechanical bond.
- G. Leak Test: Coils shall be leak tested with air underwater.
- H. Refrigerant Coil Capacity Reduction: Circuit coils for interleaved control.
- I. Refrigerant Coil Suction and Distributor Header Materials: Seamless copper tube with brazed joints.
- J. Coating: Phenolic epoxy corrosion-protection coating after assembly.

2.6 HEATING SYSTEM

- A. Indirect-fired natural gas furnace section, with 400-series stainless steel heat exchanger, gas train, venting, ignition, blower pre-and post-purge controls, safety and high-limit controls.
- B. Heating modulation minimum 5:1 turndown, blow-through configuration.
- C. Minimum efficiency, 82%.
- D. Furnace to have a current Mass. Plumbing Board approval number as a gas appliance.
- E. Heating system may also be a hydronic system consisting of an in-unit coil using 40% glycol by weight in water. This heating approach shall be served by a condensing boiler inside the building.

2.7 REFRIGERATION SYSTEM

- A. Comply with requirements in ASHRAE 15, "Safety Standard for Refrigeration Systems."
- B. Configuration: Packaged with self-contained units mounted exterior to the building. Split systems where the evaporator portions are interior to the building and the refrigeration system condensing unit is external to the building. Split system arrangements shall have all field refrigerant piping, insulation, jacketing and controls provided by the Design-Builder.
- C. Refrigerant Charge: Factory charged with refrigerant and filled with oil.
- D. Compressors: Variable Speed Inverter-Driven Scroll compressors with integral vibration isolators, internal overcurrent and overtemperature protection, internal pressure relief, and crankcase heater.
- E. Refrigerant: R-410A.
 - 1. Classified as Safety Group A1 according to ASHRAE 34.
 - 2. Provide unit with operating charge of refrigerant.
- F. Refrigeration System Specialties:
 - 1. Expansion valve with replaceable thermostatic element.
 - 2. Refrigerant dryer with replaceable core.

3. High-pressure switch.
 4. Low-pressure switch.
 5. Thermostat for coil freeze-up protection during low ambient temperature operation or loss of air.
 6. Brass service valves installed in discharge and liquid lines.
- G. Capacity Control:
1. Single or multiple variable speed compressor with evaporator and condenser coil within the refrigerant section to provide initial pre-cooling and refrigerant hot gas reheat for humidity control.
- H. Refrigerant reheat condenser coils:
1. Capacity Ratings: Complying with ASHRAE 33 and ARI 410.
 2. Tube Material: Copper.
 3. Fin Material: Aluminum.
 4. Fin and Tube Joint: Mechanical bond.
 5. Leak Test: Coils shall be leak tested with air underwater.
- I. Refrigerant condenser coils:
1. Capacity Ratings: Complying with ASHRAE 33 and ARI 410.
 2. Tube Material: Copper.
 3. Fin Material: Aluminum.
 4. Fin and Tube Joint: Mechanical bond.
 5. Leak Test: Coils shall be leak tested with air underwater.
 6. Coil protection and hail guards on all external coil faces.
- J. Condenser Fans:
1. Direct-drive propeller fans, vertical discharge.
 2. Motors TEFC, inverter-driven with line power, staged for capacity control and head pressure control.
 3. Furnish with wire guards.
- K. Safety Controls:
1. Overcurrent protection for individual compressor motors.

2.8 ENERGY RECOVERY WHEEL

- A. Refer to Section 15785 AIR TO AIR ENERGY RECOVERY EQUIPMENT.

2.9 FILTERS

- A. Extended-Surface, Disposable Panel Filters:
1. Comply with NFPA 90A.
 2. Factory-fabricated, dry, extended-surface type.
 3. Thickness: 2 inches.
 4. Initial Resistance: 0.2 inches wg
 5. Recommended Final Resistance: 0.5 inches.

6. Minimum MERV: 8, according to ASHRAE 52.2.
 7. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent and held by self-supporting wire grid.
- B. Extended-Surface, Disposable Panel Filters:
1. Comply with NFPA 90A.
 2. Factory-fabricated, dry, extended-surface, self-supporting type.
 3. Thickness: 4 inches.
 4. Initial Resistance: 0.2 inches wg.
 5. Recommended Final Resistance: 0.5 inches wg.
 6. Minimum MERV: 13, according to ASHRAE 52.2.
 7. Media: Fibrous material coated with an antimicrobial agent and constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.
- C. Mounting Frames:
1. Panel filters arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or from access plenum.
 2. Extended surface filters arranged for flat orientation, removable from access plenum.
 3. Galvanized or stainless steel with gaskets and fasteners, suitable for bolting together into built-up filter banks with space for prefilter.

2.10 ELECTRICAL POWER CONNECTIONS

- A. General Electrical Power Connection Requirements: Factory-installed and -wired switches, motor controllers, transformers, and other necessary electrical devices shall provide a single-point field power connection to unit.
- B. Auxiliary power for lights and GFCI convenience receptacle shall be split off with a separate transformer and disconnect on the line side of the main power disconnect, so that lights and receptacles, each on separate 120V circuits, shall be powered when the main unit disconnect is in the closed position.
1. In lieu of unit-source power, separate external parallel 120V. circuits shall be provided by the Design-Builder.
- C. Wiring: Numbered and color-coded to match wiring diagram.
- D. Wiring Location: Install factory wiring outside an enclosure in a raceway.
- E. Power Interface: Field power interface shall be to NEMA KS 1, heavy-duty, non-fused disconnect switch.
- F. Factory Wiring: Branch power circuit to each motor and to controls with one of the following disconnecting means:
1. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.

- 2. UL 489, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
- G. Factory-Mounted, Overcurrent-Protection Service: For each motor.
- H. Transformer: Factory mounted with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
- I. Controls: Factory wire unit-mounted controls where indicated.
- J. Lights: Factory wire unit-mounted lights, powered and controlled independently of unit main power.
- K. Receptacle: Factory wire unit-mounted, ground fault interrupt (GFI) duplex receptacle, powered independently of unit main power.
- L. Control Relays: Auxiliary and adjustable time-delay relays.

2.11 CONTROLS

- A. Control Valves: Comply with requirements in Section 15900 "HVAC INSTRUMENTATION AND CONTROLS."
- B. Control Wiring: Factory wire connection for controls' power supply.
- C. Control Devices: Sensors, transmitters, relays, switches, detectors, operators, actuators, and valves shall be manufacturer's standard items to accomplish indicated control functions.
- D. Remote-Mounted Status Panel:
 - 1. Cooling/Off/Heating Controls: Control operational mode.
 - 2. Damper Position: Indicate position of outdoor-air dampers in terms of percentage of outdoor air.
 - 3. Status Lights:
 - a. Filter dirty.
 - b. Fan operating.
 - c. Enthalpy wheel operating.
 - d. Cooling operating.
 - e. Heating operating.
 - f. Smoke alarm.
 - g. General alarm.
 - 4. Digital Numeric Display:
 - a. Outdoor airflow.
 - b. Supply airflow.
 - c. Outdoor dry-bulb temperature.
 - d. Outdoor dew point temperature.
 - e. Supply temperature.

E. Control Dampers:

1. Damper Location: Factory installed inside unit for ease of blade axle and bushing service. Arrange dampers located in a mixing box to achieve convergent airflow to minimize stratification.
2. Damper Leakage: Comply with requirements in AMCA 500-D. Leakage shall not exceed 6.5 cfm per sq. ft. at a static-pressure differential of 4.0 inches water column when a torque of 5 inch pounds per sq. ft. is applied to the damper jackshaft.
3. Damper Rating: Rated for close-off pressure equal to the fan shutoff pressure.
4. Damper Label: Bear the AMCA seal for both air leakage and performance.
5. Blade Configuration: Unless otherwise indicated, use parallel blade configuration for two-position control and equipment isolation service and use modulating control when mixing two airstreams. For other applications, use an opposed-blade configuration.
6. Damper Frame Material: Extruded aluminum.
7. Blade Type: hollow-shaped airfoil.
8. Blade Material: Extruded aluminum.
9. Maximum Blade Width: 6 inches.
10. Maximum Blade Length: 48 inches.
11. Blade Seals: Replaceable, continuous perimeter vinyl seals and jambs with stainless-steel compression-type seals.
12. Bearings: Thrust bearings for vertical blade axles.
13. Airflow Measurement:
 - a. Monitoring System: Complete and functioning system of airflow monitoring as an integral part of the damper assembly where indicated.
 - b. Remote Monitoring Signal: 0-10 volt or 4-20 mA scaled signal.
 - c. Accuracy of flow measurement: Within 5 percent of the actual flow rate between the range of the scheduled minimum and maximum airflow. For units with a large range between minimum and maximum airflow, configure the damper sections and flow measurement assembly as necessary to comply with accuracy.
 - d. Straightening Device: Integral to the flow measurement assembly if required to achieve the specified accuracy as installed.
 - e. Flow measuring device: Suitable for operation in untreated and unfiltered outdoor air. If necessary, include temperature and altitude compensation and correction to maintain the accuracy.

F. Damper Operators:

1. Factory-installed electric operator for each damper assembly with one operator for each damper assembly mounted to the damper frame.
2. Operator capable of shutoff against fan pressure and able to operate the damper with sufficient reserve power to achieve smooth modulating action and proper speed of response at the velocity and pressure conditions to which the damper is subjected.
3. Maximum Operating Time: Open or close damper 90 degrees in 90 seconds.
4. Adjustable Stops: For both maximum and minimum positions.
5. Position Indicator and Graduated Scale: Factory installed on each actuator with words "OPEN" and "CLOSED," or similar identification, at travel limits.
6. Spring-return operator to fail-safe; either closed or open as required by application.
7. Operator Type: Direct coupled, designed for minimum 60,000 full-stroke cycles at rated torque.
8. Position feedback Signal: For remote monitoring of damper position.
9. Coupling: V-bolt and V-shaped, toothed cradle.
10. Circuitry: Electronic overload or digital rotation-sensing circuitry.

G. Refrigeration System Controls:

1. Unit-mounted enthalpy controller shall lock out refrigerant system when outdoor-air enthalpy is less than 28 Btu/lb of dry air or outdoor-air temperature is less than 60 deg F.
2. Outdoor-air sensor de-energizes dehumidifier operation when outdoor-air temperature is less than 60 deg F.
3. Relative-humidity sensor energizes dehumidifier operation when relative humidity is more than 50 percent.

H. Integral Smoke Alarm: Smoke detector installed in supply and return air.

I. DDC Temperature Control: Standalone control module for link between unit controls and DDC temperature-control system. Control module shall be compatible with control system specified in Section 15900 "HVAC INSTRUMENTATION AND CONTROLS." Links shall include the following:

1. Start/stop interface relay, and relay to notify DDC temperature-control system alarm condition.
2. Hardware interface or additional sensors for the following:
 - a. Discharge-air temperature.
 - b. Refrigeration system operating.
 - c. Furnace operating.
 - d. Cooling load.
 - e. Economizer cycles.

- f. Air-distribution static pressure and ventilation-air volumes.
- J. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display unit status and alarms.
- 1. Hardwired and BAS Points:
 - a. Monitoring: On-off status, common trouble alarm to BAS.
 - b. Control: On-off operation via BMS.
 - c. Smoke detector activation hardwired to unit VFDs/Starter with alarm output to BAS.
 - d. Freeze-stat activation hardwired to unit VFDs/Starter with alarm output to BAS.
 - e. High-level unit condensate alarm and cooling process shut-down.
 - 2. ASHRAE 135 (BACnet) communication interface with the BAS shall enable the BAS operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the BAS.

2.12 ACCESSORIES

- A. Service Lights and Switch: Factory installed in each accessible section with weatherproof cover. Factory wire lights to a single-point field connection.
- B. Duplex Receptacle: Factory mounted in unit supply-fan section, with 20 amp 120 V GFI duplex receptacle and weatherproof cover.
- C. Power to service lights and duplex receptacle shall remain active when AHU main power disconnect is in the off position.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping, ducts, and electrical systems to verify actual locations of connections before equipment installation.
- C. Examine roof curbs and equipment supports for suitable conditions where units will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Comply with manufacturer's rigging and installation instructions for unloading units and moving to final locations.
- B. Equipment Mounting:

1. Where installed on grade, install air units on cast-in-place concrete equipment bases with an elevated roof curb, minimum 22 inches high. Comply with requirements for equipment bases and foundations specified in Section 03300 "CAST-IN-PLACE CONCRETE."
 2. Where installed on roof dunnage steel, elevated above the roof, install air units on a post-welding galvanized, welded tube steel frame base to fit standard unit curb-mounting and the dunnage steel, with a neoprene buffer strip continuous along all bearing surfaces. Tube steel frame shall be field/shop fabricated from certified dimension drawings and installed in advance of rigging.
 3. Where installed on roof curb, the manufacturer shall supply a minimum 22-inch high roof curb designed for flat top over roof pitch. Install air unit with a neoprene buffer strip continuous along all bearing surfaces.
- C. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.

3.3 CONNECTIONS

- A. Where installing piping adjacent to units, allow space for service and maintenance.
- B. Hydronic Piping Connections:
1. Comply with requirements in Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES."
 2. Install shutoff valve and union or flange on each supply connection and install balancing valve and union or flange on each return connection.
- C. Duct Connections:
1. Comply with requirements in Section 15815 "METAL DUCTS."
 2. Drawings indicate the general arrangement of ducts.
 3. Connect ducts to units with flexible duct connectors. Comply with requirements for flexible duct connectors in Section 15820 "DUCT ACCESSORIES."
- D. Install drain pipes from unit drain pans to storm drain or splash block on roof.
1. Drain Piping: Drawn-temper copper water tubing complying with ASTM B 88, Type L, with soldered joints.
 2. Pipe Size: Same size as condensate drain pan connection with P-Trap with depth one inch greater than total unit static pressure. Drain trap assemblies shall have pipe unions for seasonal removal and cleanouts for cleaning and drainage.
 3. Pipe secondary drain in same manner as primary, except secondary drain shall be instrumented with a high-level water detector to shut down the cooling process.
- E. Electrical Connections: Comply with requirements for power wiring, switches, and motor controls in electrical Sections.
1. Install electrical devices furnished by unit manufacturer but not factory mounted.

3.4 STARTUP SERVICE

- A. Perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Inspect units for visible damage to furnace combustion chamber.
 3. Verify operation of remote panel including pilot-light operation and failure modes. Inspect the following:
 - a. High-limit heat exchanger.
 - b. Alarms.
 4. Inspect units for visible damage to refrigerant compressor, condenser and evaporator coils, and fans.
 5. Start refrigeration system when outdoor-air temperature is within normal operating limits and measure and record the following:
 - a. Cooling coil leaving-air, dry- and wet-bulb temperatures.
 - b. Cooling coil entering-air, dry- and wet-bulb temperatures.
 - c. Condenser coil entering-air dry-bulb temperature.
 - d. Condenser coil leaving-air dry-bulb temperature.
 6. Simulate maximum cooling demand and inspect the following:
 - a. Compressor refrigerant suction and hot-gas pressures.
 - b. Short-circuiting of air through outside coil or from outside coil to outdoor-air intake.
 7. Inspect casing insulation for integrity, moisture content, and adhesion.
 8. Verify that clearances have been provided for servicing.
 9. Verify that controls are connected and operable.
 10. Verify that filters are installed.
 11. Clean coils and inspect for construction debris.
 12. Clean furnace flue and inspect for construction debris.
 13. Inspect operation of power vents.
 14. Purge gas line.
 15. Inspect and adjust vibration isolators and seismic restraints.
 16. Verify bearing lubrication.
 17. Clean fans and inspect fan-wheel rotation for movement in correct direction without vibration and binding.
 18. Adjust fan belts to proper alignment and tension.
 19. Start unit.
 20. Inspect and record performance of interlocks and protective devices including response to smoke detectors by fan controls and fire alarm.
 21. Operate unit for run-in period.
 22. Calibrate controls.
 23. Adjust and inspect high-temperature limits.
 24. Inspect outdoor-air dampers for proper stroke and interlock with return-air dampers.
 25. Verify operational sequence of controls.
 26. Measure and record the following airflows. Plot fan volumes on fan curve.
 - a. Supply-air volume.
 - b. Return-air flow (where so fitted).

- c. Outdoor-air flow.
- B. After startup, change filters, verify bearing lubrication, and adjust belt tension.
- C. Remove and replace components that do not properly operate and repeat startup procedures as specified above.
- D. Prepare written report of the results of startup services.

3.5 ADJUSTING

- A. Adjust initial temperature and humidity set points.
- B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- C. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Train MBTA's maintenance personnel to adjust, operate, and maintain units.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15739

SPLIT SYSTEM AIR CONDITIONING UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 03300 – CAST IN PLACE CONCRETE
 - 2. Section 01800 - SUSTAINABILITY REQUIRMENTS
 - 3. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 4. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
 - 5. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 6. Section 15074 – VIBRATION AND SEISMIC CONTROLSS FOR PIPING AND EQUIPMENT
 - 7. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 8. Section 15086 – DUCT INSULATION
 - 9. Section 15088 – HVAC PIPING INSULATION
 - 10. Section 15093 – SLEEVES AND SLEEVE SEALS FOR PIPING
 - 11. Section 15112 – GENERAL-DUTY VALVES FOR PIPING
 - 12. Section 15127 – METER AND GAGES FOR PIPING
 - 13. Section 15183 – REFRIGERANT PIPING
 - 14. Section 15815 – METAL DUCTS
 - 15. Section 15830 – DUCT ACCESSORIES
 - 16. Section 15855 – DIFFUSERS, REGISTERS, AND GRILLES
 - 17. Section 15900 – HVAC INSTRUMENTATION AND CONTROLS
 - 18. Section 15940 – SEQUENCE OF OPERATIONS FOR HVAC SYSTEMS
 - 19. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.2 SUMMARY

- A. Section includes split-system air-conditioning and heat-pump units consisting of separate evaporator- fan and compressor-condenser components.
- B. Systems to use R410a refrigerant or equal non-CFC refrigerant.
- C. Systems include several configurations, both ducted and non-ducted, systems with a 1:1 evaporator/condensing unit ratio and systems with multiple evaporators to a single condensing unit.
- D. Where used for primary heating, systems shall be capable of conventional air-source heat pump operation down to outdoor temperatures of 32F or lower and be capable of 100% of space heating needs down to zero (0) degrees F. without the use of additional electrical resistance heat. In this full heating mode, the systems shall operate at a coefficient of performance of not less than 1.60.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.
 - 1. Ductless and ducted mini-split system units.
 - 2. Minisplit condensate pumps
 - 3. Controls including BACnet® cards for web-based control.
- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
- B. Warranty: Sample of special warranty.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For split-system air-conditioning units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: three set(s) for each evaporator unit.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ASHRAE Compliance:
 - 1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems." ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Procedures," and Section 7 - "Construction and System Start-up."
- C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Section 03300 "CAST-IN- PLACE CONCRETE."

- 1.9 Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.10 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of split-system air-conditioning units that fail in materials or workmanship within specified warranty period.

- 1. Warranty Period:

- a. For Compressor: Five year(s) from date of Substantial Completion.
- b. For Parts: Five year(s) from date of Substantial Completion.
- c. For Labor: Five year(s) from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Carrier Corporation; Home Comfort and HVAC Building & Industrial Systems.
 - 2. Daikin North America, LLC.
 - 3. Mitsubishi Electric & Electronics USA, Inc.; HVAC Advanced Products Division.
 - 4. SANYO North America Corporation; SANYO Fisher Company.

2.2 INDOOR UNITS (5 TONS OR LESS)

- A. Ceiling Mounted Recessed Cassette, Evaporator-Fan Components:
 - 1. Four-way cassette style indoor unit that recesses into the ceiling with a ceiling grille. The indoor unit shall be factory assembled, wired and run tested. Contained within the unit shall be all factory wiring, piping, electronic modulating linear expansion device, control circuit board and fan motor. The unit shall have a self-diagnostic function, 3-minute time delay mechanism, an auto restart function, an emergency operation function, a test run switch, and the ability to adjust airflow patterns for different ceiling heights. Indoor unit and refrigerant pipes shall be charged with dehydrated air before shipment from the factory.
 - a. The indoor unit shall have an adjustable air outlet system offering 4-way airflow, 3-way airflow, or 2-way airflow.

- b. The indoor unit shall have switches that can be set to provide optimum airflow based on ceiling height and number of outlets used.
 - c. The indoor unit vanes shall have 5 fixed positions and a swing feature that shall be capable of automatically swinging the vanes up and down for uniform air distribution.
 - d. The vanes shall have an Auto-Wave selectable option in the heating mode that shall randomly cycle the vanes up and down to evenly heat the space.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.
- a. The tubing shall have inner grooves for high efficiency heat exchange.
 - b. All tube joints shall be brazed with phosphorus-copper or silver alloy.
 - c. The coils shall be pressure tested at the factory.
 - d. Both refrigerant lines to the indoor units shall be insulated.
3. Fan: Direct drive, centrifugal.
- a. The indoor fan shall be statically and dynamically balanced to run on a motor with permanently lubricated bearings.
 - b. The indoor fan shall consist of five (5) speed settings, Low, Mid1, Mid2, High and Auto.
 - c. The fan shall have a selectable Auto fan setting that will adjust the fan speed based on the difference between controller set-point and space temperature.
 - d. If specified, the grille shall have an optional i-see sensor that will measure room temperature variations and adjust the airflow accordingly to evenly condition the space.
4. Fan Motors:
- a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
 - b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
 - c. Enclosure Type: Totally enclosed, fan cooled.
 - d. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
 - e. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
 - f. Mount unit-mounted disconnect switches on exterior of unit.
5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in 62.1.
6. Condensate Drain Pans:

- a. A condensate pan and drain shall be provided under the coil.
 - b. The unit shall be provided with an integral condensate lift mechanism that will be able to raise drain water 33 inches above the condensate pan.
 - c. Manufacturer to provide drain pan level sensor powered by a 20-year life lithium battery.
 - d. Sensor shall require no external power for operation and shall have an audible indication of low battery condition.
 - e. The drain pan sensor shall provide protection against drain pan overflow by sensing a high condensate level in the drain pan. Should this occur, the control shuts down the indoor unit before an overflow can occur. A thermistor error code will be produced should the sensor activate indicating a fault which must be resolved before the unit re- starts.
 - f. Fabricated with two percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
 - 1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
 - 2) Depth: A minimum of 1 inch deep.
 - g. Single-wall, stainless-steel sheet.
 - h. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.
 - 1) Minimum Connection Size: NPS 1.
 - i. Pan-Top Surface Coating: Asphaltic waterproofing compound.
7. Air Filtration Section:
- a. General Requirements for Air Filtration Section:
 - 1) Comply with NFPA 90A.
 - b. Extended-Surface, Disposable Panel Filters:
 - 1) Factory-fabricated, dry, extended-surface type.
 - 2) Thickness: 1 inch.
 - 3) Merv according to ASHRAE 52.2: 8.
 - 4) Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
 - 5) Media-Grid Frame: Nonflammable cardboard.

B. Concealed Evaporator-Fan Components:

1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
2. Insulation: Faced, glass-fiber duct liner.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.
4. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch; leak tested to 300 psig underwater; with a two-position control valve.
5. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
6. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
7. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
 - b. Multi-tapped, multispeed with internal thermal protection and permanent lubrication.
 - c. Wiring Terminations: Connect motor to chassis wiring with plug connection.
8. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
9. Filters: Permanent, cleanable.
10. Condensate Drain Pans:
 - a. Fabricated with one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
 - 1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
 - 2) Depth: A minimum of 2 inches deep.
 - b. Single-wall, stainless-steel sheet.
 - c. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.
 - 1) Minimum Connection Size: NPS 1.
 - d. Pan-Top Surface Coating: Asphaltic waterproofing compound.
 - e. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

C. Wall-Mounted, Evaporator-Fan Components:

1. Cabinet: Enameled steel with removable panels on front and ends in color selected by Architect, and discharge drain pans with drain connection.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and thermal-expansion valve. Comply with ARI 206/110.
3. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements; with refractory ceramic support bushings, automatic-reset thermal cutout, built-in magnetic contactors, manual-reset thermal cutout, airflow proving device, and one-time fuses in terminal box for overcurrent protection.
4. Fan: Direct drive, centrifugal.
5. Fan Motors:
 - a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
 - b. Multi-tapped, multispeed with internal thermal protection and permanent lubrication.
 - c. Enclosure Type: Totally enclosed, fan cooled.
 - d. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.
 - e. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in electrical Sections.
 - f. Mount unit-mounted disconnect switches on interior of unit.
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
7. Condensate Drain Pans:
 - a. Fabricated with two percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
 - 1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
 - 2) Depth: A minimum of 1 inch deep.
 - b. Single-wall, stainless-steel sheet.
 - c. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.
 - 1) Minimum Connection Size: NPS 1.
 - d. Pan-Top Surface Coating: Asphaltic waterproofing compound.
8. Air Filtration Section:
 - a. General Requirements for Air Filtration Section:
 - 1) Comply with NFPA 90A.
 - 2) Minimum Arrestance: According to ASHRAE 52.1 and MERV according to ASHRAE 52.2.

- 3) Filter-Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
- b. Disposable Panel Filters:
- 1) Factory-fabricated, viscous-coated, flat-panel type.
 - 2) Thickness: 1 inch.
 - 3) >.
 - 4) Merv according to ASHRAE 52.2: 7
 - 5) Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent.
 - 6) Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, and hinged; with pull and retaining handles.

2.3 OUTDOOR UNITS (5 TONS OR LESS)

A. Air-Cooled, Compressor-Condenser Components:

1. Casing: Steel, finished with baked enamel, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
 - a. Compressor Type: Scroll.
 - b. Multispeed compressor motor with manual-reset high-pressure switch and automatic- reset low-pressure switch.
 - c. Refrigerant Charge: R-410A.
 - d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 206/110.
 - e. Unit shall have a marine/salt-water environment factory treatment including coil coatings, stainless steel hardware.
3. Heat-Pump Components: Reversing valve and low-temperature-air cutoff thermostat.
4. Fan: Aluminum-propeller type, directly connected to motor.
5. Motor: Permanently lubricated, with integral thermal-overload protection.
6. Low Ambient Kit: Permits cooling operation down to 23 deg F. or lower, full heating operation down to -5 deg. F. or lower.
7. Mounting Base: Polyethylene or fiberglass reinforced plastic (FRP, for on-grade. Power-coated steel adjustable rack system for sidewall installation. On-grade and roof applications shall have elevated snow stand, minimum 18 inches depth above mounting base.

2.4 MINISPLIT CONDENSATE PUMPS

- A. Manufacturers:
 - 1. Hartell Pumps Div.; Milton Roy Co. Mini Split Pump
 - 2. Little Giant Pump Co.; Subsidiary of Tecumseh Products Co.
 - 3. Submitted Split System Manufacturer's matching minisplit condensate pumps.
- B. Description: Miniature packaged unit designed for use with ductless split system units with corrosion-resistant pump, 1¼" high, & automatic controls. Include a 72-inch- minimum, electrical power cord with plug.

2.5 ACCESSORIES

- A. Control equipment and sequence of operation are specified in Section 15900 "HVAC INSTRUMENTATION AND CONTROLS" and Section 15940 "SEQUENCE OF OPERATION FOR HVAC SYSTEMS."
- B. Low-Ambient Operation Kits, including wind baffles, head pressure controller, crankcase heater, to allow both heating and cooling operation down to -5 deg. F.
- C. Thermostat controller: Low voltage with subbase to control compressor and evaporator fan, speed, mode setting, dehumidification. Include BACnet® communication and programming.
- D. Automatic-reset timer to prevent rapid cycling of compressor.
- E. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends, limited to single-lengths of longest manufacturer-furnished line sets. For longer lengths use brazed hard-temper ACR copper refrigerant tubing.
- F. Drain Hose: For condensate.
- G. Marine/Salt Water Environment factory treatment package.
- H. Snow stand, minimum 18 inch elevation above base.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install units level and plumb.
- B. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure. Locate for ease of service, high enough including ladder staging locations, to avoid traffic and circulation impacts.
- C. Install roof-mounted, compressor-condenser components on equipment supports specified in Section 07720 "ROOF ACCESSORIES." Anchor units to supports with removable, stainless steel fasteners.

- D. Equipment Mounting:
1. Install ground-mounted, compressor-condenser components on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in Section 03300 "CAST-IN-PLACE CONCRETE."
 2. Install roof-mounted, compressor-condenser components on roof sleepers compatible with roofing system or similar compatible support system, all with wind bracing.
 3. Comply with requirements for vibration isolation and seismic control devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
 4. Install wall-mounted compressor-condenser components on rack support systems recommended by the manufacturer and specifically engineered for these applications.
- E. Where within standard line set length distances and recommended by the system manufacturer, install and connect pre-charged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit. Protect exposed tubing under 16 Gauge minimum sheet metal covers.
- F. Furnish and install a network of hard-temper ACR refrigerant tubing as specified in Section 15183 "REFRIGERANT PIPING", including system-specific refrigerant fittings per the system manufacturer's requirements. Protect exposed tubing under 16 Gauge minimum sheet metal covers.

3.2 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where piping is installed adjacent to unit, allow space for service and maintenance of unit.
- C. Duct Connections: Duct installation requirements are specified in Section 15815 "METAL DUCTS." Drawings indicate the general arrangement of ducts. Connect supply and return ducts to split-system air-conditioning units with flexible duct connectors. Flexible duct connectors are specified in Section 15820 "DUCT ACCESSORIES."

3.3 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.

2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Prepare test and inspection reports.

3.4 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.
 2. Include start-up and performance verification in appropriate seasons for cooling and heating. Heating tests shall be performed between Dec. 1 and March 1; Cooling tests shall be performed between June 1 and Sept.1.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain units.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15761

HYDRONIC AIR COILS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes hydronic heating and cooling air coils.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
 2. Include rated capacities, operating characteristics, and pressure drops for each air coil.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

1.6 FIELD CONDITIONS

- A. Altitude above Mean Sea Level: Up to 500.

2.1 DESCRIPTION

PART 2 - PRODUCTS

- A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

2.2 COILS

- A. Manufacturers: Subject to compliance with requirements, provide products equal to the following:
 1. Aerofin.
 2. Carrier Corporation; a UTC company.
 3. Coil Company, LLC.
 4. Colmac Coil Manufacturing, Inc.
 5. Dunham-Bush USA.
 6. Heatcraft Worldwide Refrigeration.

7. Technical Systems Inc (TSI).
 8. Greenheck Fan Corporation.
 9. Super Radiator Coils.
 10. Trane.
 11. USA Coil & Air.
- B. Performance Ratings: Tested and rated according to AHRI 410 and ASHRAE 33.
 - C. Minimum Working-Pressure/Temperature Ratings: 200 psig, 325 deg F.
 - D. Source Quality Control: Factory tested to 300 psig.
 - E. Tubes: ASTM B 743 copper, minimum 0.035 inch, with tube bends at 0.049 inch thick.
 - F. Fins: Aluminum, minimum 0.010 inch thick.
 - G. Headers: Cast iron with cleaning plugs and drain and air vent tappings Seamless copper tube with brazed joints, prime coated.
 - H. Frames for In-Duct Coils: Galvanized-steel channel frame, minimum 0.064 inch thick for flanged mounting.
 - I. Frames for in Air Handling Unit Coils: ASTM A 666, Type 304 stainless steel, minimum 0.0625 inch thick for flanged mounting.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.
- B. Examine roughing-in for piping systems to verify actual locations of piping connections before coil installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install coils level and plumb.
- B. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
- C. Install stainless-steel drain pan under each cooling coil.

1. Construct drain pans with connection for drain; insulated and complying with ASHRAE 62.1.
 2. Construct drain pans to extend beyond coil length and width and to connect to condensate trap and drainage.
 3. Extend drain pan upstream and downstream from coil face.
 4. Extend drain pan under coil headers and exposed supply piping.
- D. Install moisture eliminators for cooling coils. Extend drain pan under moisture eliminator.
- E. Straighten bent fins on air coils.
- F. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to coils to allow service and maintenance.
- C. Connect water piping with unions and shutoff valves to allow coils to be disconnected without draining piping. Control valves are specified in Section 15900 "HVAC Instrumentation and Controls," and other piping specialties are specified in Section 15179 "Hydronic Piping Specialties."

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15765

ELECTRIC RESISTANCE AIR COILS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATEERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15074 – VIBRATION AND SEISMIC CONTROLSS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15086 – DUCT INSULATION
 - 6. Section 15815 – METAL DUCTS
 - 7. Section 15820 – DUCT ACCESSORIES
 - 8. Section 15900 – HVAC INSTRUMENTATION AND CONTROLS
 - 9. Section 15940 – SEQUENCE OF OPERATIONS FOR THE HVAC SYSTMS
 - 10. Section 15950 – TESTING, ADJUSTING AND BALANCING
 - 11. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK
 - 12. Section 16050 – GROUNDING AND BONDING

1.2 SUMMARY

- A. Section includes electric resistance air coils, packaged with control panel and related operational and safety controls.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
 - 2. Include rated capacities, operating characteristics, and pressure drops for each air coil.
- B. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which coil location and ceiling-mounted access panels are shown and coordinated with each other.
- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 DESCRIPTION

- A. ASHRAE Compliance: Comply with applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND STARTUP."

2.2 COILS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Q-Mark
 - 2. Chromalox.
 - 3. Greenheck
 - 4. INDEECO.
 - 5. Redi
- B. Testing Agency Listing and Labeling: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Coil Assembly: Comply with UL 1995.
- D. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
- E. High-Temperature Coil Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or casing.
 - 1. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with heater.
- F. Frames: Galvanized-steel channel frame, minimum 0.064 inch thick for slip-in or flanged mounting.
 - 1. Slip-in units shall have integral spacers on all sides to accommodate duct liner thickness, if any.
- G. Control Panel: Unit mounted sheet metal with disconnecting means and overcurrent protection. Include the following features and controls:
 - 1. NEMA-1 enclosure for general use. NEMA 3 for use in VMF shop areas for dust protection.
 - 2. SCR (Sine Curve Rectifier) controller.
 - 3. Time-delay relay.
 - 4. Pilot lights, Power On Amber-Coil Energized Green- Fault Red
 - 5. Airflow proving switch
 - 6. Downstream duct high limit temperature switch
 - 7. Door Labels for warnings and to maintain door swing clear of all obstructions.
- H. See Section 15900 "HVAC Instrumentation and Controls" for thermostat.

- I. Thermostats: Duct-mounted thermostats for discharge air control applications, with temperature range from 50 to 90 deg F, and 2.5 deg F throttling range. Exterior temperature setpoint control.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance including lining, distances to fittings, clearance for duct insulation.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install coils level and plumb.
- B. Install coils in metal ducts and casings constructed per SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
- C. Install all external controls including airflow proving switch, high-limit downstream thermal cut-out switch, in ductwork.
- D. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.
- E. Demonstrate access including door swings and maintaining electrical code clearances at control panel, free of obstructions of any trade.

3.3 CONNECTIONS

- A. Ground equipment per Section 16060 "Grounding and Bonding", by the Division 16 contractor.
- B. Connect wiring per Section 16050 Basic Materials and Methods for Electrical Work", by the Division 16 contractor.

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Prepare test and inspection reports.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A.** Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15778

HEAT TRACING FOR PLUMBING PIPING

PART 1 - GENERAL

1.0 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.1 SUMMARY

- A. Section includes plumbing piping heat tracing for freeze prevention with the following electric heating cables:
 - 1. Self-regulating, parallel resistance.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK
 - 2. Section 15051 – BASIC MATERIALS AND METHODS FOR PLUMBING WORK.
 - 3. Section 15060 – GROUNDING AND BONDING
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15085 – PLUMBING PIPING INSULATION
 - 6. Section 15140 – DOMESTIC WATER PIPING
 - 7. Section 15150 – SANITARY WASTE AND VENT PIPING
 - 8. Section 15160 – STORM WATER PIPING
 - 9. Section 15412 – EMERGENCY PLUMBING FIXTURES

1.2 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
 - 2. Schedule heating capacity, length of cable, spacing, and electrical power requirement for each electric heating cable required.
- B. Shop Drawings: For electric heating cable.
 - 1. Include plans, elevations, sections, and attachment details.
 - 2. Include diagrams for power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

- A. Field quality-control reports.
- B. Sample Warranty: For special warranty.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For electric heating cables to include in operation and maintenance manuals.

1.5 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.
 - 1. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 SELF-REGULATING, PARALLEL-RESISTANCE HEATING CABLES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Chromalox.
 - 2. Delta-Therm Corporation.
 - 3. Raychem; a brand of Tyco Thermal Controls LLC.
 - 4. Thermon
- B. Comply with IEEE 515.1.
- C. Heating Element: Pair of parallel No. 16 AWG, nickel-coated, stranded copper bus wires embedded in crosslinked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled, nonheating leads with connectors at one end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.
- D. Electrical Insulating Jacket: Flame-retardant polyolefin.
- E. Cable Cover: Tinned-copper braid and polyolefin outer jacket with ultraviolet inhibitor.
- F. Maximum Operating Temperature (Power On): 150 deg F.
- G. Maximum Exposure Temperature (Power Off): 185 deg F.
- H. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- I. Capacities and Characteristics:
 - 1. Refer to drawings for capacities.

2.2 CONTROLS

- A. Pipe-Mounted Thermostats for Freeze Protection and Tempered Water Maintenance:

1. Remote bulb unit with adjustable temperature range from 30 to 100 deg F.
2. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected cable.
3. Remote bulb on capillary, resistance temperature device, or thermistor for directly sensing pipe-wall temperature.
4. Corrosion-resistant, waterproof control enclosure.

2.3 ACCESSORIES

- A. Cable Installation Accessories: Fiberglass tape, heat-conductive putty, cable ties, silicone end seals and splice kits, and installation clips all furnished by manufacturer, or as recommended in writing by manufacturer. Refer to drawings for additional information
- B. Warning Labels: Refer to Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."
- C. Warning Tape: Continuously printed "Electrical Tracing"; vinyl, at least 3 mils thick, and with pressure-sensitive, permanent, waterproof, self-adhesive back. Apply full-circumference bands at ends of labels and where continuous, at maximum 48 inch spacing, not over lettering.
 1. Width for Markers on Pipes with OD, Including Insulation, Less Than 6 Inches: 3/4 inch minimum.

PART 3 - EXECUTION

3.0 EXAMINATION

- A. Examine surfaces and substrates to receive electric heating cables for compliance with requirements for installation tolerances and other conditions affecting performance.
 1. Ensure surfaces and pipes in contact with electric heating cables are free of burrs and sharp protrusions.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.1 INSTALLATION

- A. Install electric heating cable on all pressure and gravity-flow water-bearing piping ("subject piping"), where exposed to freezing temperatures.
- B. The subject piping shall only be so exposed where unavoidable. The use of heat trace protection shall not be used to avoid interior routing in heated spaces; heat trace protection shall be "protection for the exception".
- C. For the purposes of this specification, locations subject to "freezing temperatures" shall include:

1. The exterior of a heated building to a point twelve inches inside the heated building's interior wall.
 2. Soffits, shafts and other interior locations not specifically heated but which have exterior exposure.
 3. Interior spaces, heated or not, which have a retractable door where prolonged open-door periods are a necessary use and function.
 - a. Heat trace treatment in spaces with such doors shall include all subject piping for the entire space if the space less than fifty (50) feet in depth perpendicular to the door.
 - b. In spaces deeper than 50 feet, heat trace shall be applied to the subject piping within the full volume of this space to a point not less than fifty (50) feet from said door.
 - c. Example 1: A space larger than 50 feet deep with a loading door, rolling stock track doors, shipping/receiving doors, shall have heat trace on all piping within that space, to a point not less than 50 feet from the door.
 - d. Example 2: A space less than 50 feet deep with a retractable door shall have heat trace on all subject piping within the space volume.
 - e. Example 3: Heated egress corridors with doors used for personnel access only, will not require heat trace on the subject piping.
- D. Install electric heating cable across expansion, construction, and control joints according to manufacturer's written instructions; use cable-protection conduit and slack cable to allow movement without damage to cable.
- E. Electric Heating-Cable Installation for Freeze Protection for Piping:
1. Install electric heating cables after piping has been tested and before insulation is installed.
 2. Install electric heating cables according to IEEE 515.1.
 3. Install insulation over piping with electric cables according to Section 15085 "PLUMBING Piping Insulation."
 4. Install warning tape on piping insulation where piping is equipped with electric heating cables.
- F. Set field-adjustable switches and circuit-breaker trip ranges.

3.2 CONNECTIONS

The trade contractor shall terminate heat tracing cable in a junction box, labeled with the identified line, length of cable, total Watts capacity, voltage, phase and Amperes, ready for field connection by DIV 16. The DIV 16 contractor shall extend power:

1. To the heat trace connection via the control panel serving each heat trace circuit or group of circuits and,
 2. To each heat trace control panel from the appropriate power distribution panel.
- B. Ground equipment according to Section 16060 "GROUNDING AND BONDING."

- C. Connect wiring according to Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

3.3 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
 - 1. Perform tests after cable installation but before application of coverings such as insulation, wall or ceiling construction, or concrete.
 - 2. Test cables for electrical continuity and insulation integrity before energizing.
 - 3. Test cables to verify rating and power input. Energize and measure voltage and current simultaneously.
- D. Repeat tests for continuity, insulation resistance, and input power after applying thermal insulation on pipe-mounted cables.
- E. Cables will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

3.4 PROTECTION

- A. Protect installed heating cables, including non-heating leads, from damage during construction.
- B. Remove and replace damaged heat-tracing cables.
- C. Provide warning labels per 2.3 B. and 2.3 C.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15785

AIR-TO-AIR ENERGY RECOVERY EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15733 – DEDICATED OUTDOOR AIR UNITS
 - 2. Section 15815 – METAL DUCTS

1.2 SUMMARY

- A. Section Includes:
 - 1. Heat wheels.
 - 2. Fixed-plate sensible heat exchangers.
 - 3. Packaged energy recovery units.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings: For air-to-air energy recovery equipment. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
 - 1. Suspended ceiling components.
 - 2. Structural members to which equipment or suspension systems will be attached.
- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air-to-air energy recovery equipment to include in maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Filters: One set of each type of filter specified.
 - 2. Wheel Belts: One set of belts for each heat wheel.

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. ARI Compliance:
 - 1. Capacity ratings for air-to-air energy recovery equipment shall comply with ARI 1060, "Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment."
 - 2. Capacity ratings for air coils shall comply with ARI 410, "Forced-Circulation Air- Cooling and Air-Heating Coils."
- C. ASHRAE Compliance:
 - 1. Applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND STARTUP."
 - 2. Capacity ratings for air-to-air energy recovery equipment shall comply with ASHRAE 84, "Method of Testing Air-to-Air Heat Exchangers."
- D. NRCA Compliance: Roof curbs for roof-mounted equipment shall be constructed per recommendations of NRCA.
- E. UL Compliance:
 - 1. Packaged heat recovery ventilators shall comply with requirements in UL 1812, "Ducted Heat Recovery Ventilators"; or UL 1815, "Nonducted Heat Recovery Ventilators."

1.8 COORDINATION

- A. Coordinate layout and installation of air-to-air energy recovery equipment and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.9 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air-to-air energy recovery equipment that fail in materials or workmanship within specified warranty period.
1. Warranty Period for Packaged Energy Recovery Units: Two years.
 2. Warranty Period for Fixed-Plate Total Heat Exchangers: 10 years.
 3. Warranty Period for Heat Wheel Heat Exchangers: Two years.

PART 2 - PRODUCTS

2.1 ENTHALPY WHEELS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Advanced Thermal Technologies.
 2. AirXchange Inc.
 3. American Energy Exchange, Inc.
 4. Loren Cook Company.
 5. SEMCO Incorporated.
 6. Trane; American Standard Companies, Inc.
 7. Valent Air Systems.
- B. Casing:
1. Steel with standard factory-painted finish.
 2. Integral purge section limiting carryover of exhaust air to between 0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg pressure.
 3. Casing seals on periphery of rotor and on duct divider and purge section.
 4. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings or permanently lubricated bearings. Support horizontal rotors on tapered roller bearing.
- C. Rotor: Aluminum segmented wheel strengthened with radial spokes, with nontoxic, noncorrosive, silica-gel desiccant coating, 4 Angstrom criteria.
- D. Drive: Fractional horsepower motor and gear reducer, with speed changed by variable frequency controller and self-adjusting multilink belt around outside of rotor.
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- E. Controls:
1. Starting relay, factory mounted and wired, and manual motor starter for field wiring.
 2. Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air enthalpy sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and

maintain exhaust temperature above freezing and air differential temperature above set point. Rotor speed shall increase to maximum when exhaust-air temperature is less than outdoor-air temperature.

3. Pilot-Light Indicator: Display rotor rotation and speed.

2.2 FIXED-PLATE SENSIBLE HEAT EXCHANGERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. American Energy Exchange, Inc.
 2. Des Champs Technologies.
 3. Eclipse, Inc.; Exothermics Business Group.
 4. Nutech Brands Inc.
 5. RenewAire LLC.
 6. UAS, Inc.; a CLARCOR company.
 7. Titan Air Incorporated
 8. Xetex, Inc.; Unison Comfort Technologies
 9. Air Zone International
 10. Valent Air Systems.
- B. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- C. Drain Pan: Same material as casing, with drain connections on exhaust and supply side.
 1. Comply with requirements in ASHRAE 62.1.
- D. Plates: Evenly spaced and sealed and arranged for counter airflow.
 1. Plate Material: Aluminum.
 2. Plate Coating: Phenolic.
- E. Bypass Plenum: Face-and-bypass dampers shall be mounted flush to the face of the exchanger and operated by a spring return, direct-coupled, modulating proportional actuator. Dampers shall be interlocked so that when the face damper is open the bypass damper shall be closed. A common square shaft shall drive both section with a single direct-coupled actuator. Dampers shall have opposed blades.
- F. Extended-Surface, Disposable Panel Filters:
 1. Comply with NFPA 90A.
 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 3. Factory-fabricated, dry, extended-surface type.
 4. Thickness: 2 inches (50mm).
 5. Initial Resistance: 0.1 inches wg.
 6. Recommended Final Resistance: 0.3 inches wg.
 7. Minimum MERV: 8, per ASHRAE 52.2.
 8. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
 9. Media-Grid Frame: Nonflammable cardboard.

10. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

2.3 EXTERIOR PACKAGED ENERGY RECOVERY UNITS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Advanced Thermal Technologies.
 2. Greenheck Fan Corporation.
 3. Loren Cook Company.
 4. RenewAire LLC.
 5. SEMCO Incorporated.
 6. Trane; American Standard Companies, Inc.
 7. Venmar CES Inc.
 8. Wing, L. J.; Mestek Technology, Inc.
 9. Titan Air Incorporated
 10. Xetex Inc; Unison Comfort Technologies
- B. Description:
 1. Packaged exterior heating and ventilating unit and/or make-up air unit with return/exhaust fans and supply fans, to extract thermal energy from the leaving waste air stream and impart that to the incoming supply air stream. Units depending on application may include gas-fired indirect heating furnaces, or if without, will supply air to either appropriate spaces or to the return of a conditioning unit.
 2. Units of this type will typically be above 1,000 cfm airflow capacity and may range upward of 10,000 cfm airflow capacity.
- C. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Housing: Double-wall galvanized steel construction with corrosion-protection primer coating and exterior finish, removable, hinged access doors with neoprene gaskets for inspection and access to internal parts, minimum 2-inch- (50mm-thick thermal insulation, knockouts for electrical and piping connections, exterior drain connection, and lifting lugs. Exterior finish color shall be selected by Architect from manufacturer's full range.
 1. Inlet: Weatherproof hood, with damper for exhaust and supply.
 - a. Exhaust: Spring-return, two-position, motor-operated damper.
 - b. Supply: Spring-return, two-position, motor-operated damper.
- E. Heat Recovery Device: Fixed-plate heat exchanger.
- F. Supply and Exhaust Fans: Backward-inclined, plenum centrifugal fan with elastomer isolators and flexible duct connections.
 1. Motor and Drive: Direct driven.
 2. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT."
- G. Extended-Surface, Disposable Panel Filters:

1. Comply with NFPA 90A.
2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
3. Factory-fabricated, dry, extended-surface type.
4. Thickness: 4 inches (100mm).
5. Initial Resistance: 0.15 inches wg.
6. Recommended Final Resistance: 0.3 inches wg.
7. Minimum MERV: 13, per ASHRAE 52.2.
8. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
9. Media-Grid Frame: Nonflammable cardboard.
10. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

H. Indirect-Fired Gas Furnaces:

1. Description: Factory assembled, piped, and wired; complying with NFPA 54, "National Fuel Gas Code," and ANSI Z21.47, "Gas-Fired Central Furnaces."
 - a. AGA Approval: Furnace shall bear label of AGA.
2. Burners: 400-Series Stainless steel.
 - a. Ignition: Electronically controlled electric spark with flame sensor.
3. Heat-Exchanger Drain Pan: Stainless steel.
4. Power Vent: Integral, motorized centrifugal fan interlocked with gas valve.
5. Gas Control Valve: Electronic modulating.
6. Gas Train: Single-body, regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff. Control devices and control sequence shall comply with requirements of FMG.
7. Access: Fabricate section to allow removal and replacement of furnace and to allow in-place access for service.

I. Piping and Wiring: Fabricate units with space within housing for piping and electrical conduits. Wire motors and controls so only external connections are required during installation.

1. Outdoor Enclosure: NEMA 250, Type 3R enclosure contains relays, starters, and terminal strip.
2. Include fused disconnect switches.
3. Variable-speed controller to vary fan capacity from 100 to approximately 50 percent.

J. Indirect-Fired-Gas-Furnaces Controls:

1. Factory-mounted sensor in unit discharge, with sensor adjustment located in control panel to control gas furnace burner to maintain temperature where indicated on drawings.
2. Wall-mounted, space-temperature sensor with adjustment on remote-control panel to control gas furnace burner to maintain temperature, where indicated on drawings.

3. Burner Controls: Modulating.

K. Accessories:

1. Roof Curb: Aluminum with gasketing, and factory-installed wood nailer; complying with NRCA standards; minimum height of 36 inches.
2. Exhaust weather hood with birdscreen.
3. Low-Leakage, Isolation Dampers: Double-skin, airfoil-blade, aluminum dampers with compressible jamb seals and extruded-vinyl blade edge seals, in parallel-blade arrangement with steel operating rods rotating in sintered bronze or nylon bearings mounted in a single extruded-aluminum frame, with operating rods connected with a common linkage, and electric damper operator factory wired with an end switch to be interlocked with the respective supply or exhaust air motor relay. Leakage rate shall not exceed 5 cfm/sq. ft. at 1-inch wg and 9 cfm/sq. ft. at 4-inch wg.
4. Duct flanges.
5. Unit shall be BACnet® compliant, ready for BMS connection.

2.4 INTERIOR PACKAGED ENERGY RECOVERY UNITS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Advanced Thermal Technologies.
2. Greenheck Fan Corporation.
3. Lifebreath, LLC
4. Loren Cook Company.
5. RenewAire LLC.
6. SEMCO Incorporated.
7. Venmar CES Inc.
Xetex Inc; Unison Comfort Technologies

B. Description:

1. Packaged interior sensible heat recovery air unit with return/exhaust fans and supply fans, to extract thermal energy from the leaving waste air stream and impart that to the incoming supply air stream.
2. Units of this type will typically be of less than 1,000 cfm air capacity and used in conjunction with toilet and locker/shower exhaust extraction, with the supply air directed to adjacent occupied spaces. This supply air may be supplied directly to the space if it will not adversely affect comfort conditions in that space, otherwise the supply air will be directed to the terminal conditioning unit serving the space, for final conditioning.

C. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Housing: Double-wall galvanized steel construction with corrosion-protection primer coating and exterior finish, removable, hinged access doors with neoprene gaskets for inspection and access to internal parts, minimum 1-inch- (25mm-thick thermal insulation, knockouts for electrical and piping connections, exterior drain connection, and lifting lugs.

- E. Heat Recovery Device: Fixed-plate counter-cross-flow heat exchanger.
- F. Supply and Exhaust Fans: Backward-inclined, plenum centrifugal fan with elastomer isolators and flexible duct connections.
 - 1. Motor and Drive: Direct driven brushless DC (ECM or EBM) constant torque motors.
 - 2. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT."
- G. Extended-Surface, Disposable Panel Filters:
 - 1. Comply with NFPA 90A.
 - 2. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
 - 3. Factory-fabricated, dry, extended-surface type.
 - 4. Thickness: 1 inch.
 - 5. Initial Resistance: 0.15 inches wg.
 - 6. Recommended Final Resistance: 0.3 inches wg.
 - 7. Minimum MERV: 8, per ASHRAE 52.2.
 - 8. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
 - 9. Media-Grid Frame: Coated beverage board.
 - 10. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.
- H. Wire motors and controls so only external connections are required during installation.
- I. Accessories:
 - 1. Integral controls with terminal strips to allow external contact closure commands for time of day, humidity, temperature and occupancy-based operation.
 - 2. Duct collars with integral balancing dampers.
 - 3. Flexible compression duct connection collars.
 - 4. Motorized backdraft dampers in outside air and exhaust airstreams.

2.5 CAPACITIES AND CHARACTERISTICS

- A. Refer to drawings for additional information.
- B. Applications are limited to exhaust airstreams of ASHRAE Class 1 and Class 2 air only. No dust processes or hazardous applications shall be connected. Where high moisture is to be exhausted and which would impose a latent load on the cooling process, or where excessive dust is present, shall use sensible heat exchangers. Applications such as comfort cooling where exhaust air quality can offset dehumidification loads, an enthalpy heat exchanger shall be used.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine casing insulation materials and filter media before air-to-air energy recovery equipment installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for electrical services to verify actual locations of connections before installation.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install fixed-plate heat exchangers so supply and exhaust airstreams flow in opposite directions.
 - 1. Install duct access doors in both supply and exhaust ducts, both upstream and downstream, for access to heat exchanger. Access doors and panels are specified in Section 15820 "DUCT ACCESSORIES."
- B. Install gas-fired furnaces per NFPA 54 and 248 CMR Massachusetts Fuel Gas Code. Extend venting with listed vent system away from air intakes,
- C. Roof Curb: Install on roof structure, level and secure, per The NRCA "Roofing and Waterproofing Manual - Volume 4: Construction Details - Low-Slope Roofing," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts." Install air-to-air energy recovery equipment on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 07720 "ROOF ACCESSORIES." Secure air-to-air energy recovery equipment to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.
- D. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.

3.3 CONNECTIONS

- A. Comply with requirements for piping specified in Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to unit to allow service and maintenance.
- C. Connect piping to units mounted on vibration isolators with flexible connectors.
- D. Gas Piping: Comply with requirements in Section 15195 "FACILITY NATURAL-GAS PIPING." Connect gas piping with shutoff valve and union and with sufficient clearance for burner removal and service. Make connection with AGA-approved flexible connectors.
- E. Comply with requirements for ductwork specified in Section 15815 "METAL DUCTS."

- F. Indirect-Fired Furnace Vent Connections: Comply with Section 15550 "BREECHINGS, CHIMNEYS, AND STACKS."
- G. Install electrical devices furnished with units but not factory mounted.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- C. Tests and Inspections:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 2. Adjust seals and purge.
 - 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 4. Set initial temperature and humidity set points.
 - 5. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
- D. Air-to-air energy recovery equipment will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.

3.5 DEMONSTRATION

- A. Train MBTA's maintenance personnel to adjust, operate, and maintain air-to-air energy recovery units.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15791

CABINET UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes cabinet unit heaters with centrifugal fans and hot-water coils.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15074–VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15084 - HVAC INSTRUMENTATION AND CONTROL
 - 6. Section 15940 – SEQUENCE OF OPERATION FOR THE HVAC SYSTEMS
 - 7. Section 15850 – TESTING, ADJUSTING AND BALANCING
 - 8. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK
 - 9. Section 16060 – GROUNDING AND BONDING

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. CWP: Cold working pressure.
- C. PTFE: Polytetrafluoroethylene plastic.
- D. TFE: Tetrafluoroethylene plastic.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and details.

2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Include location and size of each field connection.
 4. Include details of anchorages and attachments to structure and to supported equipment.
 5. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.
 6. Indicate location and arrangement of piping valves and specialties.
 7. Indicate location and arrangement of integral controls.
 8. Wiring Diagrams: Power, signal, and control wiring.
- C. Samples: For each exposed product and for each color and texture specified.
- D. Samples for Initial Selection: Finish colors for units with factory-applied color finishes.
- E. Samples for Verification: Finish colors for each type of cabinet unit heater indicated with factory-applied color finishes.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Suspended ceiling components.
 2. Structural members to which cabinet unit heaters will be attached.
 3. Method of attaching hangers to building structure.
 4. Size and location of initial access modules for acoustical tile.
 5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 6. Perimeter moldings for exposed or partially exposed cabinets.
- B. Seismic Qualification Certificates: Submit certification that cabinet unit heaters, accessories, and components will withstand seismic forces defined in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR HVAC." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Include detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For cabinet unit heaters to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Cabinet Unit-Heater Filters: Furnish one spare filter(s) for each filter installed.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Airtherm; a Mestek company.
 - 2. Berko; Marley Engineered Products.
 - 3. Carrier Corporation; a UTC company.
 - 4. Chromalox, Inc.
 - 5. Dunham-Bush, Inc.
 - 6. Engineered Air.
 - 7. Indeeco.
 - 8. International Environmental Corporation.
 - 9. Markel Products Company; TPI Corporation.
 - 10. Marley Engineered Products.
 - 11. McQuay International.
 - 12. Ouellet Canada Inc.
 - 13. QMark; Marley Engineered Products.
 - 14. Rosemex Products.
 - 15. Trane Inc.
 - 16. USA Coil & Air.

2.2 DESCRIPTION

- A. Factory-assembled and -tested unit complying with AHRI 440.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with UL 2021.

2.3 PERFORMANCE REQUIREMENTS

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND STARTUP."
- B. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "HEATING, VENTILATING, AND AIR-CONDITIONING."

2.4 COIL SECTION INSULATION

- A. Insulation Materials: Comply with NFPA 90A or NFPA 90B. Unicellular polyethylene thermal plastic, preformed sheet insulation complying with ASTM C 534, Type II, except for density.
 - 1. Thickness: 1 inch.
 - 2. Thermal Conductivity (k-Value): 0.24 Btu x in./h x sq. ft. at 75 deg F mean temperature.
 - 3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM C 411.
 - 4. Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
 - 5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2.5 CABINETS

- A. Material: Steel with factory prime coating, ready for field painting.
 - 1. Vertical Unit, Exposed Front Panels: Minimum 14 gauge- thick sheet steel, removable panels with channel-formed edges secured with tamperproof cam fasteners.
 - 2. Horizontal Unit, Exposed Bottom Panels: Minimum 14 gauge thick sheet steel, removable panels secured with tamperproof cam fasteners and safety chain.
 - 3. Recessed Flanges: Steel, finished to match cabinet.
 - 4. Control Access Door: Key operated.
 - 5. Base: Minimum 0.0528-inch-thick steel, finished to match cabinet, 4 inches high with leveling bolts.
 - 6. Extended Piping Compartment: 8-inch-wide piping end pocket.
 - 7. False Back: Minimum 0.0428-inch-thick steel, finished to match cabinet.
 - 8. Surface-mount default configuration to allow replacement over time without reconfiguring wall finishes and framing.

2.6 FILTERS

- A. Minimum Arrestance: According to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
 - 1. Pleated: 90 percent arrestance and MERV 7.

2.7 COILS

- A. Hot-Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain.
- B. Coils shall be selected for capacities using low temperature hot water, 140 degrees F. EWT and 110 degrees LWT to promote condensing in hot water condensing boilers.

2.8 CONTROLS

- A. Fan and Motor Board: Removable.
 - 1. Fan: Forward curved, double width, centrifugal, directly connected to motor; thermoplastic or painted-steel wheels and aluminum, painted-steel, or galvanized-steel fan scrolls.
 - 2. Motor: Permanently lubricated, electronically commuted multispeed; resiliently mounted on motor board.
 - 3. Wiring Terminations: Connect motor to chassis wiring with plug connection.
- B. Factory, Hot-Water Piping Package: ASTM B 88, Type L copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.
 - 1. Two-way, two-position control valve.
 - 2. Hose Kits: Minimum 400-psig working pressure, and operating temperatures from 33 to 211 deg F. Tag hose kits to equipment designations.
 - a. Length: 36 inches.
 - b. Minimum Diameter: Equal to cabinet unit-heater connection size.
 - 3. Two-Piece, Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.
 - 4. Automatic Flow-Control Valve: Brass or ferrous-metal body, 300-psig working pressure at 250 deg F, with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow within plus or minus 10 percent of differential pressure range of 2 to 80 psig.
 - 5. Y-Pattern, Hot-Water Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig minimum working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 threaded pipe and full-port ball valve in strainer drain connection.
 - 6. Wrought-Copper Unions: ASME B16.22.
- C. DDC Terminal Controller:
 - 1. Where DDC controls are used in a facility, the sequences below apply. Where standard hard-wired logic control is used (e.g. at sporadically attended remote facilities including the several TPSS and pump stations), manual control shall be used.

2. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
 3. Unit Supply-Air Fan Operations:
 - a. Occupied Periods: Fan runs continuously.
 - b. Unoccupied Periods: Fan cycles with heating element to maintain setback room temperature.
 4. Heating-Coil Operations:
 - a. Occupied Periods: Modulate control valve or Energize electric-resistance coil to provide heating if room temperature falls below thermostat set point.
 - b. Unoccupied Periods: Start fan and modulate control valve or energize electric-resistance coil if room temperature falls below setback temperature.
 5. Controller shall have volatile-memory backup.
- D. BAS Interface Requirements:
1. Interface relay for scheduled operation.
 2. Interface relay to provide indication of fault at central workstation.
 3. Interface shall be BAC-net compatible for central BAS workstation and include the following functions:
 - a. Adjust set points.
 - b. Cabinet unit-heater start, stop, and operating status.
 - c. Data inquiry, including supply-air and room-air temperature.
 - d. Occupied and unoccupied schedules.
- E. Electrical Connection: Factory-wired motors and controls for a single field connection.

2.9 CAPACITIES AND CHARACTERISTICS

- A. Cabinet:
1. Vertical, Surface Mounted: Upflow.
 - a. Top: Sloped.
 - b. Air Inlet: Open bottom.
 - c. Air Outlet: Extruded-aluminum bar grille.
 - d. Note that this is the default application which allows simpler replacement over time without cutting and reconfiguring wall finishes and framing. It also allows full wall insulation on exterior walls.
 2. Vertical, Semirecessed: Upflow.
 - a. Air Inlet: Front, punched louver
 - b. Air Outlet: Front or top, extruded-aluminum bar grille.

3. Vertical, Fully Recessed: Upflow.
 - a. Air Inlet: Front, punched louver.
 - b. Air Outlet: Front, extruded-aluminum bar grille.
 4. Horizontal, Surface Mounted:
 - a. Air Inlet: Bottom, punched louver.
 - b. Air Outlet: Front, extruded-aluminum bar grille.
 5. Horizontal, Fully Recessed:
 - a. Air Inlet: Bottom, punched louver.
 - b. Air Outlet: Duct connection.
- B. Fan:
1. Airflow: As indicated on drawings.
 2. Fan Speed: As indicated on drawings.
 3. Motor Horsepower: As indicated on drawings.
- C. Heating Capacity:
1. Output: As indicated on drawings.
 2. Entering-Air Temperature: As indicated on drawings.
- D. Hot-Water Heating Coil:
1. Water Flow: As indicated on drawings.
 2. Water-Side Pressure Loss: As indicated on drawings.
 3. Entering-Water Temperature: As indicated on drawings.
- E. Filters:
1. Thickness: 1 inch.
- F. Electrical Characteristics for Single-Point Connection:
1. Volts: 115 V.
 2. Phase: One.
 3. Hertz: 60 Hz
 4. Full-Load Amperes: As indicated on drawings.
 5. Minimum Circuit Ampacity: As indicated on drawings.
 6. Maximum Overcurrent Protection: As indicated on drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive cabinet unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

- B. Examine roughing-in for piping and electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install wall boxes in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Section 07920 "JOINT SEALANTS."
- B. Install cabinet unit heaters to comply with NFPA 90A.
- C. Suspend cabinet unit heaters from structure with elastomeric hangers and seismic restraints. Vibration isolators and seismic restraints are specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR HVAC."
- D. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.
- E. Install new filters in each fan-coil unit within two weeks of Substantial Completion.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in Section 15181 "HYDRONIC PIPING," Section 15179 "HYDRONIC PIPING SPECIALTIES," Section 15182 "Steam and Condensate Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to machine to allow service and maintenance.
- C. Connect piping to cabinet unit heater's factory, hot-water piping package. Install the piping package if shipped loose.
- D. Connect supply and return ducts to cabinet unit heaters with flexible duct connectors specified in Section 15820 "DUCT ACCESSORIES."
- E. Comply with safety requirements in UL 1995.
- F. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of cabinet unit heater. Hydronic specialties are specified in Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES."
- G. Ground equipment according to Section 16060 "GROUNDING AND BONDING."
- H. Connect wiring according to Section 16120 "CONDUCTORS AND CABLES."

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
 - 3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.
- B. Units will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Adjust initial temperature set points.
- B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain cabinet unit heaters.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15792

PROPELLER UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HHVAC WORK
 - 2. Section 15058 – COMMON MOTOR REQUIRMENTS FOR EQUIPMENT
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15900 – HVAC INSTRUMENTATION CONTROL
 - 7. Section 15940 – SEQUENCE OF OPERATION FOR THE HVAC SYSTEMS
 - 8. Section 15950 – TESTING, ADJUSTING AND BALANCING
 - 9. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK
 - 10. Section 16060 – GROUNDING AND BONDING

1.2 SUMMARY

- A. Section includes propeller unit heaters with hot-water and electric-resistance heating coils.

1.3 DEFINITIONS

- A. BMS: Building Management System.
- B. CWP: Cold working pressure.
- C. PTFE: Polytetrafluoroethylene plastic.
- D. TFE: Tetrafluoroethylene plastic.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings:

1. Include plans, elevations, sections, and details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include location and size of each field connection.
4. Include details of anchorages and attachments to structure and to supported equipment.
5. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.
6. Indicate location and arrangement of piping valves and specialties.
7. Indicate location and arrangement of integral controls.
8. Wiring Diagrams: Power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans, reflected ceiling plans, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Suspended ceiling components.
 2. Structural members to which propeller unit heaters will be attached.
 3. Method of attaching hangers to building structure.
 4. Size and location of initial access modules for acoustical tile.
 5. Items penetrating finished ceiling, including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
- B. Seismic Qualification Certificates: Submit certification that propeller unit heaters, accessories, and components will withstand seismic forces defined in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR HVAC." Include the following:
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Include detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For propeller unit heaters to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Airtherm; a Mestek company.
 - 2. Engineered Air.
 - 3. McQuay International.
 - 4. Rosemex Products.
 - 5. Ruffneck Heaters; a division of Lexa Corporation.
 - 6. Trane Inc.

2.2 DESCRIPTION

- A. Assembly including casing, coil, fan, and motor in horizontal discharge configuration with adjustable discharge louvers.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with UL 2021.
- D. Comply with UL 823.

2.3 PERFORMANCE REQUIREMENTS

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND STARTUP."
- B. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, And Air-Conditioning."

2.4 HOUSINGS

- A. Finish: Manufacturer's standard baked enamel applied to factory-assembled and -tested propeller unit heaters before shipping.
- B. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- C. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

2.5 COILS

- A. General Coil Requirements: Test and rate hot-water propeller unit-heater coils according to ASHRAE 33.
- B. Hot-Water Coil: Copper tube, minimum 0.025-inch wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 325 deg F, with manual air vent. Test for leaks to 350 psig underwater.
- C. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in steel or corrosion-resistant metallic sheath with fins no closer than 0.16 inch. Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F at any point during normal operation.
 - 1. Circuit Protection: One-time fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters.
 - 2. Wiring Terminations: Stainless-steel or corrosion-resistant material.

2.6 FAN AND MOTOR

- A. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.
- B. Motor: Permanently lubricated, multispeed. Comply with requirements in Section 15058 "COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT."

2.7 CONTROLS

- A. Control Devices:
 - 1. Wall-mounted thermostat.
 - 2. Return-line mounted aquastat, reverse acting.

2.8 CAPACITIES AND CHARACTERISTICS

- A. Heating Capacity:
 - 1. Heat Output: As indicated on drawings.
 - 2. Length of Throw: As indicated on drawings.
 - 3. Mounting Height: As indicated on drawings.
- B. Water Coil:
 - 1. Entering-Water Temperature: As indicated on drawings.
 - 2. Temperature Difference: As indicated on drawings.
 - 3. Water Flow: As indicated on drawings.
 - 4. Water-Side Pressure Drop: As indicated on drawings.

- C. Electric Coil:
 - 1. Heating Capacity: As indicated on drawings.
 - 2. Number of Steps: As indicated on drawings.
- D. Supply Air:
 - 1. Airflow: As indicated on drawings.
 - 2. Leaving-Air Temperature: As indicated on drawings.
 - 3. Entering-Air Temperature: As indicated on drawings.
- E. Fan Motor:
 - 1. High Speed: As indicated on drawings.
 - 2. Motor Size: As indicated on drawings.
- F. Electrical Characteristics for Single-Point Connection:
 - 1. Volts: As indicated on drawings.
 - 2. Phase: As indicated on drawings.
 - 3. Hertz: 60.
 - 4. Full-Load Amperes: As indicated on drawings.
 - 5. Minimum Circuit Amperes: As indicated on drawings.
 - 6. Maximum Overcurrent Protection: As indicated on drawings.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive propeller unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for piping and electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install propeller unit heaters to comply with NFPA 90A.
- B. Install propeller unit heaters level and plumb.
- C. Suspend propeller unit heaters from structure with all-thread hanger rods and spring hangers. Hanger rods and attachments to structure are specified in Section 15062 "HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT." Vibration hangers are specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR HVAC."

- D. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in Section 15181 "HYDRONIC PIPING," Section 15179 "HYDRONIC PIPING SPECIALTIES," Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to machine to allow service and maintenance.
- C. Connect piping to propeller unit heater's factory, hot-water piping package. Install the piping package if shipped loose.
- D. Comply with safety requirements in UL 1995.
- E. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of propeller unit heater. Hydronic specialties are specified in Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES."
- F. Ground equipment according to Section 16060 "GROUNDING AND BONDING", by Division 16 Design-Builder, including wiring of line-voltage aquastat to fan start contacts.
- G. Connect wiring according to Section 16120 "CONDUCTORS AND CABLES", by Division 16 Design-Builder.

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 2. Operate electric heating elements through each stage to verify proper operation and electrical connections.
 - 3. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.
- B. Units will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.5 ADJUSTING

- A. Adjust initial temperature set points and aquastat setpoints.

- B. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15793

ELECTRIC WALL AND CEILING UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes wall and ceiling heaters with propeller fans and electric-resistance heating coils.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include details of anchorages and attachments to structure and to supported equipment.
 - 4. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.
 - 5. Wiring Diagrams: Power, signal, and control wiring.
- C. Samples: For each exposed product and for each color and texture specified.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For wall and ceiling unit heaters to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following available manufacturers:
1. Berko; Marley Engineered Products.
 2. Chromalox, Inc.
 3. Indeeco.
 4. Markel Products Company; TPI Corporation.
 5. Marley Engineered Products.
 6. Ouellet Canada Inc.
 7. QMark; Marley Engineered Products.
 8. Trane Inc.

2.2 DESCRIPTION

- A. Assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 CABINET

- A. Front Panel: Extruded-aluminum bar grille, with removable panels fastened with tamperproof fasteners.
- B. Finish: Baked enamel over baked-on primer with manufacturer's standard color selected by Architect, applied to factory-assembled and -tested wall and ceiling heaters before shipping.
- C. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Surface-Mounted Cabinet Enclosure: Steel or aluminum with finish to match cabinet. Surface mounting shall be the default installation to promote future placement without affecting surface openings.

2.4 COIL

- A. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high-temperature protection. Provide integral circuit breaker for overcurrent protection.

2.5 FAN AND MOTOR

- A. Fan: Aluminum propeller directly connected to motor.
- B. Motor: Permanently lubricated, multispeed. Comply with requirements in Section 15058 "Common Motor Requirements for HVAC Equipment."

2.6 CONTROLS

- A. Controls: Unit-mounted thermostat with tamper-proof concealment as the default installation for public and utility areas; manually adjustable for attended private areas. Provide line to low-voltage relay with transformer kit where installations require remote thermostat. Thermostat shall be 24 Volts and have tamper-proof covers.
- B. Electrical Connection: Factory wire motors and controls for a single field connection with integral disconnect switch.

2.7 CAPACITIES AND CHARACTERISTICS

- A. Airflow: Refer to equipment schedule.
- B. Fan Speed: Refer to equipment schedule.
- C. Heating Coil: Refer to equipment schedule.
- D. Electrical Characteristics for Single-Point Connection:
 - 1. Volts: Refer to equipment schedule.
 - 2. Phase: Refer to equipment schedule.
 - 3. Hertz: 60
 - 4. Full-Load Amperes: Refer to equipment schedule.
 - 5. Minimum Circuit Ampacity and Maximum Overcurrent Protection: Refer to equipment schedule.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive wall and ceiling unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for electrical connections to verify actual locations before unit-heater installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install wall and ceiling unit heaters to comply with NFPA 90A.
- B. Install wall and ceiling unit heaters level and plumb.
- C. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.
- D. Grounding of equipment by Division 16 contractor per Section 16060 "Grounding and Bonding."
- E. Connect wiring according by Division 16 contractor per Section 16120 "Conductors and Cables."

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15798

FINNED-TUBE RADIATION HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15112 – GENERAL DUTY VALVES FOR PIPING
 - 4. Section 15179 – HYDRONIC PIPING SPECIALTIES
 - 5. Section 15181 – HYDRONIC PIPING
 - 6. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 7. Section 15900 – HVAC INSTRUMENTATION AND CONTROL
 - 8. Section 15940 – SEQUENCE OF OPERATIONS FOR THE HVAC SYSTEMS
 - 9. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.2 SUMMARY

- A. Section includes hydronic, baseboard and finned-tube radiation heaters, related covers and trim.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings:
 - 1. Include plans, elevations, sections, and details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include details and dimensions of custom-fabricated enclosures.
 - 4. Indicate location and size of each field connection.
 - 5. Indicate location and arrangement of piping valves and specialties.
 - 6. Indicate location and arrangement of integral controls.
 - 7. Include enclosure joints, corner pieces, access doors, and other accessories.
 - 8. Include diagrams for power, signal, and control wiring.
- C. Samples: For each exposed product and for each color and texture specified.

- D. Color Samples for Initial Selection: For finned-tube radiation heaters with factory-applied color finishes.
- E. Color Samples for Verification: For each type of exposed finish.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Structural members, including wall construction, to which finned-tube radiation heaters will be attached.
 - 2. Method of attaching finned-tube radiation heaters to building structure.
 - 3. Penetrations of fire-rated wall and floor assemblies.
- B. Field quality-control reports.

PART 2 - PRODUCTS

2.1 HOT-WATER FINNED-TUBE RADIATION HEATERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Rittling
 - 2. Slant/Fin Corporation.
 - 3. Sterling Hydronics; a Mestek company.
 - 4. Trane Inc.
 - 5. Vulcan; a Mestek company.
- B. Performance Ratings: Rate finned-tube radiation heaters according to Hydronics Institute's "I=B=R Testing and Rating Standard for Finned-Tube (Commercial) Radiation."
- C. Heating Elements: Copper tubing mechanically expanded into flanged collars of evenly spaced aluminum fins resting on element supports. One end of tube shall be belled.
 - 1. Tube Diameter: NPS 3/4.
 - 2. Fin Size: 4 by 4 inches.
 - 3. Fin Spacing: 50 per foot.
 - 4. Number of Tiers: One.
 - 5. Heat Output: 800 Btu/h per ft.
 - 6. Entering-Air Temperature: 65 deg F.
 - 7. Average Water Temperature: 130 deg f.
 - 8. Minimum Water Velocity: 3 fps.
- D. Deviation from the above criteria requires additional element length including cover to meet capacity at conditions, all at no additional cost to the project.
- E. Element Supports: Ball-bearing cradle type to permit longitudinal movement on enclosure brackets.
- F. Front Panel: Minimum 14 gauge steel.

- G. Wall-Mounted Back Panel: Minimum 18 Gauge steel, full height, with full-length channel support for front panel without exposed fasteners.
- H. Floor-Mounted Pedestals: Conceal insulated piping at maximum 36-inch spacing. Pedestal-mounted back panel shall be solid panel matching front panel. Provide stainless-steel escutcheon for floor openings at pedestals.
- I. Support Brackets: Locate at maximum 36-inch spacing to support front panel and element.
- J. Finish: Baked-enamel finish in manufacturer's custom color as selected by Architect.
- K. Access Doors: Factory made, permanently hinged with tamper-resistant fastener, minimum size 6 by 7 inches, integral with enclosure.
- L. Enclosure Style: Sloped top.
 - 1. Front Inlet Grille: Punched louver; painted to match enclosure.
 - 2. Top Outlet Grille: Punched louver; painted to match enclosure.
 - 3. Enclosure Height: 14 inches.
 - 4. Enclosure Depth: 5 inches.
- M. Accessories: Filler sections, corners, relay sections, and splice plates all matching the enclosure and grille finishes.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas to receive finned-tube radiation heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for hydronic-piping connections to verify actual locations before installation of finned-tube radiation heaters.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 FINNED-TUBE RADIATION HEATER INSTALLATION

- A. Install units level and plumb.
- B. Install enclosure continuously around corners, using outside and inside corner fittings.
- C. Join sections with splice plates and filler pieces to provide continuous enclosure.
- D. Install access doors for access to valves.
- E. Install enclosure continuously from wall to wall.
- F. Terminate enclosures with manufacturer's end caps except where enclosures are indicated to extend to adjoining walls.

- G. Install valves within reach of access door provided in enclosure.
- H. Install air-seal gasket between wall and recessed flanges or front cover of fully recessed unit.
- I. Install piping within pedestals for freestanding units.
- J. Where multiple-tier elements are to be installed, the top element shall be the first supplied with hot water and the bottom tier shall carry the return water, to promote counterflow. Where two-tier radiation is used, piping shall be in-series to promoted higher tube velocities and even temperature differences across elements.

3.3 CONNECTIONS

- A. Piping installation requirements are specified in Section 15181 "Hydronic Piping" and Section 15179 "HYDRONIC PIPING SPECIALTIES." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Connect hot-water finned-tube radiation heaters and components to piping according to Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES."
 - 1. Install shutoff valves on inlet and outlet, control valve on inlet or outlet, drain valve at low point, vents at high points and balancing valve on outlet.
- C. Install control valves as required by Section 15900 "HVAC INSTRUMENTATION AND CONTROLS", as furnished by the mechanical contractor.
- D. Install piping adjacent to finned-tube radiation heaters to allow service and maintenance.

3.4 FIELD QUALITY CONTROL

- A. Perform the following field tests and inspections:
 - 1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Operational Test: After electrical circuitry has been energized, stroke control valves to confirm proper operation.
 - 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Units will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15815

METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Single-wall rectangular ducts and fittings.
 - 2. Single-wall round ducts and fittings.
 - 3. Sheet metal materials.
 - 4. Hangers and supports.
 - 5. Seismic-restraint devices.

- B. Related Sections:
 - 1. Section 09900 – PAINTING
 - 2. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15086 – DUCT INSULATION
 - 7. Section 15820 – DUCT ACCESSORIES
 - 8. Section 15838 – POWER VENTILATORS
 - 9. Section 15855 – DIFFUSERS, REGISTERS, AND GRILLES
 - 10. Section 15900 – HVAC INSTRUMENTATION AND CONTROLS
 - 11. Section 15940 – SEQUENCE OF OPERATION FOR THE HVAC SYSTEMS
 - 12. Section 15950 – TESTING, ADJUSTING, AND BALANCING

1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.

- B. Default minimum construction for sheet metal ductwork shall be G-90 galvanized sheet steel of minimum 24 Gauge thickness, conforming with ASTM A653/A653M. Pressure class default minimum shall be 2.0 inches positive and negative. Default minimum seal class and leakage class shall be Seal Class A, Leakage Class 3 for all general HVAC systems. Greater pressure classes, materials and construction shall conform to service application requirements in the DUCT SCHEDULE.
- C. Structural Performance: Duct hangers and supports and seismic restraints shall withstand the effects of gravity and seismic loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7.
 - 1. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.
- D. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of the following products:
 - 1. Liners and adhesives.
 - 2. Sealants and gaskets.
 - 3. Seismic-restraint devices.
- B. Shop Drawings:
 - 1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
 - 2. Factory- and shop-fabricated ducts and fittings.
 - 3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes. Scale 3/8"=1 foot
 - 4. Elevation of top of ducts.
 - 5. Dimensions of main duct runs from building grid lines.
 - 6. Fittings.
 - 7. Reinforcement and spacing.
 - 8. Seam and joint construction.
 - 9. Equipment installation based on equipment being used on Project.
 - 10. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
 - 11. Hangers and supports, including methods for duct and building attachment, seismic restraints, and vibration isolation.
- C. Delegated-Design Submittal:
 - 1. Sheet metal thicknesses.
 - 2. Joint and seam construction and sealing.
 - 3. Reinforcement details and spacing.
 - 4. Materials, fabrication, assembly, and spacing of hangers and supports.
 - 5. Design Calculations: Calculations, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation for selecting hangers and supports.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, drawn to 3/8"=1foot scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
 - 2. Suspended ceiling components.
 - 3. Structural members to which duct will be attached.
 - 4. Size and location of initial access modules for acoustical tile.
 - 5. Penetrations of smoke barriers and fire-rated construction.
 - 6. Items penetrating finished ceiling including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - c. Access panels.
- B. Welding certificates.
- C. Field quality-control reports.

1.6 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.
- B. Welding Qualifications: Qualify procedures and personnel according to the following:
 - 1. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
 - 2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
 - 3. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.
- C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND SYSTEM START-UP."
- D. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

PART 2 - PRODUCTS

2.1 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

- B. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- C. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.2 SINGLE-WALL ROUND DUCTS AND FITTINGS

- A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.
- B. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).
- C. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. Transverse Joints in Ducts Larger Than 60 Inches in Diameter: Flanged.
- D. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 1. Fabricate round ducts larger than 90 inches in diameter with butt-welded longitudinal seams.
 - 2. Fabricate flat-oval ducts larger than 72 inches in width (major dimension) with butt-welded longitudinal seams.
- E. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SHEET METAL MATERIALS

- A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
- B. Galvanized Sheet Metal: Comply with ASTM A653/A653M-15, minimum G90 zinc coating thickness, lock-forming quality and minimum 24 gauge.
- C. Stainless Steel Sheets: Comply with ASTM A480/A480M, minimum 24 gauge for forming, minimum 18 gauge for welding by the TIG process.
- D. Aluminum Sheets: Comply with ASTM B 209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view. Gauge thickness of aluminum shall be two (2) gauges heavier than corresponding galvanized steel for the same duty.
- E. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
 - 1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.
- F. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches. Where tie rods cross, they shall be welded to one-another.

2.4 SEALANT AND GASKETS

- A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
- B. Water-Based Joint and Seam Sealant:
 - 1. Application Method: Brush on.
 - 2. Solids Content: Minimum 65 percent.
 - 3. Shore A Hardness: Minimum 20.
 - 4. Water resistant.
 - 5. Mold and mildew resistant.
 - 6. VOC: Maximum 75 g/L (less water).
 - 7. Maximum Static-Pressure Class: 10-inch wg, positive and negative.
 - 8. Service: Indoor or outdoor.
 - 9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.
- C. Round Duct Joint O-Ring Seals:
 - 1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.
 - 2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.

3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.5 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."
- D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.
- E. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- F. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- G. Trapeze and Riser Supports:
 1. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.

2.6 SEISMIC-RESTRAINT DEVICES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Cooper B-Line, Inc.; a division of Cooper Industries.
 2. Ductmate Industries, Inc.
 3. Hilti Corp.
 4. Kinetics Noise Control.
 5. Loos & Co.; Cableware Division.
 6. Mason Industries.
 7. TOLCO; a brand of NIBCO INC.
 8. Unistrut Corporation; Tyco International, Ltd.
- B. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an agency acceptable to authorities having jurisdiction.
 1. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.
- C. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.

- D. Restraint Cables: ASTM A 492, stainless-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.
- E. Hanger Rod Stiffener: [Steel tube or steel slotted-support-system sleeve with internally bolted connections] [Reinforcing steel angle clamped] to hanger rod.
- F. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

- A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system.

Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.

- B. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
- C. Install round ducts in maximum practical lengths.
- D. Install ducts with fewest possible joints.
- E. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
- F. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
- G. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
- H. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.
- I. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.
- J. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.
- K. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Section 15820 "DUCT ACCESSORIES" for fire and smoke dampers.

- L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

3.2 INSTALLATION OF EXPOSED DUCTWORK

- A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.
- B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.
- C. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.
- D. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 DUCT SEALING

- A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
- B. Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":
 - 1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
 - 2. All ductwork shall be sealed to a minimum default standard of Seal Class A and a maximum leakage grade of Leakage Class 3 regardless of duty or location.
 - 3. Higher performance standards shall be used for welded, high pressure and conveying systems.

3.4 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 - 1. Where practical, install concrete inserts before placing concrete.
 - 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 - 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
 - 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
 - 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

- D. Hangers Exposed to View: Threaded rod and angle or channel supports.
- E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at maximum intervals of 16 feet.
- F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 SEISMIC-RESTRAINT-DEVICE INSTALLATION

- A. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with ASCE/SEI 7.
 - 1. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.
 - 2. Brace a change of direction longer than 12 feet.
- B. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install cable restraints on ducts that are suspended with vibration isolators.
- E. Install seismic-restraint devices using methods approved by an evaluation service member of the ICC Evaluation Service an agency acceptable to authorities having jurisdiction.
- F. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.
- G. Drilling for and Setting Anchors:
 - 1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the Architect if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
 - 2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
 - 3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
 - 4. Set anchors to manufacturer's recommended torque, using a torque wrench.
 - 5. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

3.6 CONNECTIONS

- A. Make connections to equipment with flexible connectors complying with Section 15820 "Duct Accessories."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.7 PAINTING

- A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Section 09900 "PAINTING."

3.8 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Leakage Tests:
 - 1. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
 - 2. Test the following systems:
 - a. Supply Ducts with a Pressure Class of 2-Inch wg or Higher: Test representative duct sections totaling no less than 50 percent of total installed duct area for each designated pressure class.
 - b. Exhaust Ducts with a Pressure Class of 2-Inch wg or Higher: Test representative duct sections totaling no less than 50 percent of total installed duct area for each designated pressure class.
 - c. Outdoor Air Ducts with a Pressure Class of 2-Inch wg or Higher: Test representative duct sections totaling no less than 50 percent of total installed duct area for each designated pressure class.
 - 3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
 - 4. Test for leaks before applying external insulation.
 - 5. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
 - 6. Give seven days' advance notice for testing.
- C. Duct System Cleanliness Tests:
 - 1. Visually inspect duct system to ensure that no visible contaminants are present.

2. Test sections of metal duct system, chosen randomly by MBTA, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."

a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

3.9 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing.

B. Use service openings for entry and inspection.

1. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 15820 "DUCT ACCESSORIES" for access panels and doors.

2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.

3. Remove and reinstall ceiling to gain access during the cleaning process.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.

2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

D. Clean the following components by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).

2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.

3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.

4. Coils and related components.

5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.

6. Supply-air ducts, dampers, actuators, and turning vanes.

7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide drainage and cleanup for wash-down procedures.
7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

3.10 START UP

- A. Air Balance: Comply with requirements in Section 15950 "TESTING, ADJUSTING AND BALANCING."

3.11 DUCT SCHEDULE

- A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

B. Supply Ducts; General HVAC:

1. Ducts Connected to OA Louvers, general supply, make-up air, transfer air:
 - a. Pressure Class: Positive and Negative 2-inch wg.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 3.

C. Return Ducts; General HVAC:

1. Ducts Connected to relief louvers, general return, energy recovery return/exhaust air, transfer air:
 - a. Pressure Class: Positive and Negative 2-inch wg.

- b. Minimum SMACNA Seal Class: A.
- c. SMACNA Leakage Class for Rectangular: 3.

D. Exhaust Ducts; General HVAC:

1. Ducts Connected to Fans, Louvers, Air Devices serving other than vehicle wash areas, showers, locker rooms or air drawn therefrom:
 - a. Pressure Class: Positive or negative 2-inch wg.
 - b. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
 - c. SMACNA Leakage Class for Rectangular: 3.
2. Ducts Connected to Fans, Louvers, Air Devices serving showers, locker rooms, vehicle wash areas:
 - a. Aluminum.
 - b. Pressure Class: Positive or negative 2-inch wg.
 - c. Minimum SMACNA Seal Class: A if negative pressure, and A if positive pressure.
 - d. SMACNA Leakage Class for Rectangular: 3.

E. Supply Ducts; Medium Pressure HVAC:

1. Ducts Connected to Fan Systems with Total Static Pressure Greater Than 3.0 inches W.G. across the fan or greater than 1.50 inches W.G. externally. System examples include Variable Air Volume (VAV) system ductwork on upstream/higher pressure side of controlling devices, medium pressure blower systems:
 - a. Pressure Class: Positive or negative 6-inch wg.
 - b. Minimum SMACNA Seal Class: A.
 - c. SMACNA Leakage Class for Rectangular: 3.

F. Other Ducted Air Systems Not Specifically Mentioned:

1. The Engineer of Record shall select duct materials, pressure class and construction to suit the specific design requirements of each application not otherwise specified. This shall include industrial and material handling exhaust, kitchen hood grease duct exhaust, exterior duct systems, ductwork finished and exposed to public view as an architectural aesthetic directive. Construction types shall include welded. Nothing in this section shall prohibit the use of agency-listed manufactured systems.
 - a. Pressure Class: Positive or negative for the duty, not less than 2.0 inches W.G.
 - b. Minimum SMACNA Seal Class: Not less than A.
 - c. SMACNA Leakage Class for Rectangular: No greater than 3.

G. Intermediate Reinforcement:

1. Aluminum Ducts: Aluminum.
2. Galvanized Ducts: Galvanized carbon steel.
3. Stainless Steel Ducts: Stainless steel.

H. Elbow Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
 - a. Velocity 1000 fpm or Lower:
 - 1) Mitered Type RE 4 without vanes.
 - b. Velocity 1000 to 1500 fpm:
 - 1) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
 - c. Velocity 1500 fpm or Higher:
 - 1) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
2. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."
 - a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.
 - 1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
 - 2) Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
 - 3) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
 - 4) Radius-to Diameter Ratio: 1.5.
 - b. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated, non-adjustable.
 - c. Round Elbows, 14 Inches and Larger in Diameter: Standing seam.

I. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."
 - a. Rectangular Main to Rectangular Branch: 45-degree entry.
 - b. Rectangular Main to Round Branch: Bellmouth or conical tap.
 - c. "Spin-in" or tab collar branch connections will not be acceptable.
2. Round: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees."
 - a. Velocity 1000 fpm or Lower: 90-degree tap.
 - b. Velocity 1000 to 1500 fpm: Conical tap.

- c. Velocity 1500 fpm or Higher: 45-degree lateral.
- d. More than 25% of main flow to or from a branch: 45 degree wye fitting regardless of velocity.
- e. Where diverging or converging flows occur in mains, use double wye fittings. Bullhead tees will not be acceptable.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15820

DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 4. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 5. Section 15086 – DUCT INSULATION
 - 6. Section 15815 - METAL DUCTS
 - 7. Section 15838 – POWER VENTILATORS
 - 8. Section 15855 – DIFFUSERS, REGISTERS, AND GRILLES
 - 9. Section 15900 – HVAC INSTRUMENTATION AND CONTROLS
 - 10. Section 15940 – SEQUENCE OF OPERATION FOR THE HVAC SYSTEMS
 - 11. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.2 SUMMARY

- A. Section Includes:
 - 1. Manual volume dampers.
 - 2. Control dampers.
 - 3. Turning vanes.
 - 4. Duct-mounted access doors.
 - 5. Flexible connectors.
 - 6. Fire Dampers
 - 7. Duct accessory hardware.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.
- B. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.

1. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:
 - a. Special fittings.
 - b. Manual volume damper installations.
 - c. Control-damper installations.
 - d. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.
- B. Source quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION

- A. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
- B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

- A. Aluminum Sheets: Comply with ASTM B 209, Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.
- B. Extruded Aluminum: Comply with ASTM B 221, Alloy 6063, Temper T6.
- C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.
- D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.3 MANUAL VOLUME DAMPERS

A. Standard, Steel, Manual Volume Dampers:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Air Balance Inc.; a division of Mestek, Inc.
 - b. American Warming and Ventilating; a division of Mestek, Inc.
 - c. Flexmaster U.S.A., Inc.
 - d. McGill AirFlow LLC.
 - e. Nailor Industries Inc.
 - f. Pottorff.
 - g. Ruskin Company.
 - h. Trox USA Inc.
 - i. Vent Products Company, Inc.
2. Standard leakage rating, with linkage outside airstream.
3. Suitable for horizontal or vertical applications.
4. Frames:
 - a. Frame: Hat-shaped, 0.094-inch-thick, galvanized sheet steel.
 - b. Mitered and welded corners.
 - c. Flanges for attaching to walls and flangeless frames for installing in ducts.
5. Blades:
 - a. Multiple or single blade.
 - b. Parallel- or opposed-blade design.
 - c. Stiffen damper blades for stability.
 - d. Galvanized-steel, 0.064 inch thick.
6. Blade Axles: Stainless steel.
7. Bearings:
 - a. Molded synthetic.
 - b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
8. Tie Bars and Brackets: Galvanized steel.

B. Damper Hardware:

1. Zinc-plated, die-cast core with dial and handle made of 3/32-inch-thick zinc-plated steel, and a 3/4-inch hexagon locking nut.
2. Include center hole to suit damper operating-rod size.
3. Include elevated platform for insulated duct mounting.

2.4 FIRE DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance Inc.; a division of Mestek, Inc.
 2. Greenheck Fan Corporation.
 3. Nailor Industries Inc.
 4. NCA Manufacturing, Inc.
 5. Pottorff.
 6. Ruskin Company.
 7. Vent Products Company, Inc.
 8. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
- B. Type: Dynamic; rated and labeled according to UL 555 by an NRTL.
- C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.
- D. Fire Rating: 1-1/2 hours or 3 hours, to meet protection requirements in the wall or partition in which they are installed.
- E. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed, 0.034-inch-thick galvanized steel; with mitered and interlocking corners.
- F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.
1. Minimum Thickness: 0.138 inch thick, as indicated, and of length to suit application.
 2. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.
- G. Mounting Orientation: Vertical or horizontal as indicated.
- H. Blades: Roll-formed, interlocking, 0.034-inch- thick, galvanized sheet steel.
- I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.
- J. Heat-Responsive Device: Replaceable, 165 deg F rated, fusible links.

2.5 CONTROL DAMPERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. American Warming and Ventilating; a division of Mestek, Inc.
 2. Arrow United Industries; a division of Mestek, Inc.
 3. Cesco Products; a division of Mestek, Inc.
 4. Greenheck Fan Corporation.
 5. McGill AirFlow LLC.
 6. Metropolitan Air Technology.
 7. Metal Form Manufacturing, Inc.
 8. Nailor Industries Inc.
 9. NCA Manufacturing, Inc.
 10. Pottorff.
 11. Ruskin Company.
 12. Vent Products Company, Inc.
 13. Young Regulator Company.

- B. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
- C. Frames:
 - 1. Hat shaped.
 - 2. 0.094-inch-thick, galvanized sheet steel.
 - 3. Mitered and welded corners.
- D. Blades:
 - 1. Multiple blade with maximum blade width of 6 inches.
 - 2. Opposed-blade design.
 - 3. Galvanized-steel.
 - 4. 0.0747-inch-thick dual skin.
 - 5. Blade Edging: Closed-cell neoprene.
 - 6. Blade Edging: Inflatable seal blade edging, or replaceable rubber seals.
- E. Blade Axles: 1/2-inch-diameter; stainless steel; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
 - 1. Operating Temperature Range: From minus 40 to plus 200 deg F.
- F. Bearings:
 - 1. Molded synthetic
 - 2. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
 - 3. Thrust bearings at each end of every blade.

2.6 TURNING VANES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Ductmate Industries, Inc.
 - 2. Duro Dyne Inc.
 - 3. Elgen Manufacturing.
 - 4. METALAIRE, Inc.
 - 5. SEMCO Incorporated.
 - 6. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
- B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.
 - 1. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.
- C. Manufactured Turning Vanes for Nonmetal Ducts: Fabricate curved blades of resin-bonded fiberglass with acrylic polymer coating; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

- D. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vaness and Vane Runners," and 4-4, "Vane Support in Elbows."
- E. Vane Construction: Double wall.

2.7 DUCT-MOUNTED ACCESS DOORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. American Warming and Ventilating; a division of Mestek, Inc.
 - 2. Cesco Products; a division of Mestek, Inc.
 - 3. Ductmate Industries, Inc.
 - 4. Elgen Manufacturing.
 - 5. Flexmaster U.S.A., Inc.
 - 6. Greenheck Fan Corporation.
 - 7. McGill AirFlow LLC.
 - 8. Nailor Industries Inc.
 - 9. Pottorff.
 - 10. Ventfabrics, Inc.
 - 11. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
- B. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 7-2, "Duct Access Doors and Panels," and 7-3, "Access Doors - Round Duct."
 - 1. Door:
 - a. Double wall, rectangular.
 - b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
 - c. Vision panel.
 - d. Hinges and Latches: 1-by-1-inch butt or piano hinge and cam latches.
 - e. Fabricate doors airtight and suitable for duct pressure class.
 - 2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
 - 3. Number of Hinges and Locks:
 - a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.

2.8 FLEXIBLE CONNECTORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Ductmate Industries, Inc.
 - 2. Duro Dyne Inc.
 - 3. Elgen Manufacturing.
 - 4. Ventfabrics, Inc.
 - 5. Ward Industries, Inc.; a division of Hart & Cooley, Inc.
- B. Materials: Flame-retardant or noncombustible fabrics.

- C. Coatings and Adhesives: Comply with UL 181, Class 1.
- D. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide attached to two strips of 2-3/4-inch-wide, 0.028-inch-thick, galvanized sheet steel or 0.032-inch-thick aluminum sheets. Provide metal compatible with connected ducts.
- E. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.
 - 1. Minimum Weight: 26 oz./sq. yd..
 - 2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
 - 3. Service Temperature: Minus 40 to plus 200 deg F.
- F. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.
 - 1. Minimum Weight: 24 oz./sq. yd..
 - 2. Tensile Strength: 530 lbf/inch in the warp and 440 lbf/inch in the filling.
 - 3. Service Temperature: Minus 50 to plus 250 deg F.
- G. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.
 - 1. Minimum Weight: 16 oz./sq. yd..
 - 2. Tensile Strength: 285 lbf/inch in the warp and 185 lbf/inch in the filling.
 - 3. Service Temperature: Minus 67 to plus 500 deg F.
- H. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.
 - 1. Minimum Weight: 14 oz./sq. yd..
 - 2. Tensile Strength: 450 lbf/inch in the warp and 340 lbf/inch in the filling.
 - 3. Service Temperature: Minus 67 to plus 500 deg F.
- I. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.
 - 1. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.
 - 2. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
 - 3. Minimum Additional Travel: 50 percent of the required deflection at rated load.
 - 4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
 - 5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
 - 6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
 - 7. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch movement at start and stop.

2.9 DUCT ACCESSORY HARDWARE

- A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.
- B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.
- B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.
- C. Install control dampers at inlet of exhaust fans or exhaust ducts as close as possible to louvers unless otherwise indicated.
- D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.
 - 1. Install steel volume dampers in steel ducts.
 - 2. Install aluminum volume dampers in aluminum ducts.
- E. Set dampers to fully open position before testing, adjusting, and balancing.
- F. Install test holes at fan inlets and outlets, in air handling unit sections between components and elsewhere as indicated.
- G. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:
 - 1. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
 - 2. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
 - 3. At each change in direction and at maximum 50-foot spacing.
 - 4. Upstream from turning vanes.

- H. Install access doors with swing against duct static pressure.
- I. Access Door Sizes:
 - 1. Two-Hand Access: 12 by 12 inches minimum. Enlarge ductwork to accommodate access doors.
- J. Label access doors according to Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT" to indicate the purpose of access door.
- K. Install flexible connectors to connect ducts to equipment.
- L. Connect flexible ducts to metal ducts with draw bands.
- M. Install duct test holes where required for testing and balancing purposes.

3.2 FIELD QUALITY CONTROL

- A. Tests and Inspections:
 - 1. Operate dampers to verify full range of movement.
 - 2. Inspect locations of access doors and verify that purpose of access door can be performed.
 - 3. Operate fire dampers to verify full range of movement and verify that proper heat-response device is installed.
 - 4. Inspect turning vanes for proper and secure installation.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15834

AIR CURTAINS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.2 SUMMARY

- A. Section includes air curtains and related controls.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties, and accessories.
- B. Shop Drawings: For air curtains. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air curtains to include in maintenance manuals.

1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Furnish one set of filters.

1.6 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. Comply with AMCA 220, "Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings," for airflow, outlet velocity, and power consumption.
- C. Comply with ARI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating.
 - 1. Certify coils according to ARI 410.

1.7 WARRANTY

- A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air curtains that fail in materials or workmanship within specified warranty period.
 - 1. Warranty Period One year upon substantial completion of the project.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- 1. Berner
- 2. Mars Air Systems
- 3. Powered Aire
- 4. Reznor
- 5. Schwank
- B. Housing:
 - 1. Materials: Galvanized steel with electrostatically-applied epoxy-enamel finish over powdered mirror.
 - 2. Discharge Nozzle: Integral part of the housing, containing air-directional vanes adjustable in 5-degree increments through a 45-degree sweep front to back.
- C. Mounting Brackets: Steel, for wall mounting.
- D. Air-Intake Grille:
 - 1. Grille: Integral part of and same material as the housing.
- E. Fans:

1. Direct drive and equipped with belt guards and adjustable sheaves and pulleys].
- F. Motors: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
 2. Multispeed.
 3. Resiliently mounted.
 4. Continuous duty.
 5. Totally enclosed, air over
 6. Integral thermal-overload protection.
 7. Bearings: Permanently sealed, lifetime, pre-lubricated, ball bearings.
 8. Disconnect: Internal power cord with plug and receptacle.
- G. Controls:
1. Automatic Door Switch: Plunger type installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.
 2. Time-Delay Relay: Factory installed and adjustable to allow air curtain to operate from 0.5 seconds to 10 hours in concert with automatic door switch.
 3. Start-Stop, Push-Button Switch: Manually activates and deactivates air curtain.
 4. Three-Speed Switch: Manually activates, deactivates, and controls air-curtain fan speed.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install air curtains with clearance for equipment service and maintenance.

3.3 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. After installing air curtains completely, perform visual and mechanical check of individual components.
 - 2. After electrical circuits have been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.
 - 3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- C. Air-curtain unit will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.4 ADJUSTING

- A. Adjust motor and fan speed to achieve specified airflow.
- B. Adjust discharge louver and dampers to regulate airflow.
- C. Adjust air-directional vanes.

3.5 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain air curtains.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15838

POWER VENTILATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15058 – COMMON MOTOR REQUIREMENTS FOR EQUIPMENT
 - 3. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 4. Section 15074 – VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT
 - 5. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 6. Section 15086 – DUCT INSULATION
 - 7. Section 15815 – METAL DUCTS
 - 8. Section 15820 – DUCT ACCESSORIES
 - 9. Section 15855 – DIFFUSERS, REGISTERS, AND GRILLES
 - 10. Section 15900 – HVAC INSTRUMENTATION AND CONTROL
 - 11. Section 15940 – SEQUENCE OF OPERATION FOR THE HVAC SYSTEMS
 - 12. Section 15950 – TESTING, ADJUSTING, AND BALANCING

1.2 SUMMARY

- A. Section Includes:
 - 1. Direct-drive DC fans
 - 2. In-line centrifugal fans.
 - 3. Curb-mounted centrifugal roof fans.

1.3 PERFORMANCE REQUIREMENTS

- A. Operating Limits: Classify according to AMCA 99.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Also include the following:
 - 1. Certified fan performance curves with system operating conditions indicated.
 - 2. Certified fan sound-power ratings.
 - 3. Motor ratings and electrical characteristics, plus motor and electrical accessories.
 - 4. Material thickness and finishes, including color charts.
 - 5. Dampers, including housings, linkages, and operators.
 - 6. Fan speed controllers.

- B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
 - 1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 2. Wiring Diagrams: For power, signal, and control wiring.
- C. Delegated-Design Submittal: For unit hangars and supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
 - 1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
 - 2. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
 - 1. Ceiling suspension assembly members.
 - 2. Size and location of initial access modules for acoustical tile.
 - 3. Ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
- B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Belts: One set(s) for each belt-driven unit.

1.8 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- B. AMCA Compliance: Fans shall have AMCA-Certified performance ratings and shall bear the AMCA- Certified Ratings Seal.
- C. Bearings shall be air handling quality, heavy duty grease lubricated, ball or roller type. Bearings shall be selected for a Basic Rating Life, (L10) of 200,000 hours at maximum operating speed and horsepower for each construction level.
- D. UL Standards: Power ventilators shall comply with UL 705. Power ventilators for use for restaurant kitchen exhaust shall also comply with UL 762 and shall include raised, vented curb and grease collection system.

1.9 COORDINATION

- A. Coordinate size and location of structural-steel support members.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided.
- C. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

PART 2 - PRODUCTS

2.1 ECM MOTOR FANS

- A. Products: Subject to compliance with requirements, provide one of the following:
 - 1. Broan, Inc.
 - 2. Greenheck Fan Corporation.
 - 3. Loren Cook Company.
 - 4. NuTone, Inc.
 - 5. Panasonic Whisper Green.
- B. Housing: Galvanized steel, enameled steel or aluminum with integral plastic or aluminum gridded. Outlet duct with backdraft damper. Support brackets adaptable to floor, side wall, or ceiling mounting.
- C. Direct-Drive Units: Brushless DC ECM Motor mounted in airstream, factory wired to disconnect plug located in side of fan housing. Internally wired with harness to speed control and power connections.
- D. Integral on-board controls including motion detectors, delay-off timer, cfm settings.
- E. Fan Wheels: Aluminum, FRP or thermoplastic, airfoil blades bonded to motor hub.
- F. Accessories:
 - 1. Fan-Speed Controller: Solid-state control to reduce speed in fixed increments from 100 to less than 50 percent or as scheduled.

2. Motion detector to activate fan upon sensing occupancy. Sensor shall include a timer circuit to allow adjustable time periods of continued operation post-occupancy, from 5 to 30 minutes.

G. MOTORS

1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
2. Motor Sizes: Minimum size as indicated.
3. Enclosure Type: Totally enclosed, brushless DC ECM motor operating on single phase power input.

H. SOURCE QUALITY CONTROL

1. Certify sound-power level ratings according to AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.
2. Certify fan performance ratings, including flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating." Label fans with the AMCA-Certified Ratings Seal.

2.2 IN-LINE CENTRIFUGAL FANS

- A. Products: Subject to compliance with requirements, provide one of the following:
1. Greenheck Fan Corporation.
 2. Loren Cook Company.
 3. PennBarry.
 4. Twin City Blower.
- B. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.
- C. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing; with wheel, inlet cone, and motor on swing-out service door.
- D. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.
- E. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.
- F. Accessories:
1. Fan-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 2. Companion Flanges: For inlet and outlet duct connections.

3. Fan Guards: 1/2- by 1-inch mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
4. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.
5. Wired Screened Inlet
6. Motorized Dampers: Parallel-blade dampers mounted in fan housing with electric actuator; wired to close when fan stops.

2.3 CURB-MOUNTED CENTRIFUGAL ROOF FANS

See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers. Retain one of first two paragraphs and list of manufacturers below. See Section 016000 "Product Requirements."

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Aerovent; a division of Twin City Fan Companies, Ltd.
 2. Greenheck Fan Corporation.
 3. Loren Cook Company
 4. PennBarry.
- B. Housing: Removable, spun-aluminum, dome top and outlet baffle; square, one-piece, aluminum base with venturi inlet cone.
- C. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains.
- D. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.
- E. Belt Drives:
 1. Resiliently mounted to housing.
 2. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
 3. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
 4. Pulleys: Cast-iron, adjustable-pitch motor pulley.
 5. Fan and motor isolated from exhaust airstream.
- F. Accessories:
 1. Accessories listed in subparagraphs below are optional features.
 2. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
 3. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted [inside] [outside] fan housing, factory wired through an internal aluminum conduit.
 4. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
 5. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
 6. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

- G. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch-thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.
 - 1. Configuration: Self-flashing without a cant strip, with mounting flange.
 - 2. Coordinate curb height with roof deck construction and insulation thickness; other heights are available. 16-inch (400-mm) height in first subparagraph below is for sound curb.
 - 3. Overall Height: 18 inches.
 - 4. Sound Curb: Curb with sound-absorbing insulation.
 - 5. Pitch Mounting: Manufacture curb for roof slope.
 - 6. Metal Liner: Galvanized steel.
 - 7. Burglar Bars: 1/2-inch- thick steel bars welded in place to form 6-inch squares.
 - 8. Mounting Pedestal: Galvanized steel with removable access panel.
- H. For capacities and characteristics, refer to drawings.

2.2 MOTORS

- A. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Section 15058 "COMMON MOTOR REQUIREMENTS FOR EQUIPMENT."
 - 1. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
- B. Enclosure Type: Totally enclosed, fan cooled.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install power ventilators level and plumb.
- B. Equipment Mounting:
 - 1. Comply with requirements for vibration isolation and seismic control devices specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- C. Support suspended units from structure using threaded steel rods and spring hangers having a static deflection of 1 inch. Vibration-control devices are specified in Section 15074 "VIBRATION AND SEISMIC CONTROLS FOR PIPING AND EQUIPMENT."
- D. Install units with clearances for service and maintenance.
- E. Label units according to requirements specified in Section 15077 "IDENTIFICATION FOR PIPING AND EQUIPMENT."

3.2 CONNECTIONS

- A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 15820 "DUCT ACCESSORIES."
- B. Install ducts adjacent to power ventilators to allow service and maintenance.

3.3 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- B. Tests and Inspections:
 - 1. Verify that shipping, blocking, and bracing are removed.
 - 2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
 - 3. Verify that cleaning and adjusting are complete.
 - 4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
 - 5. Adjust belt tension.
 - 6. Adjust damper linkages for proper damper operation.
 - 7. Verify lubrication for bearings and other moving parts.
 - 8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
 - 9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
 - 10. Shut unit down and reconnect automatic temperature-control operators.
 - 11. Remove and replace malfunctioning units and retest as specified above.
- C. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Prepare test and inspection reports.

3.4 ADJUSTING

- A. Adjust damper linkages for proper damper operation.
- B. Adjust belt tension.
- C. Comply with requirements in Section 15950 "TESTING, ADJUSTING, AND BALANCING" for testing, adjusting, and balancing procedures.
- D. Replace fan and motor pulleys as required to achieve design airflow.
- E. Lubricate bearings.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15840

AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15086 - DUCT INSULATION
 - 4. Section 15815 – METAL DUCTS
 - 5. Section 15820 – DUCT ACCESSORIES
 - 6. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.2 SUMMARY

- A. Section Includes:
 - 1. Shutoff, single-duct air terminal units, with and without hot water reheat coils.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of the following products, including rated capacities, furnished specialties, sound-power ratings, and accessories.
 - 1. Air terminal units.
 - 2. Liners and adhesives.
 - 3. Sealants and gaskets.
 - 4. Seismic-restraint devices.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
 - 1. Ceiling suspension assembly members.
 - 2. Size and location of initial access modules for acoustic tile.
 - 3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

- B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 01782 "OPERATION AND MAINTENANCE DATA," include the following:
 - 1. Instructions for resetting minimum and maximum air volumes.
 - 2. Instructions for adjusting software set points.

1.6 QUALITY ASSURANCE

- A. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "SYSTEMS AND EQUIPMENT" and Section 7 - "CONSTRUCTION AND SYSTEM START-UP."

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Structural Performance: Hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible".
 - 1. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.

2.2 SYSTEM DESCRIPTION

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 SHUTOFF, SINGLE-DUCT AIR TERMINAL UNITS

- A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:
 - 1. Krueger.
 - 2. METALAIRE, Inc.
 - 3. Nailor Industries Inc.
 - 4. Price Industries.
 - 5. Titus.
 - 6. Tuttle and Bailey
- B. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.
- C. Casing: 0.034-inch steel, single wall.

1. Casing Lining: Adhesive attached, 1/2-inch thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested per ASTM E 84.
 2. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
 3. Air Outlet: S-slip and drive connections.
 4. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
 5. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
- D. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
1. Maximum Damper Leakage: ARI 880 rated, 2 percent of nominal airflow at 3-inch inlet static pressure.
 2. Damper Position: Normally closed.
- E. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig and a maximum entering-water temperature of 220 deg F. Include manual air vent and drain valve. Hydronic coils shall be selected for 140 degree F. entering low temperature hot water and 100 degree F. leaving hot water. The coils shall be circuited for above-laminar flow at 25% of design flow rate. The use of turbulators will be acceptable.
- F. Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Section 15900 "HVAC INSTRUMENTATION AND CONTROLS" and shall have the following features:
1. Damper Actuator: 24 V, powered closed, powered open.
 2. Terminal Unit Controller: Pressure-independent, variable-air-volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
 - a. Occupied and unoccupied operating mode.
 - b. Remote reset of airflow or temperature set points.
 - c. Adjusting and monitoring with portable terminal.
 - d. Communication with temperature-control system specified in Section 15900 "HVAC INSTRUMENTATION AND CONTROLS."
 3. Room Sensor: DDC system standard; wall mounted with temperature set-point adjustment and access for connection of portable operator terminal in private attended areas. Blank cover sensor wall plate without manual adjustment for public areas.
- G. Control Sequence:
1. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg inlet static pressure.
 2. System-powered, wall-mounted thermostat.

3. Terminal boxes shall be set up to the following applications:
 - a. Variable Air Volume (VAV) with Minimum CFM for Ventilation and Reheat at Minimum.
 - b. Constant Air Volume with Discharge Temperature Control referenced and indexed to space temperature.
 - c. Demand Controlled Ventilation Responding to Room CO2 Levels. Hot water coil temperature control governs when above minimum ventilation rates due to elevated CO2.

2.4 HANGERS AND SUPPORTS

- A. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
- B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
- C. Steel Cables: Galvanized steel complying with ASTM A 603.
- D. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
- E. Air Terminal Unit Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
- F. Trapeze and Riser Supports: Steel shapes and plates for units with steel casings; aluminum for units with aluminum casings.

2.5 SOURCE QUALITY CONTROL

- A. Factory Tests: Test assembled air terminal units per ARI 880.
 1. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, coil type, and ARI certification seal.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install air terminal units per NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."
- B. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.
- C. ATC to connect wall-mounted thermostats.

3.2 HANGER AND SUPPORT INSTALLATION

- A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."
- B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
 - 1. Where practical, install concrete inserts before placing concrete.
 - 2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
 - 3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches thick.
 - 4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches thick.
 - 5. Do not use powder-actuated concrete fasteners for seismic restraints.
- C. Hangers Exposed to View: Threaded rod and angle or channel supports.
- D. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.3 CONNECTIONS

- A. Install piping adjacent to air terminal unit to allow service and maintenance.
- B. Hot-Water Piping: In addition to requirements in Section 15181 "HYDRONIC PIPING" and Section 15179 "HYDRONIC PIPING SPECIALTIES," connect heating coils to supply with shutoff valve, strainer, control valve, and union or flange; and to return with balancing valve and union or flange.
- C. Connect ducts to air terminal units per Section 15815 "METAL DUCTS."
- D. Make connections to air terminal units with flexible connectors complying with requirements in Section 15820 "DUCT ACCESSORIES."

3.4 IDENTIFICATION

- A. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Section 15077 "IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT" for equipment labels and warning signs and labels.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
 - 2. Demonstrate clearances in front of control cabinet, free of all obstructions.
- D. Tests and Inspections:
 - 1. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
 - 2. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- E. Air terminal unit will be considered defective if it does not pass tests and inspections.
- F. Prepare test and inspection reports.

3.6 STARTUP SERVICE

- A. Perform startup service.
 - 1. Complete installation and startup checks per manufacturer's written instructions.
 - 2. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
 - 3. Verify that controls and control enclosure are accessible.
 - 4. Verify that control connections are complete.
 - 5. Verify that nameplate and identification tag are visible.
 - 6. Verify that controls respond to inputs as specified.

3.7 DEMONSTRATION

- A. Train MBTA's maintenance personnel to adjust, operate, and maintain air terminal units.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15855

DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15086 - DUCT INSULATION
 - 4. Section 15815 – METAL DUCTS
 - 5. Section 15820 – DUCT ACCESSORIES
 - 6. Section 15838 – POWER VENTILATORS
 - 7. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.3 SUMMARY

- A. Section Includes:
 - 1. Fixed face registers, diffusers and grilles.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated, include the following:
 - 1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
 - 2. Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.
- B. Samples for Verification: For diffusers, registers, and grilles, in manufacturer's standard sizes to verify color selected.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
 - 1. Ceiling suspension assembly members.
 - 2. Method of attaching hangers to building structure.
 - 3. Size and location of initial access modules for acoustical tile.

4. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
5. Duct access panels.

PART 2 - PRODUCTS

2.1 REGISTERS AND GRILLES

A. Adjustable Bar Register:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. A-J Manufacturing Co., Inc.
 - b. Anemostat Products; a Mestek company.
 - c. Krueger.
 - d. METALAIRE, Inc.
 - e. Nailor Industries Inc.
 - f. Price Industries.
 - g. Titus.
 - h. Tuttle & Bailey.
2. Material: Aluminum.
3. Finish: Baked enamel, color selected by Architect.
4. Face Blade Arrangement: Horizontal spaced 1-1/2 inches apart.
5. Core Construction: Integral.
6. Rear-Blade Arrangement: Vertical spaced 3/4 inch apart.
7. Frame: 1-1/4 inches wide.
8. Mounting: Countersunk screw.
9. Damper Type: Adjustable opposed blade.

B. Fixed Face Register:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Price Industries.
 - b. Titus.
 - c. Tuttle & Bailey.
2. Material: Aluminum.
3. Finish: Baked enamel, color selected by Architect.
4. Face Arrangement: 1/2-by-1/2-by-1/2-inch grid core.
5. Core Construction: Integral.
6. Frame: 1-1/4 inches wide.
7. Mounting: Countersunk screw.
8. Damper Type: Adjustable opposed blade.
9. Accessory: Filter, MERV 8, where scheduled as a filter grille.

2.2 SOURCE QUALITY CONTROL

- A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install registers, and grilles level and plumb.
- B. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect for a determination of final location.
- C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

- A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment"

END OF SECTION

SECTION 15856

INTAKE AND RELIEF VENTILATORS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Louvered-penthouse ventilators.
 - 2. Roof hoods.

1.3 PERFORMANCE REQUIREMENTS

- A. Structural Performance: Ventilators shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated without permanent deformation of ventilator components, noise or metal fatigue caused by ventilator blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act normal to the face of the building.
 - 1. Wind Loads: Determine loads based on a uniform pressure of 20 lbf/sq. ft., acting inward or outward.
 - 2. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
- B. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes, without buckling, opening of joints, overstressing of components, failure of connections, or other detrimental effects.
 - 1. Temperature Change (Range): 120 deg F, ambient; 180 deg F, material surfaces.
- C. Water Entrainment: Limit water penetration through unit to comply with ASHRAE 62.1.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For gravity ventilators. Include plans, elevations, sections, details, ventilator attachments to curbs, and curb attachments to roof structure.

1. Show weep paths, gaskets, flashing, sealant, and other means of preventing water intrusion.
- C. Samples for Initial Selection: For units with factory-applied color finishes.
- D. Delegated-Design Submittal: For shop-fabricated ventilators indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Detail fabrication and assembly of shop-fabricated ventilators.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Roof framing plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
1. Structural members to which roof curbs and ventilators will be attached.
 2. Sizes and locations of roof openings.
- B. Welding certificates.

1.6 QUALITY ASSURANCE

- A. Welding Qualifications: Qualify procedures and personnel according to the following:
1. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
 2. AWS D1.3, "Structural Welding Code - Sheet Steel."

1.7 COORDINATION

- A. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

PART 2 - PRODUCTS

2.1 MATERIALS

- A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5 or T-52.
- B. Aluminum Sheet: ASTM B 209, Alloy 3003 or 5005 with temper as required for forming or as otherwise recommended by metal producer for required finish.
- C. Galvanized-Steel Sheet: ASTM A 653/A 653M, G90 zinc coating, mill phosphatized.
- D. Fasteners: Same basic metal and alloy as fastened metal or 300 Series stainless steel unless otherwise indicated. Do not use metals that are incompatible with joined materials.

1. Use types and sizes to suit unit installation conditions.
 2. Use hex-head or Phillips pan-head screws for exposed fasteners unless otherwise indicated.
- E. Post-Installed Fasteners for Concrete and Masonry: Torque-controlled expansion anchors made from stainless-steel components, with capability to sustain without failure a load equal to 4 times the loads imposed for concrete, or 6 times the load imposed for masonry, as determined by testing per ASTM E 488, conducted by a qualified independent testing agency.
- F. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

2.2 FABRICATION, GENERAL

- A. Factory or shop fabricate gravity ventilators to minimize field splicing and assembly. Disassemble units to the minimum extent as necessary for shipping and handling. Clearly mark units for reassembly and coordinated installation.
- B. Fabricate frames, including integral bases, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.
- C. Fabricate units with closely fitted joints and exposed connections accurately located and secured.
- D. Fabricate supports, anchorages, and accessories required for complete assembly.
- E. Perform shop welding by AWS-certified procedures and personnel.

2.3 LOUVERED-PENTHOUSE VENTILATORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Acme Engineering & Mfg. Corporation.
 2. Carnes.
 3. Greenheck Fan Corporation.
 4. JencoFan.
 5. Loren Cook Company.
 6. PennBarry.
- B. Construction: All-welded assembly with 4-inch-deep louvers, mitered corners, and aluminum sheet roof with mineral-fiber insulation and vapor barrier.
- C. Frame and Blade Material and Nominal Thickness: Extruded aluminum, of thickness required to comply with structural performance requirements, but not less than 0.080 inch for frames and 0.080 inch for blades with condensate deflectors.
1. Blade Spacing: 6 inches.
 2. Blade Angle: 45 degrees.
 3. AMCA Seal: Mark units with the AMCA Certified Ratings Seal.

4. Exterior Corners: Prefabricated corner units with mitered blades with concealed close-fitting splices and with fully recessed mullions at corners.
- D. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch-thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to fit roof opening and ventilator base.
1. Configuration: Built-in cant and mounting flange.
 2. Overall Height: 36 inches.
- E. Bird Screening: Aluminum, 1/2-inch-square mesh, 0.063-inch wire.
- F. Galvanized-Steel Sheet Finish:
1. Surface Preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas and repair galvanizing according to ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
 2. Baked-Enamel Finish: Immediately after cleaning and pretreating, apply manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum dry film thickness of 1 mil for topcoat and an overall minimum dry film thickness of 2 mils.
 - a. Color and Gloss: Match Architect's sample As selected by Architect from manufacturer's full range.
- G. Accessories:
1. Dampers:
 - a. Location: Penthouse neck.
 - b. Control: Motorized.
- H. Capacities and Characteristics:
1. Height: As indicated on drawings.
 2. Width and Depth: As indicated on drawings.
 3. Free Area: Not less than 6.0 sq. ft. for 48-inch-wide by 48-inch-high louver.
 4. Air Performance: Not more than 0.10-inch wg static pressure drop at 500-fpm free-area exhaust or intake velocity.
 5. Wind-Driven Rain Performance: Not less than 95 percent effectiveness when subjected to a rainfall rate of 3 inches per hour and a wind speed of 29 mph at a core-area intake velocity of 500 fpm.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install gravity ventilators level, plumb, and at indicated alignment with adjacent work.
- B. Install gravity ventilators with clearances for service and maintenance.

- C. Install perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.
- D. Install concealed gaskets, flashings, joint fillers, and insulation as installation progresses. Comply with Section 07920 "JOINT SEALANTS" for sealants applied during installation.
- E. Label gravity ventilators according to requirements specified in Section 15077 "IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT."
- F. Protect galvanized and nonferrous-metal surfaces from corrosion or galvanic action by applying a heavy coating of bituminous paint on surfaces that will be in contact with concrete, masonry, or dissimilar metals.
- G. Repair finishes damaged by cutting, welding, soldering, and grinding. Restore finishes so no evidence remains of corrective work. Return items that cannot be refinished in the field to the factory, make required alterations, and refinish entire unit or provide new units.

3.2 CONNECTIONS

- A. Duct installation and connection requirements are specified in Section 15815 "METAL DUCTS" and Section 15816 "NONMETAL DUCTS." Drawings indicate general arrangement of ducts and duct accessories.

3.3 ADJUSTING

- A. Adjust damper linkages for proper damper operation.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15900

HVAC INSTRUMENTATION AND CONTROLS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Related Sections:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15062 – HANGERS AND SUPPORTS FOR PIPING AND EQUIPMENT
 - 3. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 4. Section 15739 – SPLIT-SYSTEM AIR-CONDITIONING UNITS
 - 5. Section 15765 – ELECTRIC RESISTANCE AIR COILS
 - 6. Section 15791 – CABINET UNIT HEATERS
 - 7. Section 15792 – PROPELLER UNIT HEATERS
 - 8. Section 15798 – FINNED TUBE RADIATION HEATERS
 - 9. Section 15738 – POWER VENTILATORS
 - 10. Section 15815 – METAL DUCTS
 - 11. Section 15950 – TESTING, ADJUSTING AND BALANCING
 - 12. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK
 - 13. Section 16060 – GROUNDING AND BONDING
 - 14. Section 16492 – SCADA MASTER STATION AND SCADA INTERFACE
 - 15. Section 16711 – SECURITY AND COMMUNICATIONS CABLE
 - 16. Specifications – SECTIONS SUBMITTED BY DESIGN-BUILDER, including appropriate instrumentation, controls, sequences of operation applicable thereto.

1.2 SUMMARY

- A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls.
- B. The use of DDC controls is intended for the Vehicle Maintenance Facility (VMF) and adjacent Transportation Building, the occupied portions of Lechmere Station, all to control and manage the several disparate systems required for those facilities in a reliable, interactive, adaptable and cost-effective manner.
- C. Stations in general, Transport Power Substations (TPSS), pump stations and other transiently attended spaces, may be direct “hard-wired logic” control for the intended stand-alone heaters, fans, air conditioning systems and other constant setpoint-based systems intended for those locations. Nothing in this specification shall prohibit use of DDC applications for any portion of any facility, if economically justified.
- D. Notwithstanding the use of DDC controls, all alarms shall be generated and sent via the SCADA system to 45 High Street. This shall include alarms generated within buildings served by DDC controls. Provide all interfaces, test and verification.

1.3 DEFINITIONS

- A. DDC: Direct digital control.
- B. I/O: Input/output.
- C. MS/TP: Master slave/token passing.
- D. PC: Personal computer.
- E. PID: Proportional plus integral plus derivative.
- F. RTD: Resistance temperature detector.

1.4 SYSTEM PERFORMANCE

- A. Comply with the following performance requirements:
 - 1. Graphic Display: Display graphic with minimum 20 dynamic points with current data within 10 seconds.
 - 2. Graphic Refresh: Update graphic with minimum 20 dynamic points with current data within 8 seconds.
 - 3. Object Command: Reaction time of less than two seconds between operator command of a binary object and device reaction.
 - 4. Object Scan: Transmit change of state and change of analog values to control units or workstation within six seconds.
 - 5. Alarm Response Time: Annunciate alarm at workstation within 45 seconds. Multiple workstations must receive alarms within five seconds of each other.
 - 6. Program Execution Frequency: Run capability of applications as often as five seconds, but selected consistent with mechanical process under control.
 - 7. Performance: Programmable controllers shall execute DDC PID control loops, and scan and update process values and outputs at least once per second.
 - 8. Reporting Accuracy and Stability of Control: Report values and maintain measured variables within tolerances as follows:
 - a. Water Temperature: Plus or minus 1 deg F.
 - b. Water Flow: Plus or minus 5 percent of full scale.
 - c. Water Pressure: Plus or minus 2 percent of full scale.
 - d. Space Temperature: Plus or minus 1 deg F.
 - e. Ducted Air Temperature: Plus or minus 1 deg F.
 - f. Outside Air Temperature: Plus or minus 2 deg F.
 - g. Dew Point Temperature: Plus or minus 3 deg F.
 - h. Temperature Differential: Plus or minus 0.25 deg F.
 - i. Relative Humidity: Plus or minus 5 percent.
 - j. Airflow (Pressurized Spaces): Plus or minus 3 percent of full scale.

- k. Airflow (Measuring Stations): Plus or minus 5 percent of full scale.
- l. Airflow (Terminal): Plus or minus 10 percent of full scale.
- m. Air Pressure (Space): Plus or minus 0.01-inch wg.
- n. Air Pressure (Ducts): Plus or minus 0.1-inch wg.
- o. Carbon Monoxide: Plus or minus 5 percent of reading.
- p. Carbon Dioxide: Plus or minus 50 ppm.
- q. Electrical: Plus or minus 5 percent of reading.

1.5 SEQUENCE OF OPERATION

- A. As submitted by the Design-Builder for review and acceptance prior to implementation.

1.6 ACTION SUBMITTALS

- A. Product Data: Include manufacturer's technical literature for each control device. Indicate dimensions, capacities, performance characteristics, electrical characteristics, finishes for materials, and installation and startup instructions for each type of product indicated.
 - 1. DDC System Hardware: Bill of materials of equipment indicating quantity, manufacturer, and model number. Include technical data for operator workstation equipment, interface equipment, control units, transducers/transmitters, sensors, actuators, valves, relays/switches, control panels, and operator interface equipment.
 - 2. Control System Software: Include technical data for operating system software, operator interface, color graphics, and other third-party applications.
 - 3. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Bill of materials of equipment indicating quantity, manufacturer, and model number.
 - 2. Schematic flow diagrams showing fans, pumps, coils, dampers, valves, and control devices.
 - 3. Wiring Diagrams: Power, signal, and control wiring.
 - 4. Details of control panel faces, including controls, instruments, and labeling.
 - 5. Written description of sequence of operation.
 - 6. Schedule of dampers including size, leakage, and flow characteristics.
 - 7. Schedule of valves including flow characteristics.
 - 8. DDC System Hardware:
 - a. Wiring diagrams for control units with termination numbers.
 - b. Schematic diagrams and floor plans for field sensors and control hardware.
 - c. Schematic diagrams for control, communication, and power wiring, showing trunk data conductors and wiring between operator workstation and control unit locations.
 - 9. Control System Software: List of color graphics indicating monitored systems, data (connected and calculated) point addresses, output schedule, and operator notations.
 - 10. Controlled Systems:

- a. Schematic diagrams of each controlled system with control points labeled and control elements graphically shown, with wiring.
- b. Scaled drawings showing mounting, routing, and wiring of elements including bases and special construction.
- c. Written description of sequence of operation including schematic diagram.
- d. Points list.

1.7 INFORMATIONAL SUBMITTALS

- A. Data Communications Protocol Certificates: Certify that each proposed DDC system component complies with ASHRAE 135.
- B. Qualification Data: For Installer and manufacturer.
- C. Software Upgrade Kit: For MBTA to use in modifying software to suit future systems revisions or monitoring and control revisions.
- D. Field quality-control test reports.

1.8 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For HVAC instrumentation and control system to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 01782 "Operation and Maintenance Data," include the following:
 1. Maintenance instructions and lists of spare parts for each type of control device.
 2. Interconnection wiring diagrams with identified and numbered system components and devices.
 3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
 4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
 5. Calibration records and list of set points.
- B. Software and Firmware Operational Documentation: Include the following:
 1. Software operating and upgrade manuals.
 2. Program Software Backup: On a magnetic media or compact disc, complete with data files.
 3. Device address list.
 4. Printout of software application and graphic screens.
 5. Software license required by and installed for DDC workstations and control systems.

1.9 QUALITY ASSURANCE

- A. Installer Qualifications: Automatic control system manufacturer's authorized representative who is trained and approved for installation of system components required for this Project.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- C. Comply with ASHRAE 135 for DDC system components.

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Factory-Mounted Components: Where control devices specified in this Section are indicated to be factory mounted on equipment, arrange for shipping of control devices to equipment manufacturer.
- B. System Software: Update to latest version of software at Project completion.

1.11 COORDINATION

- A. Coordinate location of thermostats, humidistats, and other exposed control sensors with plans and room details before installation.
- B. Coordinate equipment with Section 16443 "Motor-Control Centers" to achieve compatibility with motor starters and annunciation devices.
- C. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 03300 "Cast-in-Place Concrete."

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
 - 1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.
 - 2. Any Direct Digital Control (DDC) system used on this project shall be Native BACnet® conforming to the latest edition of ASHRAE/ANSI Standard 135.
 - 3. Manufacturers: Subject to compliance with requirements, provide products by one of the manufacturers specified.

2.2 CONTROL SYSTEM

- A. Manufacturers:
 - 1. Andover Controls; Division of Schneider Electric
 - 2. Controls Technologies, Inc./CTI
 - 3. Delta Controls
 - 4. Invensys; Division of Schneider Electric
 - 5. Johnson Controls, Inc.; Controls Group.

6. Siemens Building Technologies, Inc.
- B. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, and accessories to control mechanical systems.
 - C. Control system shall consist of sensors, indicators, actuators, final control elements, interface equipment, other apparatus, accessories, and software connected to distributed controllers operating in multiuser, multitasking environment on token-passing network and programmed to control mechanical systems. An operator workstation permits interface with the network via dynamic color graphics with each mechanical system, building floor plan, and control device depicted by point-and-click graphics.
 - D. Control system shall include interlocking with the following:
 1. Building lighting control system specified in Section 16145 "Lighting Control Devices."
 2. Fire alarm system specified in Section 16705 "Digital, Addressable Fire-Alarm System".

2.3 DDC EQUIPMENT

- A. Diagnostic Terminal Unit: Portable notebook-style, PC-based microcomputer terminal capable of accessing system data by connecting to system network with minimum configuration as follows:
 1. System: With two integrated USB 3.0 port, integrated Intel Pro 10/100/1000 (Ethernet), integrated audio, bios, and hardware monitoring.
 2. Processor: Intel Core i7 2.8 GHz
 3. Random-Access Memory: 8GB.
 4. Graphics: Video adapter, minimum 1024 x 768 pixels, 2 GB video memory.
 5. Monitor: 15 inch LCD color.
 6. Keyboard: QWERTY 105 keys in ergonomic shape.
 7. Hard-Disk Drive: 1 TB 5400 RPM.
 8. DVD-ROM Read/Write Drive: 48x24x48.
 9. Pointing Device: Touch pad or other internal device.
 10. Operating System: Windows 7
 - a. ASHRAE 135 Compliance: Workstation shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
 11. Application Software:
 - a. System security for each operator via software password and access levels.
 - b. Automatic system diagnostics; monitor system and report failures.
 - c. Database creation and support.
 - d. Automatic and manual database save and restore.
 - e. Dynamic color graphic displays with up to 10 screen displays at once.
 - f. Custom graphics generation and graphics library of HVAC equipment and symbols.
 - g. Alarm processing, messages, and reactions.
 - h. Trend logs retrievable in spreadsheets and database programs.
 - i. Alarm and event processing.
 - j. Object and property status and control.
 - k. Automatic restart of field equipment on restoration of power.
 - l. Data collection, reports, and logs. Include standard reports for the following:
 - 1) Current values of all objects.
 - 2) Current alarm summary.

- 3) Disabled objects.
 - 4) Alarm lockout objects.
 - 5) Logs.
- m. Custom report development.
 - n. Utility and weather reports.
 - o. Workstation application editors for controllers and schedules.
 - p. Maintenance management.
12. Custom Application Software:
- a. English language oriented.
 - b. Full-screen character editor/programming environment.
 - c. Allow development of independently executing program modules with debugging/simulation capability.
 - d. Support conditional statements.
 - e. Support floating-point arithmetic with mathematic functions.
 - f. Contains predefined time variables.
- B. Control Units: Modular, comprising processor board with programmable, nonvolatile, random-access memory; local operator access and display panel; integral interface equipment; and backup power source.
- 1. Units monitor or control each I/O point; process information; execute commands from other control units, devices, and operator stations; and download from or upload to operator workstation or diagnostic terminal unit.
 - 2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
 - a. Global communications.
 - b. Discrete/digital, analog, and pulse I/O.
 - c. Monitoring, controlling, or addressing data points.
 - d. Software applications, scheduling, and alarm processing.
 - e. Testing and developing control algorithms without disrupting field hardware and controlled environment.
 - 3. Standard Application Programs:
 - a. Electric Control Programs: Demand limiting, duty cycling, automatic time scheduling, start/stop time optimization, night setback/setup, on-off control with differential sequencing, staggered start, antishort cycling, PID control, DDC with fine tuning, and trend logging.
 - b. HVAC Control Programs: Optimal run time, supply-air reset, and enthalpy switchover.
 - c. Programming Application Features: Include trend point; alarm processing and messaging; weekly, monthly, and annual scheduling; energy calculations; run-time totalization; and security access.
 - d. Remote communications.
 - e. Maintenance management.

- f. Units of Measure: Inch-pound and SI (metric).
 - 4. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.
 - 5. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
- C. Local Control Units: Modular, comprising processor board with electronically programmable, nonvolatile, read-only memory; and backup power source.
- 1. Units monitor or control each I/O point, process information, and download from or upload to operator workstation or diagnostic terminal unit.
 - 2. Stand-alone mode control functions operate regardless of network status. Functions include the following:
 - a. Global communications.
 - b. Discrete/digital, analog, and pulse I/O.
 - c. Monitoring, controlling, or addressing data points.
 - 3. Local operator interface provides for download from or upload to operator workstation or diagnostic terminal unit.
 - 4. ASHRAE 135 Compliance: Control units shall use ASHRAE 135 protocol and communicate using ISO 8802-3 (Ethernet) datalink/physical layer protocol.
- D. I/O Interface: Hardwired inputs and outputs may tie into system through controllers. Protect points so that shorting will cause no damage to controllers.
- 1. Binary Inputs: Allow monitoring of on-off signals without external power.
 - 2. Pulse Accumulation Inputs: Accept up to 10 pulses per second.
 - 3. Analog Inputs: Allow monitoring of low-voltage (0- to 10-V dc), current (4 to 20 mA), or resistance signals.
 - 4. Binary Outputs: Provide on-off or pulsed low-voltage signal, selectable for normally open or normally closed operation with three-position (on-off-auto) override switches and status lights.
 - 5. Analog Outputs: Provide modulating signal, either low voltage (0- to 10-V dc) or current (4 to 20 mA) with status lights, two-position (auto-manual) switch, and manually adjustable potentiometer.
 - 6. Tri-State Outputs: Provide two coordinated binary outputs for control of three-point, floating-type electronic actuators.
 - 7. Universal I/Os: Provide software selectable binary or analog outputs.
- E. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:

1. Output ripple of 5.0 mV maximum peak to peak.
 2. Combined 1 percent line and load regulation with 100-mic.sec. response time for 50 percent load changes.
 3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.
- F. Power Line Filtering: Internal or external transient voltage and surge suppression for workstations or controllers with the following:
1. Minimum dielectric strength of 1000 V.
 2. Maximum response time of 10 nanoseconds.
 3. Minimum transverse-mode noise attenuation of 65 dB.
 4. Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

2.4 UNITARY CONTROLLERS

- A. Unitized, capable of stand-alone operation with sufficient memory to support its operating system, database, and programming requirements, and with sufficient I/O capacity for the application.
1. Configuration: Local keypad and display; diagnostic LEDs for power, communication, and processor; wiring termination to terminal strip or card connected with ribbon cable; memory with bios; and 72-hour battery backup.
 2. Operating System: Manage I/O communication to allow distributed controllers to share real and virtual object information and allow central monitoring and alarms. Perform automatic system diagnostics; monitor system and report failures.
 3. ASHRAE 135 Compliance: Communicate using read (execute and initiate) and write (execute and initiate) property services defined in ASHRAE 135. Reside on network using MS/TP datalink/physical layer protocol and have service communication port for connection to diagnostic terminal unit.
 4. Enclosure: Dustproof rated for operation at 32 to 120 deg F.
 5. Enclosure: Waterproof rated for operation at 40 to 150 deg F.

2.5 ALARM PANELS

- A. Unitized cabinet with suitable brackets for wall or floor mounting. Fabricate of 0.06-inch-thick, furniture-quality steel or extruded-aluminum alloy, totally enclosed, with hinged doors and keyed lock and with manufacturer's standard shop-painted finish. Provide common keying for all panels.
- B. Indicating light for each alarm point, single horn, acknowledge switch, and test switch, mounted on hinged cover.
1. Alarm Condition: Indicating light flashes and horn sounds.
 2. Acknowledge Switch: Horn is silent and indicating light is steady.
 3. Second Alarm: Horn sounds and indicating light is steady.

4. Alarm Condition Cleared: System is reset and indicating light is extinguished.
5. Contacts in alarm panel allow remote monitoring by independent alarm company.

2.6 TIME CLOCKS

A. Manufacturers:

1. ATC-Diversified Electronics.
2. Grasslin Controls Corporation.
3. Paragon Electric Co., Inc.
4. Precision Multiple Controls, Inc.
5. SSAC Inc.; ABB USA.
6. TCS/Basys Controls.
7. Theben AG - Lumilite Control Technology, Inc.
8. Time Mark Corporation.

- B. Solid-state, programmable time control with 4 separate programs each with up to 100 on-off operations; 1-second resolution; lithium battery backup; keyboard interface and manual override; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; system fault alarm; and communications package allowing networking of time controls and programming from PC.

2.7 ELECTRONIC SENSORS

- A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Thermistor Temperature Sensors and Transmitters:

1. Manufacturers:

- a. BEC Controls Corporation.
- b. Ebtron, Inc.
- c. Heat-Timer Corporation.
- d. I.T.M. Instruments Inc.
- e. MAMAC Systems, Inc.
- f. Minco, Inc.
- g. RDF Corporation.

2. Accuracy: Plus or minus 0.5 deg Fat calibration point.

3. Wire: Twisted, shielded-pair cable.

4. Insertion Elements in Ducts: Single point, 18 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft.

5. Averaging Elements in Ducts: 72 inches long, flexible; use where prone to temperature stratification or where ducts are larger than 10 sq. ft.

6. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 2-1/2 inches.

7. Room Sensor Cover Construction: Manufacturer's standard locking covers.
 - a. Set-Point Adjustment: Concealed.
 - b. Set-Point Indication: Concealed.
 - c. Color: White
 - d. Orientation: Vertical.
 8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
 9. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
- C. RTDs and Transmitters:
1. Manufacturers:
 - a. BEC Controls Corporation.
 - b. MAMAC Systems, Inc.
 - c. RDF Corporation.
 2. Accuracy: Plus or minus 0.2 percent at calibration point.
 3. Wire: Twisted, shielded-pair cable.
 4. Insertion Elements in Ducts: Single point, 18 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft.
 5. Averaging Elements in Ducts: 18 inches long, rigid; use where prone to temperature stratification or where ducts are larger than 9 sq. ft.; length as required.
 6. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches.
 7. Room Sensor Cover Construction: Manufacturer's standard locking covers.
 - a. Set-Point Adjustment: Concealed.
 - b. Set-Point Indication: Concealed.
 - c. Color: White.
 - d. Orientation: Vertical.
 8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.
 9. Room Security Sensors: Stainless-steel cover plate with insulated back and security screws.
- D. Humidity Sensors: Bulk polymer sensor element.
1. Manufacturers:
 - a. BEC Controls Corporation.
 - b. General Eastern Instruments.
 - c. MAMAC Systems, Inc.
 - d. ROTRONIC Instrument Corp.
 - e. TCS/Basys Controls.
 - f. Vaisala.

2. Accuracy: 5 percent full range with linear output.
 3. Room Sensor Range: 20 to 80 percent relative humidity.
 4. Room Sensor Cover Construction: Manufacturer's standard locking covers.
 - a. Set-Point Adjustment: Concealed.
 - b. Set-Point Indication: Concealed.
 - c. Color: White.
 - d. Orientation: Vertical.
 5. Duct Sensor: 20 to 80 percent relative humidity range with element guard and mounting plate.
 6. Outside-Air Sensor: 20 to 80 percent relative humidity range with mounting enclosure, suitable for operation at outdoor temperatures of minus 40 to plus 170 deg F.
 7. Duct and Sensors: With element guard and mounting plate, range of 0 to 100 percent relative humidity.
- E. Pressure Transmitters/Transducers:
1. Manufacturers:
 - a. BEC Controls Corporation.
 - b. General Eastern Instruments.
 - c. MAMAC Systems, Inc.
 - d. ROTRONIC Instrument Corp.
 - e. TCS/Basys Controls.
 - f. Vaisala.
 2. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
 - a. Accuracy: 2 percent of full scale with repeatability of 0.5 percent.
 - b. Output: 4 to 20 mA.
 - c. Building Static-Pressure Range: 0- to 0.25-inch wg.
 - d. Duct Static-Pressure Range: 0- to 5-inch wg.
 3. Water Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure; linear output 4 to 20 mA.
 4. Water Differential-Pressure Transducers: Stainless-steel diaphragm construction, suitable for service; minimum 150-psig operating pressure and tested to 300-psig; linear output 4 to 20 mA.
 5. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.
 6. Pressure Transmitters: Direct acting for gas, liquid, or steam service; range suitable for system; linear output 4 to 20 mA.
- F. Room Sensor Cover Construction: Manufacturer's standard locking covers.
1. Set-Point Adjustment: Concealed.

2. Set-Point Indication: Concealed.
3. Color: White.
4. Orientation: Vertical.

G. Room sensor accessories include the following:

1. Insulating Bases: For sensors located on exterior walls.
2. Guards: Locking; heavy-duty, transparent plastic; mounted on separate base.
3. Adjusting Key: As required for calibration and cover screws.

2.8 STATUS SENSORS

- A. Status Inputs for Fans: Differential-pressure switch with pilot-duty rating and with adjustable range of 0- to 5-inch wg.
- B. Status Inputs for Pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig, piped across pump.
- C. Status Inputs for Electric Motors: Comply with ISA 50.00.01, current-sensing fixed- or split-core transformers with self-powered transmitter, adjustable and suitable for 175 percent of rated motor current.
- D. Current Switches: Self-powered, solid-state with adjustable trip current, selected to match current and system output requirements.
- E. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
- F. Water-Flow Switches: Snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.
 1. Manufacturers:
 - a. BEC Controls Corporation.
 - b. I.T.M. Instruments Inc.

2.9 FLOW MEASURING STATIONS

- A. Duct Airflow Station: Combination of air straightener and multiport, self-averaging pitot tube station.
 1. Manufacturers:
 - a. Air Monitor Corporation.
 - b. Wetmaster Co., Ltd.
 2. Casing: Galvanized-steel frame.
 3. Flow Straightener: Aluminum honeycomb, 3/4-inch parallel cell, 3 inches deep.
 4. Sensing Manifold: Copper manifold with bullet-nosed static pressure sensors positioned on equal area basis.

2.10 THERMOSTATS

- A. Manufacturers:
1. Erie Controls.
 2. Danfoss Inc.; Air-Conditioning and Refrigeration Div.
 3. Heat-Timer Corporation.
 4. Sauter Controls Corporation.
 5. tekmar Control Systems, Inc.
 6. Theben AG - Lumilite Control Technology, Inc.
- B. Combination Thermostat and Fan Switches: Line-voltage thermostat with push-button or lever-operated fan switch.
1. Label switches "FAN ON-OFF".
 2. Mount on single electric switch box.
- C. Electric, solid-state, microcomputer-based room thermostat with remote sensor.
1. Automatic switching from heating to cooling.
 2. Preferential rate control to minimize overshoot and deviation from set point.
 3. Set up for four separate temperatures per day.
 4. Instant override of set point for continuous or timed period from 1 hour to 31 days.
 5. Short-cycle protection.
 6. Programming based on weekday, Saturday, and Sunday.
 7. Selection features include degree F or degree C display, 12- or 24-hour clock, keyboard disable, remote sensor, and fan on-auto.
 8. Battery replacement without program loss.
 9. Thermostat display features include the following:
 - a. Time of day.
 - b. Actual room temperature.
 - c. Programmed temperature.
 - d. Programmed time.
 - e. Duration of timed override.
 - f. Day of week.
 - g. System mode indications include "heating," "off," "fan auto," and "fan on."
- D. Low-Voltage, On-Off Thermostats: NEMA DC 3, 24-V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.
- E. Line-Voltage, On-Off Thermostats: Bimetal-actuated, open contact or bellows-actuated, enclosed, snap-switch or equivalent solid-state type, with heat anticipator; listed for electrical rating; with concealed set-point adjustment, 55 to 85 deg F set-point range, and 2 deg F maximum differential.
1. Electric Heating Thermostats: Equip with off position on dial wired to break ungrounded conductors.
 2. Selector Switch: Integral, manual on-off-auto.
- F. Remote-Bulb Thermostats: On-off or modulating type, liquid filled to compensate for changes in ambient temperature; with copper capillary and bulb, unless otherwise indicated.

1. Bulbs in water lines with separate wells of same material as bulb.
 2. Bulbs in air ducts with flanges and shields.
 3. Averaging Elements: Copper tubing with either single- or multiple-unit elements, extended to cover full width of duct or unit; adequately supported.
 4. Scale settings and differential settings are clearly visible and adjustable from front of instrument.
 5. On-Off Thermostat: With precision snap switches and with electrical ratings required by application.
 6. Modulating Thermostats: Construct so complete potentiometer coil and wiper assembly is removable for inspection or replacement without disturbing calibration of instrument.
- G. Fire-Protection Thermostats: Listed and labeled by an NRTL acceptable to authorities having jurisdiction; with fixed or adjustable settings to operate at not less than 75 deg F above normal maximum operating temperature, and the following:
1. Reset: Manual.
 2. Reset: Automatic, with control circuit arranged to require manual reset at central control panel; with pilot light and reset switch on panel labeled to indicate operation.
- H. Immersion Thermostat: Remote-bulb or bimetal rod-and-tube type, proportioning action with adjustable throttling range and adjustable set point.
- I. Airstream Thermostats: Two-pipe, fully proportional, single-temperature type; with adjustable set point in middle of range, adjustable throttling range, plug-in test fitting or permanent pressure gage, remote bulb, bimetal rod and tube, or averaging element.
- J. Electric, Low-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual-reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or below set point.
1. Bulb Length: Minimum 20 feet.
 2. Quantity: One thermostat for every 20 sq. ft. of coil surface.
- K. Electric, High-Limit Duct Thermostat: Snap-acting, single-pole, single-throw, manual-reset switch that trips if temperature sensed across any 12 inches of bulb length is equal to or above set point.
1. Bulb Length: Minimum 20 feet.
 2. Quantity: One thermostat for every 20 sq. ft. of coil surface.
- L. Heating/Cooling Valve-Top Thermostats: Proportional acting for proportional flow, with molded-rubber diaphragm, remote-bulb liquid-filled element, direct and reverse acting at minimum shutoff pressure of 25 psig, and cast housing with position indicator and adjusting knob.

2.11 HUMIDISTATS

- A. Manufacturers:
1. MAMAC Systems, Inc.

2. ROTRONIC Instrument Corp.
- B. Duct-Mounting Humidistats: Electric insertion, 2-position type with adjustable, 2 percent throttling range, 20 to 80 percent operating range, and single- or double-pole contacts.

2.12 ACTUATORS

- A. Electric Motors: Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
1. Comply with requirements in Section 15058 "Common Motor Requirements for HVAC Equipment."
 2. Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
 3. Nonspring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
 4. Spring-Return Motors for Valves Larger Than NPS 2-1/2: Size for running and breakaway torque of 150 in. x lbf.
 5. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running torque of 150 in. x lbf and breakaway torque of 300 in. x lbf.
 6. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft.: Size for running and breakaway torque of 150 in. x lbf.
- B. Fail-Safe Positions: All actuators shall fail in the safe position for each application, to protect the building and system from extremes of temperature. For outside air shall fail closed, for hot water heating shall fail open.
- C. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
1. Manufacturers:
 - a. Belimo Aircontrols (USA), Inc.
 - b. Dodge Engineering & Controls, Inc.
 2. Valves: Size for torque required for valve close off at maximum pump differential pressure.
 3. Dampers: Size for running torque calculated as follows:
 - a. Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. of damper.
 - b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
 - c. Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft. of damper.
 - d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.
 - e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.

4. Coupling: V-bolt and V-shaped, toothed cradle.
5. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
6. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.
7. Power Requirements (Two-Position Spring Return): 24-V ac.
8. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
9. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
10. Temperature Rating: 40 to 104 deg F.
11. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 deg F.
12. Run Time: 30 seconds.

2.13 CONTROL VALVES

A. Manufacturers:

1. Danfoss Inc.; Air Conditioning & Refrigeration Div.
2. Erie Controls.
3. Hayward Industrial Products, Inc.
4. Magnatrol Valve Corporation.
5. Neles-Jamesbury.
6. Parker Hannifin Corporation; Skinner Valve Division.
7. Pneuline Controls.
8. Sauter Controls Corporation.
9. Dodge Engineering & Controls, Inc.

B. Control Valves: Factory fabricated, of type, body material, and pressure class based on maximum pressure and temperature rating of piping system, unless otherwise indicated.

C. Hydronic system globe valves shall have the following characteristics:

1. NPS 2 and Smaller: Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
2. NPS 2-1/2 and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
3. Internal Construction: Replaceable plugs and stainless-steel or brass seats.
 - a. Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
 - b. Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.

4. Sizing: 5-psig maximum pressure drop at design flow rate or the following:
 - a. Two Position: Line size.
 - b. Two-Way Modulating: Either the value specified above or twice the load pressure drop, whichever is more.
 - c. Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.
 5. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
 6. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.
- D. Butterfly Valves: 200-psig, 150-psig maximum pressure differential, ASTM A 126 cast-iron or ASTM A 536 ductile-iron body and bonnet, extended neck, stainless-steel stem, field-replaceable EPDM or Buna N sleeve and stem seals.
1. Body Style: Lug.
 2. Disc Type: Aluminum bronze.
 3. Sizing: 1-psig maximum pressure drop at design flow rate.
- E. Terminal Unit Control Valves: Bronze body, bronze trim, two or three ports as indicated, replaceable plugs and seats, and union and threaded ends.
1. Rating: Class 125 for service at 125 psig and 250 deg F operating conditions.
 2. Sizing: 3-psig maximum pressure drop at design flow rate, to close against pump shutoff head.
 3. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
 4. Default for control valves shall be two-way. Use of three-way valves shall be only on system extremities to promote line temperature maintenance for freeze protection.

2.14 DAMPERS

- A. Manufacturers:
1. Air Balance Inc.
 2. Don Park Inc.; Autodamp Div.
 3. TAMCO (T. A. Morrison & Co. Inc.).
 4. United Enertech Corp.
 5. Vent Products Company, Inc.
 6. Ruskin Company
- B. Dampers: AMCA-rated, opposed-blade design; 0.108-inch-minimum thick, galvanized-steel or 0.125-inch-minimum thick, extruded-aluminum frames with holes for duct mounting; damper blades shall

not be less than 0.064-inch-thick galvanized steel with maximum blade width of 8 inches and length of 48 inches.

1. Secure blades to 1/2-inch-diameter, zinc-plated axles using zinc-plated hardware, with oil-impregnated sintered bronze blade bearings, blade-linkage hardware of zinc-plated steel and brass, ends sealed against spring-stainless-steel blade bearings, and thrust bearings at each end of every blade.
2. Operating Temperature Range: From minus 40 to plus 200 deg F.
3. Edge Seals, Standard Pressure Applications: Closed-cell neoprene.
4. Edge Seals, Low-Leakage Applications: Use inflatable blade edging or replaceable rubber blade seals and spring-loaded stainless-steel side seals, rated for leakage at less than 10 cfm per sq. ft. of damper area, at differential pressure of 4-inch wg when damper is held by torque of 50 in. x lbf; when tested according to AMCA 500D.

2.15 CONTROL CABLE

- A. Electronic and fiber-optic cables for control wiring are specified in Section 16711 "SECURITY AND COMMUNICATIONS CABLE AND CONNECTORS."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Verify that power supply is available to control units.
- B. Verify that duct-, pipe-, and equipment-mounted devices are installed before proceeding with installation.

3.2 INSTALLATION

- A. Install software in control units and operator workstation(s). Implement all features of programs to specified requirements and as appropriate to sequence of operation.
- B. Connect and configure equipment and software to achieve sequence of operation specified.
- C. Verify location of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices 60 inches above the floor.
 1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.
- D. Install guards on thermostats in the following locations:
 1. Entrances.
 2. Public areas.
 3. Where indicated.

- E. Install automatic dampers according to Section 15820 "Duct Accessories."
- F. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.
- G. Install labels and nameplates to identify control components according to Section 15077 "Identification for HVAC Piping and Equipment."
- H. Install hydronic instrument wells, valves, and other accessories according to Section 15179 "Hydronic Piping Specialties."
- I. Install refrigerant instrument wells, valves, and other accessories according to Section 15183 "Refrigerant Piping."
- J. Install duct volume-control dampers according to Section 15815 "Metal Ducts" and Section 15816 "Nonmetal Ducts."
- K. Install electronic and fiber-optic cables according to Section 16711 "SECURITY AND COMMUNICATIONS CABLE AND CONNECTORS."

3.3 ELECTRICAL WIRING AND CONNECTION INSTALLATION

- A. Install raceways, boxes, and cabinets according to Section 16130 "Raceways and Boxes."
- B. Install building wire and cable according to Section 16120 "Conductors and Cables."
- C. Install signal and communication cable according to Section 16711 "SECURITY AND COMMUNICATIONS CABLE AND CONNECTORS."
 - 1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.
 - 2. Install exposed cable in raceway.
 - 3. Install concealed cable in raceway.
 - 4. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.
 - 5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.
 - 6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.
 - 7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.
- D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

- E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

3.4 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.
- B. Perform the following field tests and inspections and prepare test reports:
 - 1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.
 - 2. Test and adjust controls and safeties.
 - 3. Test calibration of electronic controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
 - 4. Test each point through its full operating range to verify that safety and operating control set points are as required.
 - 5. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.
 - 6. Test each system for compliance with sequence of operation.
 - 7. Test software and hardware interlocks.
- C. DDC Verification:
 - 1. Verify that instruments are installed before calibration, testing, and loop or leak checks.
 - 2. Check instruments for proper location and accessibility.
 - 3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.
 - 4. Check flow instruments. Inspect tag number and line and bore size, and verify that inlet side is identified and that meters are installed correctly.
 - 5. Check temperature instruments and material and length of sensing elements.
 - 6. Check control valves. Verify that they are in correct direction.
 - 7. Check DDC system as follows:
 - a. Verify that DDC controller power supply is from emergency power supply, if applicable.
 - b. Verify that wires at control panels are tagged with their service designation and approved tagging system.

- c. Verify that spare I/O capacity has been provided.
 - d. Verify that DDC controllers are protected from power supply surges.
- D. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.5 ADJUSTING

A. Calibrating and Adjusting:

1. Calibrate instruments.
2. Make three-point calibration test for both linearity and accuracy for each analog instrument.
3. Calibrate equipment and procedures using manufacturer's written recommendations and instruction manuals. Use test equipment with accuracy at least double that of instrument being calibrated.
4. Control System Inputs and Outputs:
 - a. Check analog inputs at 0, 50, and 100 percent of span.
 - b. Check analog outputs using milliampere meter at 0, 50, and 100 percent output.
 - c. Check digital inputs using jumper wire.
 - d. Check digital outputs using ohmmeter to test for contact making or breaking.
 - e. Check resistance temperature inputs at 0, 50, and 100 percent of span using a precision-resistant source.
5. Flow:
 - a. Set differential pressure flow transmitters for 0 and 100 percent values with 3-point calibration accomplished at 50, 90, and 100 percent of span.
 - b. Manually operate flow switches to verify that they make or break contact.
6. Pressure:
 - a. Calibrate pressure transmitters at 0, 50, and 100 percent of span.
 - b. Calibrate pressure switches to make or break contacts, with adjustable differential set at minimum.
7. Temperature:
 - a. Calibrate resistance temperature transmitters at 0, 50, and 100 percent of span using a precision-resistance source.
 - b. Calibrate temperature switches to make or break contacts.
8. Stroke and adjust control valves and dampers without positioners, following the manufacturer's recommended procedure, so that valve or damper is 100 percent open and closed.
9. Stroke and adjust control valves and dampers with positioners, following manufacturer's recommended procedure, so that valve and damper is 0, 50, and 100 percent closed.
10. Provide diagnostic and test instruments for calibration and adjustment of system.

11. Provide written description of procedures and equipment for calibrating each type of instrument. Submit procedures review and approval before initiating startup procedures.
- B. Adjust initial temperature and humidity set points.
- C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to three visits to Project during other than normal occupancy hours for this purpose.

3.6 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15921

ELECTRIC-DRIVE, CENTRIFUGAL FIRE

PUMPS PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:

1. End-suction fire pumps.
2. In-line fire pumps (pressure maintenance jockey pumps).
3. Horizontally-mounted, single-stage split case fire pumps.
4. Horizontally-mounted, multi-stage split case fire pumps.
5. Vertically-mounted, single-stage split case fire pumps.
6. Fire-pump accessories and specialties.
7. Flowmeter systems.

- B. Related Sections:

1. Section 15930 "Wet-Pipe Fire-Suppression Sprinklers"
2. Section 15935 "Dry-Pipe Fire-Suppression Sprinklers"
3. Section 15974 "Fire-Suppression Standpipes"
4. Section 15976 "Fire-Department Connections"

1.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Fire pumps shall withstand the effects of earthquake motions determined according to ASCE/SEI 7 and NFPA 20.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

- B. Pump Equipment, Accessory, and Specialty Pressure Rating: 175 psig minimum unless higher pressure rating is indicated.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, performance curves, electrical characteristics, and furnished specialties and accessories.

- B. Shop Drawings: For fire pumps, motor drivers, and fire-pump accessories and specialties. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.

1.5 INFORMATIONAL SUBMITTALS

- A. Seismic Qualification Certificates: For fire pumps, accessories, and components, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- B. Product Certificates: For each fire pump, from manufacturer.
- C. Source quality-control reports.
- D. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fire pumps to include in operation and maintenance manuals.
- B. As-Built Drawings
- C. Acceptance Testing and Inspection Documentation

1.7 QUALITY ASSURANCE

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. NFPA Compliance: Comply with NFPA 20, "Installation of Stationary Pumps for Fire Protection."

1.8 COORDINATION

- A. Coordinate sizes and locations of concrete bases with actual equipment provided.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR CENTRIFUGAL FIRE PUMPS

- A. Description: Factory-assembled and -tested fire-pump and driver unit.

- B. Base: Fabricated and attached to fire-pump and driver unit with reinforcement to resist movement of pump during seismic events when base is anchored to building substrate.
- C. Finish: Red paint applied to factory-assembled and -tested unit before shipping.

2.2 END-SUCTION FIRE PUMPS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. A-C Fire Pump Systems; a business of ITT Industries.
 - 2. Corcoran Piping System Co.
 - 3. Patterson Pump Company; a subsidiary of the Gorman-Rupp Company.
 - 4. Peerless Pump, Inc.
 - 5. Pentair Pump Group; Aurora Pump.
 - 6. Pentair Pump Group; Fairbanks Morse.
 - 7. Plad Equipment, Ltd.
 - 8. Reddy-Buffaloes Pump Company.
 - 9. S.A. Armstrong Limited.
- B. Pump:
 - 1. Standard: UL 448, for end-suction pumps for fire service.
 - 2. Casing: Radially split case, top centerline discharge, self-venting, cast iron, with ASME B16.1 pipe-flange connections.
 - 3. Impeller: Cast bronze, statically and dynamically balanced, and keyed to shaft.
 - 4. Wear Rings: Replaceable bronze.
 - 5. Shaft and Sleeve: Steel shaft with stainless-steel sleeves.
 - a. Shaft Bearings: Grease-lubricated, back-to-back thrust ball bearings and one radial roller bearing.
 - b. Seals: Stuffing box with minimum of four rings of graphite-impregnated braided yarn and bronze packing gland.
 - 6. Mounting: Back pullout design, allowing complete rotating assembly removal without disturbing the casing piping connections. Pump and driver shafts are horizontal, with pump and driver on same base.
- C. Coupling: Flexible and capable of absorbing torsional vibration and shaft misalignment. Include metal coupling guard.
- D. Driver:
 - 1. Standard: UL 1004A.
 - 2. Type: Electric motor; NEMA MG 1, polyphase Design B.

2.3 IN-LINE FIRE PUMPS (PRESSURE MAINTENANCE JOCKEY PUMPS)

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. A-C Fire Pump Systems; a business of ITT Industries.
2. Corcoran Piping System Co.
3. Patterson Pump Company; a subsidiary of the Gorman-Rupp Company.
4. Peerless Pump, Inc.
5. Pentair Pump Group; Aurora Pump.
6. Pentair Pump Group; Fairbanks Morse.
7. Plad Equipment, Ltd.
8. Reddy-Buffaloes Pump Company.
9. S.A. Armstrong Limited.

B. Pump:

1. Standard: UL 448, for in-line pumps for fire service.
2. Casing: Radially split case, cast iron, with ASME B16.1 pipe-flange connections.
3. Impeller: Cast bronze, statically and dynamically balanced, and keyed to shaft.
4. Wear Rings: Replaceable bronze.
5. Shaft and Sleeve: Steel shaft with bronze sleeve.
 - a. Shaft Bearings: Grease-lubricated ball bearings in cast-iron housing.
 - b. Seals: Stuffing box with minimum of four rings of graphite-impregnated braided yarn and bronze packing gland.
6. Mounting: Pump and driver shaft is vertical, with motor above pump and pump on base. Motor and pump rotating assembly shall be removable from top without removing the pump casing from the piping.

C. Coupling: None or rigid.

D. Driver:

1. Standard: UL 1004A.
2. Type: Electric motor; NEMA MG 1, polyphase Design B.

2.4 HORIZONTALLY MOUNTED, SINGLE-STAGE, SPLIT-CASE FIRE PUMPS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. A-C Fire Pump Systems; a business of ITT Industries.
2. Corcoran Piping System Co.
3. Patterson Pump Company; a subsidiary of the Gorman-Rupp Company.
4. Peerless Pump, Inc.
5. Pentair Pump Group; Aurora Pump.
6. Pentair Pump Group; Fairbanks Morse.
7. Plad Equipment, Ltd.
8. Reddy-Buffaloes Pump Company.
9. S.A. Armstrong Limited.

- B. Pump:
1. Standard: UL 448, for split-case pumps for fire service.
 2. Casing: Axially split case, cast iron, with ASME B16.1 pipe-flange connections.
 3. Impeller: Double suction, cast bronze, statically and dynamically balanced, and keyed to shaft.
 4. Wear Rings: Replaceable bronze.
 5. Shaft and Sleeve: Alloy steel shaft with bronze sleeve.
 - a. Shaft Bearings: Grease-lubricated ball bearings in cast-iron housing.
 - b. Seals: Stuffing box with minimum of four rings of graphite-impregnated braided yarn and bronze packing gland.
 6. Mounting: Pump and driver shafts are horizontal, with pump and driver on same base.
- C. Coupling: Flexible and capable of absorbing torsional vibration and shaft misalignment. Include metal coupling guard.
- D. Driver:
1. Standard: UL 1004A.
 2. Type: Electric motor; NEMA MG 1, polyphase Design B.

2.5 HORIZONTALLY MOUNTED, MULTISTAGE, SPLIT-CASE FIRE PUMPS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. A-C Fire Pump Systems; a business of ITT Industries.
 2. Corcoran Piping System Co.
 3. Patterson Pump Company; a subsidiary of the Gorman-Rupp Company.
 4. Peerless Pump, Inc.
 5. Pentair Pump Group; Aurora Pump.
 6. Pentair Pump Group; Fairbanks Morse.
 7. Plad Equipment, Ltd.
 8. Reddy-Buffaloes Pump Company.
 9. S.A. Armstrong Limited.
- B. Pump:
1. Standard: UL 448, for split-case pumps for fire service.
 2. Number of Stages: Two.
 3. Casing: Axially split case, cast iron with ASME B16.1 pipe-flange connections.
 4. Impeller: Single suction, cast bronze, statically and dynamically balanced, and keyed to shaft.
 5. Wear Rings: Replaceable bronze.
 6. Shaft and Sleeve: Alloy steel shaft with bronze sleeve.
 - a. Shaft Bearings: Grease-lubricated ball bearings in cast-iron housing.
 - b. Seals: Stuffing box with minimum of four rings of graphite-impregnated braided yarn and bronze packing gland.
 7. Mounting: Pump and driver shafts are horizontal, with pump and driver on same base.

- C. Coupling: Flexible and capable of absorbing torsional vibration and shaft misalignment. Include metal coupling guard.
- D. Driver:
 1. Standard: UL 1004A.
 2. Type: Electric motor; NEMA MG 1, polyphase Design B.

2.6 VERTICALLY MOUNTED, SINGLE-STAGE, SPLIT-CASE FIRE PUMPS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. A-C Fire Pump Systems; a business of ITT Industries.
 2. Corcoran Piping System Co.
 3. Patterson Pump Company; a subsidiary of the Gorman-Rupp Company.
 4. Peerless Pump, Inc.
 5. Pentair Pump Group; Aurora Pump.
 6. Pentair Pump Group; Fairbanks Morse.
 7. Plad Equipment, Ltd.
 8. Reddy-Buffaloes Pump Company.
 9. S.A. Armstrong Limited.
- B. Pump:
 1. Standard: UL 448, for split-case pumps for fire service.
 2. Casing: Axially split case, cast iron, with ASME B16.1 pipe-flange connections.
 3. Impeller: Double suction, cast bronze, statically and dynamically balanced, and keyed to shaft.
 4. Wear Rings: Replaceable bronze.
 5. Shaft and Sleeve: Alloy steel shaft with bronze sleeve.
 - a. Shaft Bearings: Grease-lubricated ball bearings in cast-iron housing.
 - b. Seals: Stuffing box with minimum of four rings of graphite-impregnated braided yarn and bronze packing gland.
 6. Mounting: Pump and driver shafts are vertical, with motor above pump and pump on base.
- C. Coupling: Flexible and capable of absorbing torsional vibration and shaft misalignment. Include metal coupling guard.
- D. Driver:
 1. Standard: UL 1004A.
 2. Type: Electric motor; NEMA MG 1, polyphase Design B.

2.7 FIRE-PUMP ACCESSORIES AND SPECIALTIES

- A. Automatic Air-Release Valves: Comply with NFPA 20 for installation in fire-pump casing.
- B. Circulation Relief Valves: UL 1478, brass, spring loaded; for installation in pump discharge piping.

C. Relief Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. BERMAD Control Valves.
 - b. CLA-VAL Automatic Control Valves.
 - c. Kunkle Valve; a part of Tyco International Ltd.
 - d. OCV Control Valves.
 - e. Watts Regulator Company; a division of Watts Water Technologies, Inc.
 - f. Zurn Plumbing Products Group; Wilkins Water Control Products.
2. Description: UL 1478, bronze or cast iron, spring loaded; for installation in fire-suppression water-supply piping.

D. Inlet Fitting: Eccentric tapered reducer at pump suction inlet.

E. Outlet Fitting: Concentric tapered reducer at pump discharge outlet.

F. Discharge Cone: Open type.

G. Hose Valve Manifold Assembly:

3. Standard: Comply with requirements in NFPA 20.
4. Header Pipe: ASTM A 53/A 53M, Schedule 40, galvanized steel with ends threaded according to ASME B1.20.1.
5. Header Pipe Fittings: ASME B16.4, galvanized cast-iron threaded fittings.
6. Automatic Drain Valve: UL 1726.
7. Manifold:
 - a. Test Connections: Comply with UL 405 except provide outlets without clappers instead of inlets.
 - b. Body: Flush type, chrome, with number of outlets required by NFPA 20.
 - c. Nipples: ASTM A 53/A 53M, Schedule 40, galvanized-steel pipe with ends threaded according to ASME B1.20.1.
 - d. Adapters and Caps with Chain: chrome, with outlet threaded according to NFPA 1963 and matching local fire-department threads.
 - e. Escutcheon Plate: chrome; rectangular.
 - f. Hose Valves: UL 668, bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads.
 - g. Exposed Parts Finish: chrome.
 - h. Escutcheon Plate Marking: Equivalent to "FIRE PUMP TEST."

2.8 FLOWMETER SYSTEMS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Emerson Process Management; Rosemount Division.
 - 2. Fire Research Corp.
 - 3. Gerand Engineering Co.
 - 4. Hydro Flow Products, Inc.
 - 5. Hyspan Precision Products, Inc.
 - 6. Meriam Process Technologies.
 - 7. Preso Meters; Division of Racine Federated Inc.
 - 8. Reddy-Buffaloes Pump Company.
 - 9. Victaulic Company.
- B. Description: UL-listed or FM-Approved, fire-pump flowmeter system with capability to indicate flow to not less than 175 percent of fire-pump rated capacity.
- C. Pressure Rating: 175 psig minimum.
- D. Sensor: Annubar probe, orifice plate, or Venturi unless otherwise indicated. Sensor size shall match pipe, tubing, flowmeter, and fittings.
- E. Permanently Mounted Flowmeter: Compatible with flow sensor; with dial not less than 4-1/2 inches in diameter. Include bracket or device for wall mounting.
 - 1. Tubing Package: NPS 1/8 or NPS 1/4 soft copper tubing with copper or brass fittings and valves.

2.9 GROUT

- A. Standard: ASTM C 1107, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- B. Characteristics: Nonshrink and recommended for interior and exterior applications.
- C. Design Mix: 5000-psi, 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

2.10 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect fire pumps according to UL 448 requirements for "Operation Test" and "Manufacturing and Production Tests."
 - 1. Verification of Performance: Rate fire pumps according to UL 448.
- B. Fire pumps will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine equipment bases and anchorage provisions, with Installer present, for compliance with requirements and for conditions affecting performance of fire pumps.
- B. Examine roughing-in for fire-suppression piping systems to verify actual locations of piping connections before fire-pump installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Fire-Pump Installation Standard: Comply with NFPA 20 for installation of fire pumps, relief valves, and related components.
- B. Equipment Mounting:
 - 1. Install fire pumps on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 03300 "Cast-in-Place Concrete."
 - 2. Comply with requirements for vibration isolation and seismic control devices specified in Section 15074 "Vibration and Seismic Controls for Piping and Equipment."
- C. Install fire-pump suction and discharge piping equal to or larger than sizes required by NFPA 20.
- D. Support piping and pumps separately so weight of piping does not rest on pumps.
- E. Install valves that are same size as connecting piping. Comply with requirements for fire-protection valves specified in Section 15974 "Fire-Suppression Standpipes," Section 15930 "Wet-Pipe Fire-Suppression Sprinklers," and Section 15935 "Dry-Pipe Fire-Suppression Sprinklers."
- F. Install pressure gages on fire-pump suction and discharge flange pressure-gage tappings. Comply with requirements for pressure gages specified in Section 15974 "Fire-Suppression Standpipes," Section 15930 "Wet-Pipe Fire-Suppression Sprinklers," and Section 15935 "Dry-Pipe Fire-Suppression Sprinklers."
- G. Install piping hangers and supports, anchors, valves, gages, and equipment supports according to NFPA 20.
- H. Install flowmeters and sensors. Install flowmeter-system components and make connections according to NFPA 20 and manufacturer's written instructions.
- I. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not factory mounted. Furnish copies of manufacturers' wiring diagram submittals to electrical Installer.
- J. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.

3.3 ALIGNMENT

- A. Align split-case pump and driver shafts after complete unit has been leveled on concrete base, grout has set, and anchor bolts have been tightened.
- B. After alignment is correct, tighten anchor bolts evenly. Fill baseplate completely with grout, with metal blocks and shims or wedges in place. Tighten anchor bolts after grout has hardened. Check alignment and make required corrections.
- C. Align piping connections.
- D. Align pump and driver shafts for angular and parallel alignment according to HI 1.4 and to tolerances specified by manufacturer.

3.4 CONNECTIONS

- A. Comply with requirements for piping and valves specified in Section 15974 "Fire-Suppression Standpipes," Section 15930 "Wet-Pipe Fire-Suppression Sprinklers," and Section 15935 "Dry-Pipe Fire-Suppression Sprinklers." Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Install piping adjacent to pumps and equipment to allow service and maintenance.
- C. Connect relief-valve discharge to drainage piping or point of discharge.
- D. Connect flowmeter-system meters, sensors, and valves to tubing.
- E. Connect fire pumps to their controllers.

3.5 IDENTIFICATION

- A. Identify system components. Comply with requirements for fire-pump marking according to NFPA 20.

3.6 FIELD QUALITY CONTROL

- A. Test each fire pump with its controller as a unit. Comply with requirements for electric-motor-driver fire-pump controllers specified in Section 15929 "Controllers for Fire-Pump Drivers."
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Tests and Inspections:
 - 1. After installing components, assemblies, and equipment including controller, test for compliance with requirements.

2. Test according to NFPA 20 for acceptance and performance testing.
 3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 4. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- E. Components, assemblies, and equipment will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.
- G. Furnish fire hoses in number, size, and length required to reach storm drain or other acceptable location to dispose of fire-pump test water. Hoses are for tests only and do not convey to MBTA.

3.7 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
1. Complete installation and startup checks according to manufacturer's written instructions.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain fire pumps.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15929

CONTROLLERS FOR FIRE-PUMP DRIVERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Full-service, full-voltage controllers rated 600 V and less.
 - 2. Controllers for pressure-maintenance pumps.

1.3 DEFINITIONS

- A. ATS: Automatic transfer switch(es).
- B. ECM: Electronic control module.
- C. MCCB: Molded-case circuit breaker.
- D. N.O.: Normally open.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Fire-pump controllers and alarm panels shall withstand the effects of earthquake motions determined according to ASCE/SEI 7 and NFPA 20.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Shop Drawings: For each type of product indicated. Include dimensioned plans, elevations, sections, details, and attachments to other work, including required clearances and service spaces around controller enclosures.
 - 1. Show tabulations of the following:

- a. Each installed unit's type and details.
 - b. Enclosure types and details for types other than NEMA 250, Type 2.
 - c. Factory-installed devices.
 - d. Nameplate legends.
 - e. Short-circuit current (withstand) rating of integrated unit.
 - f. Features, characteristics, ratings, and factory settings of individual overcurrent protective devices.
 - g. Specified modifications.
2. Detail equipment assemblies and indicate dimensions, weights, loads, method of field assembly, components, and location and size of each field connection.
 3. Schematic and Connection Diagrams: For power, signal, alarm, and control wiring and for pressure-sensing tubing.

1.6 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified testing agency.
- B. Seismic Qualification Certificates: For each type of product indicated, from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Product Certificates: For each type of product indicated, from manufacturer.
- D. Manufacturer's factory test reports of fully assembled and tested equipment.
- E. Source quality-control reports.
- F. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of product indicated to include in emergency, operation, and maintenance manuals. Include the following:
 1. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
 2. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor-based logic controls.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Indicating Lights: Two of each type and color of lens installed; two of each type and size of lamp installed.
2. Auxiliary Contacts: One for each size and type of magnetic contactor installed.
3. Power Contacts: Three for each size and type of magnetic contactor installed.
4. Contactor Coils: One for each size and type of magnetic controller installed.
5. Relay Boards: One for each size and type of relay board installed.
6. Operator Interface: One microprocessor board(s), complete with display and membrane keypad.

1.9 QUALITY ASSURANCE

- A. Testing Agency Qualifications: Member company of an NRTL.
- B. Source Limitations: Obtain fire-pump controllers and all associated equipment from single source or producer.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. Comply with standards of authorities having jurisdiction pertaining to materials and installation.
- E. Comply with NFPA 20 and NFPA 70.
- F. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS."

1.10 DELIVERY, STORAGE, AND HANDLING

- A. Store controllers indoors in clean, dry space with uniform temperature to prevent condensation. Protect enclosed controllers from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- B. If stored in areas subject to weather, protect controllers from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside controllers; install temporary electric heating, with at least 250 W per controller.

1.11 PROJECT CONDITIONS

- A. Environmental Limitations:
 1. Ambient Temperature Rating: Not less than 40 deg F and not exceeding 122 deg F unless otherwise indicated.
 2. Altitude Rating: Not exceeding 6600 feet unless otherwise indicated.
- B. Interruption of Existing Electric Service: Notify MBTA no fewer than seven days in advance of proposed interruption of electric service, and comply with NFPA 70E.

1.12 COORDINATION

- A. Coordinate layout and installation of controllers with other construction including conduit, piping, fire-pump equipment, and adjacent surfaces. Maintain required clearances for workspace and equipment access doors and panels. Ensure that controllers are within sight of fire-pump drivers.
- B. Coordinate sizes and locations of concrete bases with actual equipment provided.

PART 2 - PRODUCTS

2.1 FULL-SERVICE CONTROLLERS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Aquarius Fluid Products, Inc.
 - 2. ASCO Power Technologies, LP; Firetrol Products.
 - 3. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - 4. Hubbell Incorporated; Hubbell Industrial Controls.
 - 5. Joslyn Clark Corporation.
 - 6. Master Control Systems, Inc.
 - 7. Metron, Inc.
 - 8. Tornatech.
- B. General Requirements for Full-Service Controllers:
 - 1. Comply with NFPA 20 and UL 218.
 - 2. Listed by an NRTL for electric-motor driver for fire-pump service.
 - 3. Combined automatic and nonautomatic operation.
 - 4. Factory assembled, wired, and tested; continuous-duty rated.
 - 5. Service Equipment Label: NRTL labeled for use as service equipment.
- C. Method of Starting:
 - 1. Pressure-switch actuated.
 - a. Water-pressure-actuated switch and pressure transducer with independent high- and low-calibrated adjustments responsive to water pressure in fire-suppression piping.
 - b. System pressure recorder, electric ac driven, with spring backup.
 - c. Programmable minimum-run-time relay to prevent short cycling.
 - d. Programmable timer for weekly tests.
 - 2. Magnetic Controller: Across-the-line type.
 - 3. Emergency Start: Mechanically operated start handle that closes and retains the motor RUN contactor independent of all electric or pressure actuators.
- D. Method of Stopping: Nonautomatic.
- E. Capacity: Rated for fire-pump-driver horsepower and short-circuit-current (withstand) rating equal to or greater than short-circuit current available at controller location.

- F. Method of Isolation and Overcurrent Protection: Interlocked isolating switch and nonthermal MCCB; with a common, externally mounted operating handle, and providing locked-rotor protection.
- G. Door-Mounted Operator Interface and Controls:
 - 1. Monitor, display, and control the devices, alarms, functions, and operations listed in NFPA 20 as required for drivers and controller types used.
 - 2. Method of Control and Indication:
 - a. Microprocessor-based logic controller, with multiline digital readout.
 - b. Membrane keypad.
 - c. LED alarm and status indicating lights.
 - 3. Local and Remote Alarm and Status Indications:
 - a. Controller power on.
 - b. Motor running condition.
 - c. Loss-of-line power.
 - d. Line-power phase reversal.
 - e. Line-power single-phase condition.
 - 4. Audible alarm, with silence push button.
 - 5. Nonautomatic START and STOP push buttons or switches.
- H. Optional Features:
 - 1. Extra Output Contacts:
 - a. One N.O. contact(s) for motor running condition.
 - b. One set(s) of contacts for loss-of-line power.
 - c. One set(s) of contracts for phase reversal.
 - 2. Local alarm bell.
 - 3. Door-mounted thermal or impact printer for alarm and status logs.
 - 4. Operator Interface Communications Ports: USB and/or Ethernet.
- I. ATS:
 - 1. Complies with NFPA 20, UL 218, and UL 1008.
 - 2. Integral with controller as a listed combination fire-pump controller and power transfer switch.
 - 3. Automatically transfers fire-pump controller from normal power supply to alternate power supply in event of power failure.
 - 4. Allows manual transfer from one source to the other.
 - 5. Alternate-Source Isolating and Disconnecting Means: Integral molded-case switch, with an externally mounted operating handle.
 - 6. Alternate-Source Isolating and Disconnecting Means: Mechanically interlocked isolation switch and circuit breaker rated at a minimum of 115 percent of rated motor full-load current, with an

externally mounted operating handle; circuit breaker shall be provided with nonthermal sensing, instantaneous-only short-circuit overcurrent protection to comply with available fault currents.

7. Local and Remote Alarm and Status Indications:
 - a. Normal source available.
 - b. Alternate source available.
 - c. In normal position.
 - d. In alternate position.
 - e. Isolating means open.
8. Audible alarm, with silence push button.
9. Nonautomatic (manual, nonelectric) means of transfer.
10. Engine test push button.
11. Start generator output contacts.
12. Timer for weekly generator tests.

2.2 CONTROLLERS FOR PRESSURE-MAINTENANCE PUMPS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. Aquarius Fluid Products, Inc.
 2. ASCO Power Technologies, LP; Firetrol Products.
 3. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 4. Hubbell Incorporated; Hubbell Industrial Controls.
 5. Joslyn Clark Corporation.
 6. Master Control Systems, Inc.
 7. Metron, Inc.
 8. Tornatech.
- B. General Requirements for Pressure-Maintenance-Pump Controllers:
 1. Type: UL 508 factory assembled, -wired, and tested, across-the-line; for combined automatic and manual operation.
 2. Enclosure: UL 508 and NEMA 250, Type 2 for wall-mounting.
 3. Factory assembled, wired, and tested.
 4. Finish: Manufacturer's standard color paint.
- C. Rate controller for scheduled horsepower and include the following:
 1. Fusible disconnect switch.
 2. Pressure switch.
 3. Hand-off-auto selector switch.
 4. Pilot light.
 5. Running period timer.

2.3 ENCLOSURES

- A. Fire-Pump Controllers, ATS, and Remote Alarm Panels: NEMA 250, to comply with environmental conditions at installed locations and NFPA 20.

1. Indoor, Dry and Clean Locations: Type 1 (IEC IP10).
 2. Indoor Locations Subject to Dripping Noncorrosive Liquids: Type 2 (IEC IP11).
 3. Outdoor Locations: Type 4X (IEC IP56).
 4. Other Wet or Damp, Indoor Locations: Type 4X (IEC IP56).
 5. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12 (IEC IP12).
- B. Enclosure Color: Manufacturer's standard "fire-pump-controller red".
- C. Nameplates: Comply with NFPA 20; complete with capacity, characteristics, approvals, listings, and other pertinent data.
- D. Optional Features:
1. Floor stands, 12 inches high, for floor-mounted controllers.
 2. Space heater, 240-V ac , with thermostat.
 3. Tropicalization.

2.4 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect fire-pump controllers according to requirements in NFPA 20 and UL 218.
1. Verification of Performance: Rate controllers according to operation of functions and features specified.
- B. Fire-pump controllers will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and surfaces to receive equipment, with Installer present, for compliance with requirements and other conditions affecting performance.
- B. Examine equipment before installation. Reject equipment that is wet or damaged by moisture or mold.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CONTROLLER INSTALLATION

- A. Install controllers within sight of their respective drivers.
- B. Connect controllers to their dedicated pressure-sensing lines.
- C. Wall-Mounting Controllers: Install controllers on walls with disconnect operating handles not higher than 79 inches above finished floor, and bottom of enclosure not less than 12 inches above finished floor unless otherwise indicated. Bolt units to wall or mount on lightweight structural-steel channels

bolted to wall. For controllers not on walls, provide freestanding racks complying with Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

- D. Floor-Mounting Controllers: Install controllers on 4-inch nominal-thickness concrete bases, using floor stands high enough so that the bottom of enclosure cabinet is not less than 12 inches above finished floor. Comply with requirements for concrete bases specified in Section 03300 "CAST-IN-PLACE CONCRETE."
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- E. Seismic Bracing: Comply with requirements specified in Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS."
- F. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
- G. Comply with NEMA ICS 15.

3.3 POWER WIRING INSTALLATION

- A. Install power wiring between controllers and their services or sources, and between controllers and their drivers. Comply with requirements in NFPA 20, NFPA 70, and Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
- B. Comply with NECA 1.

3.4 CONTROL AND ALARM WIRING INSTALLATION

- A. Install wiring between controllers and the building's fire-alarm system. Comply with requirements specified in Section 16705 "STATION FIRE-ALARM SYSTEM".
- B. Bundle, train, and support wiring in enclosures.
- C. Connect remote manual and automatic activation devices where applicable.

3.5 IDENTIFICATION

- A. Comply with requirements in NFPA 20 for marking fire-pump controllers.
- B. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification in NFPA 20 and as specified in Section 16195 "ELECTRICAL IDENTIFICATION."

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Acceptance Testing Preparation:
 - 1. Inspect and Test Each Component:
 - a. Inspect wiring, components, connections, and equipment installations. Test and adjust components and equipment.
 - b. Test insulation resistance for each element, component, connecting supply, feeder, and control circuits.
 - c. Test continuity of each circuit.
 - 2. Verify and Test Each Electric-Driver Controller:
 - a. Verify that voltages at controller locations are within plus 10 or minus 1 percent of motor nameplate rated voltages, with motors off. If outside this range for any motor, notify MBTA before starting the motor(s).
 - b. Test each motor for proper phase rotation.
 - 3. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- E. Field Acceptance Tests:
 - 1. Do not begin field acceptance testing until suction piping has been flushed and hydrostatically tested and the certificate for flushing and testing has been submitted to MBTA and authorities having jurisdiction.
 - 2. Prior to starting, notify authorities having jurisdiction of the time and place of the acceptance testing.
 - 3. Engage manufacturer's factory-authorized service representative to be present during the testing.
 - 4. Perform field acceptance tests as outlined in NFPA 20.
- F. Controllers will be considered defective if they do not pass tests and inspections.

- G. Prepare test and inspection reports.

3.7 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.

3.8 ADJUSTING

- A. Adjust controllers to function smoothly and as recommended by manufacturer.
- B. Set field-adjustable switches, auxiliary relays, time-delay relays, and timers.
- C. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.
- D. Set field-adjustable pressure switches.

3.9 PROTECTION

- A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until enclosed controllers are ready to be energized and placed into service.
- B. Replace controllers whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain controllers, remote alarm panels, and to use and reprogram microprocessor-based controls within this equipment.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15930

WET-PIPE FIRE-SUPPRESSION SPRINKLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:

1. Pipes, fittings, and specialties.
2. Fire-protection valves.
3. Sprinklers.
4. Alarm devices.
5. Pressure gages.

- B. Related Sections:

1. Section 15921 "ELECTRIC-DRIVE, CENTRIFUGAL FIRE PUMPS" for fire pumps, pressure-maintenance pumps, and fire-pump controllers.
2. Section 15935 "DRY-PIPE FIRE-SUPPRESSION SPRINKLERS" for dry-pipe sprinkler piping.
3. Section 15974 "FIRE-SUPPRESSION STANDPIPES" for standpipe piping.
4. Section 15976 "FIRE-DEPARTMENT CONNECTIONS" for exposed-, flush-, and yard-type fire-department connections.

1.3 DEFINITIONS

- A. High-Pressure Sprinkler Piping: Wet-pipe sprinkler system piping designed to operate at working pressure higher than standard 175 psig, but not higher than 300 psig.
- B. Standard-Pressure Sprinkler Piping: Wet-pipe sprinkler system piping designed to operate at working pressure of 175 psig maximum.

1.4 SYSTEM DESCRIPTIONS

- A. Wet-Pipe Sprinkler System: Automatic sprinklers are attached to piping containing water and that is connected to water supply through alarm valve. Water discharges immediately from sprinklers when they are opened. Sprinklers open when heat melts fusible link or destroys frangible device. Hose connections are included if indicated.

1.5 PERFORMANCE REQUIREMENTS

- A. Standard-Pressure Piping System Component: Listed for 175-psig minimum working pressure.
- B. High-Pressure Piping System Component: Listed for 300-psig working pressure.
- C. Delegated Design: Design sprinkler system(s), including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
 - 1. Contractor shall obtain hydrant flow data from the local water authority. Test shall have been performed within the last 12 months.
- D. Sprinkler system design shall be approved by authorities having jurisdiction.
 - 1. Margin of Safety for Available Water Flow and Pressure: 10 percent, including losses through water-service piping, valves, and backflow preventers.
 - 2. Sprinkler Occupancy Hazard Classifications:
 - a. Ordinary Hazard Group I
 - b. Additional Hazard Groups applicable to the final structure.
 - 3. Minimum Density for Automatic-Sprinkler Piping Design:
 - a. 0.15 gpm over 1,500 sqft.
 - 4. Maximum Protection Area per Sprinkler:
 - a. 130 sqft.
 - 5. Total Combined Hose-Stream Demand Requirement: According to NFPA 13 unless otherwise indicated:
 - a. 250 gpm for 60 minutes.
- E. Seismic Performance: Sprinkler piping shall withstand the effects of earthquake motions determined according to NFPA 13 and ASCE/SEI 7.

1.6 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Shop Drawings: For wet-pipe sprinkler systems. Include plans, elevations, sections, details, and attachments to other work.
 - 1. Wiring Diagrams: For power, signal, and control wiring.
- C. Delegated-Design Submittal: For sprinkler systems indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

- D. Coordination Drawings: Sprinkler systems, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Domestic water piping.
 - 2. Compressed air piping.
 - 3. HVAC hydronic piping.
 - 4. Items penetrating finished ceiling include the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 - 5. Architectural elements
 - 6. Structural elements
- E. Qualification Data: For qualified Installer and professional engineer.
- F. Approved Sprinkler Piping Drawings: Working plans, prepared according to NFPA 13, that have been approved by authorities having jurisdiction, including hydraulic calculations.
- G. Welding certificates.
- H. Fire-hydrant flow test report.
- I. Field Test Reports and Certificates: Indicate and interpret test results for compliance with performance requirements and as described in NFPA 13. Include "Contractor's Material and Test Certificate for Aboveground Piping."
- J. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sprinkler specialties to include in emergency, operation, and maintenance manuals.
- B. As-Built Record Drawings: Update shop drawings to include all changes made during installation to provide as-built record drawings of all piping, equipment and systems installed.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Sprinkler Cabinets: Finished, wall-mounted, steel cabinet with hinged cover, and with space for minimum of six spare sprinklers plus sprinkler wrench. Include number of sprinklers required by NFPA 13 and sprinkler wrench. Include separate cabinet with sprinklers and wrench for each type of sprinkler used on Project.

1.9 QUALITY ASSURANCE

- A. Installer Qualifications:

1. Installer's responsibilities include designing, fabricating, and installing sprinkler systems and providing professional engineering services needed to assume engineering responsibility. Base calculations on results of fire-hydrant flow test.
 - a. Engineering Responsibility: Preparation of working plans, calculations, and field test reports by a NICET Level III certified individual and signed and sealed by a qualified professional engineer.
- B. Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. NFPA Standards: Sprinkler system equipment, specialties, accessories, installation, and testing shall comply with the following:
 1. NFPA 13, "Installation of Sprinkler Systems."
 2. NFPA 24, "Installation of Private Fire Service Mains and Their Appurtenances."

1.10 PROJECT CONDITIONS

- A. Interruption of Existing Sprinkler Service: Do not interrupt sprinkler service to facilities occupied by MBTA or others unless permitted under the following conditions and then only after arranging to provide temporary sprinkler service according to requirements indicated:
 1. Notify MBTA no fewer than seven days in advance of proposed interruption of sprinkler service.
 2. Do not proceed with interruption of sprinkler service without MBTA's written permission.

1.11 COORDINATION

- A. Coordinate layout and installation of sprinklers with other construction that penetrates ceilings, including light fixtures, HVAC equipment, and partition assemblies.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

- A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, and fitting materials, and for joining methods for specific services, service locations, and pipe sizes.

2.2 STEEL PIPE AND FITTINGS

- A. Schedule 40, Galvanized Steel Pipe: ASTM A 53/A 53M, Type E, Grade B. Pipe ends may be factory or field formed to match joining method.

- B. Galvanized-Steel Pipe Nipples: ASTM A 733, made of ASTM A 53/A 53M, standard-weight, seamless steel pipe with threaded ends.
- C. Galvanized, Steel Couplings: ASTM A 865, threaded.
- D. Galvanized, Gray-Iron Threaded Fittings: ASME B16.4, Class 125, standard pattern.
- E. Malleable- or Ductile-Iron Unions: UL 860.
- F. Cast-Iron Flanges: ASME 16.1, Class 125.
- G. Steel Flanges and Flanged Fittings: ASME B16.5, Class 150.
- H. Steel Welding Fittings: ASTM A 234/A 234M and ASME B16.9.
- I. Grooved-Joint, Steel-Pipe Appurtenances:
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Corcoran Piping System Co.
 - c. National Fittings, Inc.
 - d. Shurjoint Piping Products.
 - e. Tyco Fire & Building Products LP.
 - f. Victaulic Company.
 - 2. Pressure Rating: 175 psig minimum.
 - 3. Galvanized and Uncoated, Grooved-End Fittings for Steel Piping: ASTM A 47/A 47M, malleable-iron casting or ASTM A 536, ductile-iron casting; with dimensions matching steel pipe.
 - 4. Grooved-End-Pipe Couplings for Steel Piping: AWWA C606 and UL 213, rigid pattern, unless otherwise indicated, for steel-pipe dimensions. Include ferrous housing sections, EPDM-rubber gasket, and bolts and nuts.
- J. Steel Pressure-Seal Fittings: UL 213, FM-approved, 175-psig pressure rating with steel housing, rubber O-rings, and pipe stop; for use with fitting manufacturers' pressure-seal tools.
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following
 - a. Victaulic Company.

2.3 HIGH DENSITY POLY ETHYLENE (HDPE)

- A. HDPE Pipe: FM Approved, ASTM 3350-02 with cell classification of 34554642, Class 200.
- B. HDPE Fittings: FM Approved, ASTM 3350-02 with cell classification of 34554642, Class 200.

2.4 PIPING JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: AWWA C110, rubber, flat face, 1/8 inch thick or ASME B16.21, nonmetallic and asbestos free.
 - 1. Class 125, Cast-Iron Flanges and Class 150, Bronze Flat-Face Flanges: Full-face gaskets.
 - 2. Class 250, Cast-Iron Flanges and Class 300, Steel Raised-Face Flanges: Ring-type gaskets.
- B. Metal, Pipe-Flange Bolts and Nuts: ASME B18.2.1, carbon steel unless otherwise indicated.
- C. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for general-duty brazing unless otherwise indicated.
- D. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- E. Solvent Cements for Joining CPVC Piping and Tubing: ASTM F 493, solvent cement recommended by pipe and fitting manufacturer, and made for joining CPVC sprinkler pipe and fittings. Include cleaner or primer recommended by pipe and fitting manufacturer.
 - 1. Use solvent cement that has a VOC content of 490 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
 - 2. Use adhesive primer that has a VOC content of 650 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
- F. Plastic, Pipe-Flange Gasket, and Bolts and Nuts: Type and material recommended by piping system manufacturer unless otherwise indicated.

2.5 LISTED FIRE-PROTECTION VALVES

- A. General Requirements:
 - 1. Valves shall be UL listed or FM approved.
 - 2. Minimum Pressure Rating for Standard-Pressure Piping: 175 psig.
 - 3. Minimum Pressure Rating for High-Pressure Piping: 300 psig.
- B. Ball Valves:
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following
 - a. Anvil International, Inc.
 - b. Victaulic Company.
 - 2. Standard: UL 1091 except with ball instead of disc.
 - 3. Valves NPS 1-1/2 and Smaller: Bronze body with threaded ends.
 - 4. Valves NPS 2 and NPS 2-1/2: Bronze body with threaded ends or ductile-iron body with grooved ends.
 - 5. Valves NPS 3: Ductile-iron body with grooved ends.
- C. Bronze Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fivalco Inc.
 - b. Global Safety Products, Inc.
 - c. Milwaukee Valve Company.
2. Standard: UL 1091.
3. Pressure Rating: 175 psig.
4. Body Material: Bronze.
5. End Connections: Threaded.

D. Iron Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Fivalco Inc.
 - c. Global Safety Products, Inc.
 - d. Kennedy Valve; a division of McWane, Inc.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Pratt, Henry Company.
 - h. Shurjoint Piping Products.
 - i. Tyco Fire & Building Products LP.
 - j. Victaulic Company.
2. Standard: UL 1091.
3. Pressure Rating: 175 psig.
4. Body Material: Cast or ductile iron.
5. Style: Lug or wafer.
6. End Connections: Grooved.

E. Check Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AFAC Inc.
 - b. American Cast Iron Pipe Company; Waterous Company Subsidiary.
 - c. Anvil International, Inc.
 - d. Clow Valve Company; a division of McWane, Inc.
 - e. Crane Co.; Crane Valve Group; Crane Valves.
 - f. Crane Co.; Crane Valve Group; Jenkins Valves.
 - g. Crane Co.; Crane Valve Group; Stockham Division.
 - h. Fire-End & Croker Corporation.
 - i. Fire Protection Products, Inc.
 - j. Fivalco Inc.
 - k. Globe Fire Sprinkler Corporation.
 - l. Groeniger & Company.
 - m. Kennedy Valve; a division of McWane, Inc.
 - n. Matco-Norca.

- o. Metraflex, Inc.
- p. Milwaukee Valve Company.
- q. Mueller Co.; Water Products Division.
- r. NIBCO INC.
- s. Potter Roemer.
- t. Reliable Automatic Sprinkler Co., Inc.
- u. Shurjoint Piping Products.
- v. Tyco Fire & Building Products LP.
- w. United Brass Works, Inc.
- x. Venus Fire Protection Ltd.
- y. Victaulic Company.
- z. Viking Corporation.
- aa. Watts Water Technologies, Inc.

- 2. Standard: UL 312.
- 3. Pressure Rating: 250 psig minimum.
- 4. Type: Swing check.
- 5. Body Material: Cast iron.
- 6. End Connections: Flanged or grooved.

F. Bronze OS&Y Gate Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Stockham Division.
 - c. Milwaukee Valve Company.
 - d. NIBCO INC.
 - e. United Brass Works, Inc.
- 2. Standard: UL 262.
- 3. Pressure Rating: 175 psig.
- 4. Body Material: Bronze.
- 5. End Connections: Threaded.

G. Iron OS&Y Gate Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. American Cast Iron Pipe Company; Waterous Company Subsidiary.
 - b. American Valve, Inc.
 - c. Clow Valve Company; a division of McWane, Inc.
 - d. Crane Co.; Crane Valve Group; Crane Valves.
 - e. Crane Co.; Crane Valve Group; Jenkins Valves.
 - f. Crane Co.; Crane Valve Group; Stockham Division.
 - g. Hammond Valve.
 - h. Milwaukee Valve Company.
 - i. Mueller Co.; Water Products Division.
 - j. NIBCO INC.
 - k. Shurjoint Piping Products.
 - l. Tyco Fire & Building Products LP.

- m. United Brass Works, Inc.
 - n. Watts Water Technologies, Inc.
2. Standard: UL 262.
 3. Pressure Rating: 250 psig minimum.
 4. Body Material: Cast or ductile iron.
 5. End Connections: Flanged or grooved.

H. Indicating-Type Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Fivalco Inc.
 - c. Global Safety Products, Inc.
 - d. Kennedy Valve; a division of McWane, Inc.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Shurjoint Piping Products.
 - h. Tyco Fire & Building Products LP.
 - i. Victaulic Company.
2. Standard: UL 1091.
3. Pressure Rating: 175 psig minimum.
4. Valves NPS 2 and Smaller:
 - a. Valve Type: Ball or butterfly.
 - b. Body Material: Bronze.
 - c. End Connections: Threaded.
5. Valves NPS 2-1/2 and Larger:
 - a. Valve Type: Butterfly.
 - b. Body Material: Cast or ductile iron.
 - c. End Connections: Flanged, grooved, or wafer.
6. Valve Operation: Integral electrical, 115-V ac, prewired, single-circuit, supervisory switch indicating device.

2.6 TRIM AND DRAIN VALVES

A. General Requirements:

1. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
2. Pressure Rating: 175 psig minimum.

B. Angle Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

- a. Fire Protection Products, Inc.
- b. United Brass Works, Inc.

C. Ball Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Affiliated Distributors.
 - b. Anvil International, Inc.
 - c. Barnett.
 - d. Conbraco Industries, Inc.; Apollo Valves.
 - e. Fire-End & Croker Corporation.
 - f. Fire Protection Products, Inc.
 - g. Flowserve.
 - h. FNW.
 - i. Jomar International, Ltd.
 - j. Kennedy Valve; a division of McWane, Inc.
 - k. Kitz Corporation.
 - l. Legend Valve.
 - m. Metso Automation USA Inc.
 - n. Milwaukee Valve Company.
 - o. NIBCO INC.
 - p. Potter Roemer.
 - q. Red-White Valve Corporation.
 - r. Southern Manufacturing Group.
 - s. Stewart, M. A. and Sons Ltd.
 - t. Tyco Fire & Building Products LP.
 - u. Victaulic Company.
 - v. Watts Water Technologies, Inc.

D. Globe Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire Protection Products, Inc.
 - b. United Brass Works, Inc.

E. Plug Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Southern Manufacturing Group.

2.7 SPECIALTY VALVES

A. General Requirements:

- 1. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.

2. Pressure Rating:
 - a. Standard-Pressure Piping Specialty Valves: 175 psig minimum.
 - b. High-Pressure Piping Specialty Valves: 300 psig.
 3. Body Material: Cast or ductile iron.
 4. Size: Same as connected piping.
 5. End Connections: Flanged or grooved.
- B. Alarm Valves:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
 - c. Victaulic Company.
 - d. Viking Corporation.
 2. Standard: UL 193.
 3. Design: For horizontal or vertical installation.
 4. Include trim sets for bypass, drain, electrical sprinkler alarm switch, pressure gages, and fill-line attachment with strainer.
 5. Drip Cup Assembly: Pipe drain without valves and separate from main drain piping.
 6. Drip Cup Assembly: Pipe drain with check valve to main drain piping.
- C. Automatic (Ball Drip) Drain Valves:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
 2. Standard: UL 1726.
 3. Pressure Rating: 175 psig minimum.
 4. Type: Automatic draining, ball check.
 5. Size: NPS 3/4.
 6. End Connections: Threaded.

2.8 SPRINKLER SPECIALTY PIPE FITTINGS

- A. Branch Outlet Fittings:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. National Fittings, Inc.
 - c. Shurjoint Piping Products.
 - d. Tyco Fire & Building Products LP.
 - e. Victaulic Company.
 2. Standard: UL 213.

3. Pressure Rating: 175 psig minimum.
4. Body Material: Ductile-iron housing with EPDM seals and bolts and nuts.
5. Type: Mechanical-T and -cross fittings.
6. Configurations: Snap-on and strapless, ductile-iron housing with branch outlets.
7. Size: Of dimension to fit onto sprinkler main and with outlet connections as required to match connected branch piping.
8. Branch Outlets: Grooved, plain-end pipe, or threaded.

B. Flow Detection and Test Assemblies:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AGF Manufacturing Inc.
 - b. Reliable Automatic Sprinkler Co., Inc.
 - c. Tyco Fire & Building Products LP.
 - d. Victaulic Company.
2. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
3. Pressure Rating: 175 psig minimum.
4. Body Material: Cast- or ductile-iron housing with orifice, sight glass, and integral test valve.
5. Size: Same as connected piping.
6. Inlet and Outlet: Threaded.

C. Branch Line Testers:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Elkhart Brass Mfg. Company, Inc.
 - b. Fire-End & Croker Corporation.
 - c. Potter Roemer.
2. Standard: UL 199.
3. Pressure Rating: 175 psig.
4. Body Material: Brass.
5. Size: Same as connected piping.
6. Inlet: Threaded.
7. Drain Outlet: Threaded and capped.
8. Branch Outlet: Threaded, for sprinkler.

D. Sprinkler Inspector's Test Fittings:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AGF Manufacturing Inc.
 - b. Triple R Specialty.
 - c. Tyco Fire & Building Products LP.
 - d. Victaulic Company.
 - e. Viking Corporation.

2. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
3. Pressure Rating: 175 psig minimum.
4. Body Material: Cast- or ductile-iron housing with sight glass.
5. Size: Same as connected piping.
6. Inlet and Outlet: Threaded.

E. Adjustable Drop Nipples:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. CECA, LLC.
 - b. Corcoran Piping System Co.
 - c. Merit Manufacturing; a division of Anvil International, Inc.
2. Standard: UL 1474.
3. Pressure Rating: 250 psig minimum.
4. Body Material: Steel pipe with EPDM-rubber O-ring seals.
5. Size: Same as connected piping.
6. Length: Adjustable.
7. Inlet and Outlet: Threaded.

F. Flexible, Sprinkler Hose Fittings:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fivalco Inc.
 - b. FlexHead Industries, Inc.
 - c. Gateway Tubing, Inc.
2. Standard: UL 1474.
3. Type: Flexible hose for connection to sprinkler, and with bracket for connection to ceiling grid.
4. Pressure Rating: 175 psig minimum.
5. Size: Same as connected piping, for sprinkler.

2.9 SPRINKLERS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Reliable Automatic Sprinkler Co., Inc.
2. Tyco Fire & Building Products LP.
3. Victaulic Company.
4. Viking Corporation.

B. General Requirements:

1. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
2. Pressure Rating for Residential Sprinklers: 175 psig maximum.

3. Pressure Rating for Automatic Sprinklers: 175 psig minimum.
 4. Pressure Rating for High-Pressure Automatic Sprinklers: 300 psig.
- C. Automatic Sprinklers with Heat-Responsive Element:
1. Early-Suppression, Fast-Response Applications: UL 1767.
 2. Nonresidential Applications: UL 199.
 3. Residential Applications: UL 1626.
 4. Characteristics: Nominal 1/2-inch orifice with Discharge Coefficient K of 5.6, and for "Ordinary" temperature classification rating unless otherwise indicated or required by application.
- D. Sprinkler Finishes:
1. Chrome plated.
 2. Brass.
- E. Sprinkler Escutcheons: Materials, types, and finishes for the following sprinkler mounting applications. Escutcheons for concealed, and recessed-type sprinklers are specified with sprinklers.
1. Ceiling Mounting (Recessed Type Sprinkler): Chrome-plated steel, two piece, with 1-inch vertical adjustment.
 2. Ceiling Mounting (Concealed Type Sprinkler): Flatplate concealer plate, finish to match ceiling color, with 1-inch vertical adjustment.
 3. Sidewall Mounting: Chrome-plated steel, one piece, flat.
- F. Sprinkler Guards:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
 - c. Victaulic Company.
 - d. Viking Corporation.
 2. Standard: UL 199.
 3. Type: Wire cage with fastening device for attaching to sprinkler.

2.10 ALARM DEVICES

- A. Alarm-device types shall match piping and equipment connections.
- B. Electrically Operated Alarm Bell:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire-Lite Alarms, Inc.; a Honeywell company.
 - b. Notifier; a Honeywell company.
 - c. Potter Electric Signal Company.

2. Standard: UL 464.
3. Type: Vibrating, metal alarm bell.
4. Size: 6-inch minimum- diameter.
5. Finish: Red-enamel factory finish, suitable for outdoor use.

C. Water-Flow Indicators:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. ADT Security Services, Inc.
 - b. McDonnell & Miller; ITT Industries.
 - c. Potter Electric Signal Company.
 - d. System Sensor; a Honeywell company.
 - e. Viking Corporation.
 - f. Watts Industries (Canada) Inc.
2. Standard: UL 346.
3. Water-Flow Detector: Electrically supervised.
4. Components: Two single-pole, double-throw circuit switches for isolated alarm and auxiliary contacts, 7 A, 125-V ac and 0.25 A, 24-V dc; complete with factory-set, field-adjustable retard element to prevent false signals and tamperproof cover that sends signal if removed.
5. Type: Paddle operated.
6. Pressure Rating: 250 psig.
7. Design Installation: Horizontal or vertical.

D. Pressure Switches:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AFAC Inc.
 - b. Barksdale, Inc.
 - c. Detroit Switch, Inc.
 - d. Potter Electric Signal Company.
 - e. System Sensor; a Honeywell company.
 - f. Tyco Fire & Building Products LP.
 - g. United Electric Controls Co.
 - h. Viking Corporation.
2. Standard: UL 346.
3. Type: Electrically supervised water-flow switch with retard feature.
4. Components: Single-pole, double-throw switch with normally closed contacts.
5. Design Operation: Rising pressure signals water flow.

E. Valve Supervisory Switches:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire-Lite Alarms, Inc.; a Honeywell company.
 - b. Kennedy Valve; a division of McWane, Inc.
 - c. Potter Electric Signal Company.

- d. System Sensor; a Honeywell company.
 - 2. Standard: UL 346.
 - 3. Type: Electrically supervised.
 - 4. Components: Single-pole, double-throw switch with normally closed contacts.
 - 5. Design: Signals that controlled valve is in other than fully open position.
- F. Indicator-Post Supervisory Switches:
- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Potter Electric Signal Company.
 - b. System Sensor; a Honeywell company.
 - 2. Standard: UL 346.
 - 3. Type: Electrically supervised.
 - 4. Components: Single-pole, double-throw switch with normally closed contacts.
 - 5. Design: Signals that controlled indicator-post valve is in other than fully open position.

2.11 PRESSURE GAGES

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. AMETEK; U.S. Gauge Division.
 - 2. Ashcroft, Inc.
 - 3. Brecco Corporation.
 - 4. WIKA Instrument Corporation.
- B. Standard: UL 393.
- C. Dial Size: 3-1/2- to 4-1/2-inch diameter.
- D. Pressure Gage Range: 0 to 300 psig.
- E. Water System Piping Gage: Include "WATER" or "AIR/WATER" label on dial face.
- F. Air System Piping Gage: Include "AIR" or "AIR/WATER" label on dial face.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Perform fire-hydrant flow test according to NFPA 13 and NFPA 291. Use results for system design calculations required in "Quality Assurance" Article.
- B. Report test results promptly and in writing.

3.2 SERVICE-ENTRANCE PIPING

- A. Connect sprinkler piping to water-service piping for service entrance to building. Comply with requirements for exterior piping in Section 02713 "EXTERIOR WATER DISTRIBUTION SYSTEMS."
- B. Install shutoff valve, backflow preventer, pressure gage, drain, and other accessories indicated at connection to water-service piping. Comply with requirements for backflow preventers in Section 02713 "EXTERIOR WATER DISTRIBUTION SYSTEMS."
- C. Install shutoff valve, check valve, pressure gage, and drain at connection to water service.

3.3 PIPING INSTALLATION

- A. Locations and Arrangements: Drawing plans, schematics, and diagrams indicate general location and arrangement of piping. Install piping as indicated, as far as practical.
 - 1. Deviations from approved working plans for piping require written approval from authorities having jurisdiction. File written approval with Architect before deviating from approved working plans.
- B. Piping Standard: Comply with requirements for installation of sprinkler piping in NFPA 13.
- C. Install seismic restraints on piping. Comply with requirements for seismic-restraint device materials and installation in NFPA 13.
- D. Use listed fittings to make changes in direction, branch takeoffs from mains, and reductions in pipe sizes.
- E. Install unions adjacent to each valve in pipes NPS 2 and smaller.
- F. Install flanges, flange adapters, or couplings for grooved-end piping on valves, apparatus, and equipment having NPS 2-1/2 and larger end connections.
- G. Install "Inspector's Test Connections" in sprinkler system piping, complete with shutoff valve, and sized and located according to NFPA 13.
- H. Install sprinkler piping with drains for complete system drainage.
- I. Install sprinkler control valves, test assemblies, and drain risers adjacent to standpipes when sprinkler piping is connected to standpipes.
- J. Install automatic (ball drip) drain valve at each check valve for fire-department connection, to drain piping between fire-department connection and check valve. Install drain piping to and spill over floor drain or to outside building.
- K. Install alarm devices in piping systems.
- L. Install hangers and supports for sprinkler system piping according to NFPA 13. Comply with requirements for hanger materials in NFPA 13.

- M. Install pressure gages on riser or feed main, at each sprinkler test connection, and at top of each standpipe. Include pressure gages with connection not less than NPS 1/4 and with soft metal seated globe valve, arranged for draining pipe between gage and valve. Install gages to permit removal, and install where they will not be subject to freezing.
- N. Pressurize and check sprinkler system piping with air prior to introducing water into the system.
- O. Fill sprinkler system piping with water.
- P. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15903 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- Q. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 15093 "PIPING."
- R. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 75052 "BASIC MATERIALS AND METHODS FOR FIRE PROTECTION WORK."

3.4 JOINT CONSTRUCTION

- A. Install couplings, flanges, flanged fittings, unions, nipples, and transition and special fittings that have finish and pressure ratings same as or higher than system's pressure rating for aboveground applications unless otherwise indicated.
- B. Install unions adjacent to each valve in pipes NPS 2 and smaller.
- C. Install flanges, flange adapters, or couplings for grooved-end piping on valves, apparatus, and equipment having NPS 2-1/2 and larger end connections.
- D. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- E. Remove scale, slag, dirt, and debris from inside and outside of pipes, tubes, and fittings before assembly.
- F. Flanged Joints: Select appropriate gasket material in size, type, and thickness suitable for water service. Join flanges with gasket and bolts according to ASME B31.9.
- G. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.
- H. Twist-Locked Joints: Insert plain end of steel pipe into plain-end-pipe fitting. Rotate retainer lugs one-quarter turn or tighten retainer pin.
- I. Steel-Piping, Pressure-Sealed Joints: Join lightwall steel pipe and steel pressure-seal fittings with tools recommended by fitting manufacturer.

- J. Welded Joints: Construct joints according to AWS D10.12M/D10.12, using qualified processes and welding operators according to "Quality Assurance" Article.
 - 1. Shop weld pipe joints where welded piping is indicated. Do not use welded joints for galvanized-steel pipe.
- K. Steel-Piping, Cut-Grooved Joints: Cut square-edge groove in end of pipe according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join steel pipe and grooved-end fittings according to AWWA C606 for steel-pipe joints.
- L. Steel-Piping, Roll-Grooved Joints: Roll rounded-edge groove in end of pipe according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join steel pipe and grooved-end fittings according to AWWA C606 for steel-pipe grooved joints.
- M. Steel-Piping, Pressure-Sealed Joints: Join Schedule 5 steel pipe and steel pressure-seal fittings with tools recommended by fitting manufacturer.
- N. Brazed Joints: Join copper tube and fittings according to CDA's "Copper Tube Handbook," "Braze Joints" Chapter.
- O. Copper-Tubing Grooved Joints: Roll rounded-edge groove in end of tube according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join copper tube and grooved-end fittings according to AWWA C606 for steel-pipe grooved joints.
- P. Copper-Tubing, Pressure-Sealed Joints: Join copper tube and copper pressure-seal fittings with tools recommended by fitting manufacturer.
- Q. Extruded-Tee Connections: Form tee in copper tube according to ASTM F 2104. Use tool designed for copper tube; drill pilot hole, form collar for outlet, dimple tube to form seating stop, and braze branch tube into collar.
- R. Dissimilar-Material Piping Joints: Make joints using adapters compatible with materials of both piping systems.
- S. Plastic-Piping, Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
 - 1. Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements. Apply primer.
 - 2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.

3.5 VALVE AND SPECIALTIES INSTALLATION

- A. Install listed fire-protection valves, trim and drain valves, specialty valves and trim, controls, and specialties according to NFPA 13 and authorities having jurisdiction.
- B. Install listed fire-protection shutoff valves supervised open, located to control sources of water supply except from fire-department connections. Install permanent identification signs indicating portion of system controlled by each valve.
- C. Install check valve in each water-supply connection. Install backflow preventers instead of check valves in potable-water-supply sources.

D. Specialty Valves:

1. General Requirements: Install in vertical position for proper direction of flow, in main supply to system.
2. Alarm Valves: Include bypass check valve and retarding chamber drain-line connection.
3. Deluge Valves: Install in vertical position, in proper direction of flow, and in main supply to deluge system. Install trim sets for drain, priming level, alarm connections, ball drip valves, pressure gages, priming chamber attachment, and fill-line attachment.

3.6 SPRINKLER INSTALLATION

- A. Install sprinklers in suspended ceilings in center of acoustical ceiling panels.
- B. Install dry-type sprinklers with water supply from heated space. Do not install pendent or sidewall, wet-type sprinklers in areas subject to freezing.

3.7 IDENTIFICATION

- A. Install labeling and pipe markers on equipment and piping according to requirements in NFPA 13.
- B. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION."

3.8 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
 1. Leak Test: After installation, charge systems and test for leaks. Repair leaks and retest until no leaks exist.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 3. Flush, test, and inspect sprinkler systems according to NFPA 13, "Systems Acceptance" Chapter.
 4. Energize circuits to electrical equipment and devices.
 5. Coordinate with fire-alarm tests. Operate as required.
 6. Coordinate with fire-pump tests. Operate as required.
 7. Verify that equipment hose threads are same as local fire-department equipment.
- C. Sprinkler piping system will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.9 CLEANING

- A. Clean dirt and debris from sprinklers.
- B. Remove and replace sprinklers with paint other than factory finish.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain specialty valves and pressure-maintenance pumps.

3.11 PIPING SCHEDULE

- A. Aboveground piping between Fire-Department Connections and Check Valves: Galvanized, standard-weight steel pipe with grooved ends; grooved-end fittings; grooved-end-pipe couplings; and grooved joints.
- B. Underground Piping between Fire-Department Connections and Check Valves: High Density Polyethylene Pipe (HDPE) with HDPE fittings, and fused joints.
- C. Sprinkler specialty fittings may be used, downstream of control valves, instead of specified fittings.
- D. Standard-pressure, wet-pipe sprinkler system, NPS 2 and smaller, shall be the following:
 - 1. Schedule 40, galvanized-steel pipe with threaded ends; galvanized, gray-iron threaded fittings; and threaded joints.
- E. Standard-pressure, wet-pipe sprinkler system, NPS 2-1/2 and larger, shall be the following:
 - 1. Schedule 40, galvanized-steel pipe with threaded ends; galvanized, gray-iron threaded fittings; and threaded joints.

3.12 SPRINKLER SCHEDULE

- A. Use sprinkler types in subparagraphs below for the following applications:
 - 1. Rooms without Ceilings: Upright sprinklers.
 - 2. Rooms with Suspended Ceilings: Pendent, recessed, flush, and concealed sprinklers as indicated.
 - 3. Wall Mounting: Sidewall sprinklers.
 - 4. Spaces Subject to Freezing: Upright, pendent, dry sprinklers; and sidewall, dry sprinklers as indicated.
- B. Provide sprinkler types in subparagraphs below with finishes indicated.
 - 1. Concealed Sprinklers: Rough brass, with factory-painted cover plate to match ceiling.
 - 2. Recessed Sprinklers: Bright chrome, with bright chrome escutcheon.
 - 3. Upright Pendent and Sidewall Sprinklers: Chrome plated in finished spaces exposed to view; rough bronze in unfinished spaces not exposed to view; corrosion resistant paint for sprinklers outdoors.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment" .

END OF SECTION

SECTION 15935

DRY-PIPE FIRE-SUPPRESSION SPRINKLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions..

1.2 SUMMARY

- A. Section Includes:

1. Pipes, fittings, and specialties.
2. Dry and Pre-Action Dry sprinkler systems.
3. Fire-protection valves.
4. Fire-department connections.
5. Sprinkler specialty pipe fittings.
6. Sprinklers.
7. Alarm devices.
8. Pressure gages.

- B. Related Sections:

1. Section 16705 "STATION FIRE-ALARM SYSTEM" for alarm devices not specified in this Section.
2. Section 15921 "ELECTRIC-DRIVE, CENTRIFUGAL FIRE PUMPS" for fire pumps, pressure-maintenance pumps, and fire-pump controllers.
3. Section 15930 "WET-PIPE FIRE-SUPPRESSION SPRINKLERS" for wet-pipe sprinkler piping.
4. Section 15974 "FIRE-SUPPRESSION STANDPIPES" for standpipe piping.
5. Section 15976 "FIRE-DEPARTMENT CONNECTIONS" for exposed-, flush-, and yard-type fire-department connections.
6. Section 16195 "ELECTRICAL IDENTIFICATION"

1.3 DEFINITIONS

- A. Standard-Pressure Sprinkler Piping: Dry-pipe sprinkler system piping designed to operate at working pressure 175 psig maximum.

1.4 SYSTEM DESCRIPTIONS

- A. Dry-Pipe Sprinkler System: Automatic sprinklers are attached to piping containing compressed air. Opening of sprinklers releases compressed air and permits water pressure to open dry-pipe valve. Water then flows into piping and discharges from sprinklers that are open.
- B. Dry-Pipe Sprinkler System: Automatic sprinklers are attached to piping containing compressed air. Opening of sprinklers releases compressed air and permits water pressure to open dry-pipe valve. Water then flows into piping and discharges from opened sprinklers.
- C. Combined Dry-Pipe and Preaction Sprinkler System: Automatic sprinklers are attached to piping containing compressed air. Fire-detection system, located in same area as sprinklers, actuates tripping devices that open dry-pipe valve without loss of air pressure and actuates fire alarm. Water discharges from opened sprinklers.
- D. Single-Interlock Preaction Sprinkler System: Automatic sprinklers are attached to piping containing low-pressure air. Actuation of fire-detection system, located in same area as sprinklers, opens deluge valve, permitting water to flow into sprinkler piping and to discharge from opened sprinklers.
- E. Double-Interlock Preaction Sprinkler System: Automatic sprinklers are attached to piping containing low-pressure air. Actuation of a fire-detection system, located in same area as sprinklers, opens deluge valve, permitting water to flow into sprinkler piping. A closed solenoid valve in the sprinkler piping is opened by another fire-detection device; water will then discharge from opened sprinklers.

1.5 PERFORMANCE REQUIREMENTS

- A. Standard-Pressure Piping System Component: Listed for 175-psig minimum working pressure.
- B. Delegated Design: Design sprinkler system(s), including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
 - 1. Design-Builder shall obtain hydrant flow data from the local water authority. Test shall have been performed within the last 12 months.
- C. Sprinkler system design shall be approved by authorities having jurisdiction.
 - 1. Margin of Safety for Available Water Flow and Pressure: 10 percent, including losses through water-service piping, valves, and backflow preventers.
 - 2. Sprinkler Occupancy Hazard Classifications:
 - a. Ordinary Hazard Group I
 - b. Other as applicable to the final structure, use group and classification.
 - 3. Minimum Density for Automatic-Sprinkler Piping Design:
 - a. 0.15 gpm over 1,950 sqft. (30% increase to 1,500 sqft for a dry system)
 - 4. Maximum Protection Area per Sprinkler:
 - a. 130 sqft.

5. Total Combined Hose-Stream Demand Requirement: According to NFPA 13 unless otherwise indicated:
 - a. 250 gpm for 60 minutes.
- D. Seismic Performance: Sprinkler piping shall withstand the effects of earthquake motions determined according to NFPA 13 and ASCE/SEI 7.

1.6 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Shop Drawings: For dry-pipe sprinkler systems. Include plans, elevations, sections, details, and attachments to other work.
 1. Wiring Diagrams: For power, signal, and control wiring.
- C. Delegated-Design Submittal: For sprinkler systems indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
- D. Coordination Drawings: Sprinkler systems, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Domestic water piping.
 2. Compressed air piping.
 3. HVAC hydronic piping.
 4. Items penetrating finished ceiling including the following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
 5. Architectural elements.
 6. Structural elements.
- E. Qualification Data: For qualified Installer and professional engineer.
- F. Approved Sprinkler Piping Drawings: Working plans, prepared according to NFPA 13, that have been approved by authorities having jurisdiction, including hydraulic calculations.
- G. Welding certificates.
- H. Fire-hydrant flow test report.
- I. Field Test Reports and Certificates: Indicate and interpret test results for compliance with performance requirements and as described in NFPA 13. Include "Design-Builder's Material and Test Certificate for Aboveground Piping."
- J. Field quality-control reports.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For sprinkler specialties to include in emergency, operation, and maintenance manuals.
- B. As-Built Record Drawings: Update shop drawings to include all changes made during installation to provide as-built record drawings of all piping, equipment and systems installed.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Sprinkler Cabinets: Finished, wall-mounted, steel cabinet with hinged cover, and with space for minimum of six spare sprinklers plus sprinkler wrench. Include number of sprinklers required by NFPA 13 and sprinkler wrench. Include separate cabinet with sprinklers and wrench for each type of sprinkler used on Project.

1.9 QUALITY ASSURANCE

- A. Installer Qualifications:
 - 1. Installer's responsibilities include designing, fabricating, and installing sprinkler systems and providing professional engineering services needed to assume engineering responsibility. Base calculations on results of fire-hydrant flow test.
 - a. Engineering Responsibility: Preparation of working plans, calculations, and field test reports by a NICET Level III certified individual and signed and sealed by a qualified professional engineer.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. NFPA Standards: Sprinkler system equipment, specialties, accessories, installation, and testing shall comply with the following:
 - 1. NFPA 13, "Installation of Sprinkler Systems."
 - 2. NFPA 24, "Installation of Private Fire Service Mains and Their Appurtenances."

1.10 PROJECT CONDITIONS

- A. Interruption of Existing Services: Do not interrupt existing service to facilities occupied by MBTA or others unless permitted under the following conditions and then only after arranging to provide temporary sprinkler service according to requirements indicated:
 - 1. Notify MBTA no fewer than seven days in advance of proposed interruption of existing services.
 - 2. Do not proceed with interruption of services without MBTA's written permission.

1.11 COORDINATION

- A. Coordinate layout and installation of sprinklers with other construction that penetrates ceilings, including light fixtures, HVAC equipment, and partition assemblies.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

- A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, and fitting materials, and joining methods for specific services, service locations, and pipe sizes.

2.2 STEEL PIPE AND FITTINGS

- A. Schedule 40, Galvanized-Steel Pipe: ASTM A 53/A 53M, Type E, Grade B. Pipe ends may be factory or field formed to match joining method.
- B. Galvanized-Steel Pipe Nipples: ASTM A 733, made of ASTM A 53/A 53M, standard-weight, seamless steel pipe with threaded ends.
- C. Galvanized, Steel Couplings: ASTM A 865, threaded.
- D. Galvanized, Gray-Iron Threaded Fittings: ASME B16.4, Class 125, standard pattern.
- E. Malleable- or Ductile-Iron Unions: UL 860.
- F. Cast-Iron Flanges: ASME B16.1, Class 125.
- G. Plain-End-Pipe Fittings: UL 213, ductile-iron body with retainer lugs that require one-quarter turn or screwed retainer pin to secure pipe in fitting.
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Shurjoint Piping Products.
- H. Grooved-Joint, Steel-Pipe Appurtenances:
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Corcoran Piping System Co.
 - c. National Fittings, Inc.
 - d. Shurjoint Piping Products.
 - e. Tyco Fire & Building Products LP.
 - f. Victaulic Company.
 - 2. Pressure Rating: 175 psig minimum.

3. Galvanized, Grooved-End Fittings for Steel Piping: ASTM A 47/A 47M, malleable-iron casting or ASTM A 536, ductile-iron casting; with dimensions matching steel pipe.

2.3 HIGH DENSITY POLY ETHYLENE (HDPE)

- A. HDPE Pipe: FM Approved, ASTM 3350-02 with cell classification of 34554642, Class 200.
- B. HDPE Fittings: FM Approved, ASTM 3350-02 with cell classification of 34554642, Class 200.

2.4 PIPING JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: AWWA C110, rubber, flat face, 1/8 inch thick or ASME B16.21, nonmetallic and asbestos free.
 1. Class 125, Cast-Iron and Class 150, Bronze Flat-Face Flanges: Full-face gaskets.
 2. Class 250, Cast-Iron and Class 300, Raised-Face Flanges: Ring-type gaskets.
- B. Metal, Pipe-Flange Bolts and Nuts: ASME B18.2.1, carbon steel unless otherwise indicated.
- C. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for general-duty brazing unless otherwise indicated.

2.5 LISTED FIRE-PROTECTION VALVES

- A. General Requirements:
 1. Valves shall be UL listed or FM approved.
 2. Minimum Pressure Rating for Standard-Pressure Piping: 175 psig.
 3. Minimum Pressure Rating for High-Pressure Piping: 300 psig.
- B. Ball Valves:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Victaulic Company.
 2. Standard: UL 1091 except with ball instead of disc.
 3. Valves NPS 1-1/2 and Smaller: Bronze body with threaded ends.
 4. Valves NPS 2 and NPS 2-1/2: Bronze body with threaded ends or ductile-iron body with grooved ends.
 5. Valves NPS 3: Ductile-iron body with grooved ends.
- C. Bronze Butterfly Valves:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fivalco Inc.

- b. Global Safety Products, Inc.
 - c. Milwaukee Valve Company.
2. Standard: UL 1091.
 3. Pressure Rating: 175 psig.
 4. Body Material: Bronze.
 5. End Connections: Threaded.

D. Iron Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Fivalco Inc.
 - c. Global Safety Products, Inc.
 - d. Kennedy Valve; a division of McWane, Inc.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Pratt, Henry Company.
 - h. Shurjoint Piping Products.
 - i. Tyco Fire & Building Products LP.
 - j. Victaulic Company.
2. Standard: UL 1091.
3. Pressure Rating: 175 psig.
4. Body Material: Cast or ductile iron.
5. Style: Lug or wafer.
6. End Connections: Grooved.

E. Check Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AFAC Inc.
 - b. American Cast Iron Pipe Company; Waterous Company Subsidiary.
 - c. Anvil International, Inc.
 - d. Clow Valve Company; a division of McWane, Inc.
 - e. Crane Co.; Crane Valve Group; Crane Valves.
 - f. Crane Co.; Crane Valve Group; Jenkins Valves.
 - g. Crane Co.; Crane Valve Group; Stockham Division.
 - h. Fire-End & Croker Corporation.
 - i. Fire Protection Products, Inc.
 - j. Fivalco Inc.
 - k. Globe Fire Sprinkler Corporation.
 - l. Groeniger & Company.
 - m. Kennedy Valve; a division of McWane, Inc.
 - n. Matco-Norca.
 - o. Metraflex, Inc.
 - p. Milwaukee Valve Company.
 - q. Mueller Co.; Water Products Division.
 - r. NIBCO INC.

- s. Potter Roemer.
- t. Reliable Automatic Sprinkler Co., Inc.
- u. Shurjoint Piping Products.
- v. Tyco Fire & Building Products LP.
- w. United Brass Works, Inc.
- x. Venus Fire Protection Ltd.
- y. Victaulic Company.
- z. Viking Corporation.
- aa. Watts Water Technologies, Inc.

- 2. Standard: UL 312
- 3. Pressure Rating: 250 psig minimum.
- 4. Type: Swing check.
- 5. Body Material: Cast iron.
- 6. End Connections: Flanged or grooved.

F. Bronze OS&Y Gate Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Crane Co.; Crane Valve Group; Crane Valves.
 - b. Crane Co.; Crane Valve Group; Stockham Division.
 - c. Milwaukee Valve Company.
 - d. NIBCO INC.
 - e. United Brass Works, Inc.
- 2. Standard: UL 262.
- 3. Pressure Rating: 175 psig.
- 4. Body Material: Bronze.
- 5. End Connections: Threaded.

G. Iron OS&Y Gate Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. American Cast Iron Pipe Company; Waterous Company Subsidiary.
 - b. American Valve, Inc.
 - c. Clow Valve Company; a division of McWane, Inc.
 - d. Crane Co.; Crane Valve Group; Crane Valves.
 - e. Crane Co.; Crane Valve Group; Jenkins Valves.
 - f. Crane Co.; Crane Valve Group; Stockham Division.
 - g. Hammond Valve.
 - h. Milwaukee Valve Company.
 - i. Mueller Co.; Water Products Division.
 - j. NIBCO INC.
 - k. Shurjoint Piping Products.
 - l. Tyco Fire & Building Products LP.
 - m. United Brass Works, Inc.
 - n. Watts Water Technologies, Inc.
- 2. Standard: UL 262.

3. Pressure Rating: 250 psig minimum.
4. Body Material: Cast or ductile iron.
5. End Connections: Flanged or grooved.

H. Indicating-Type Butterfly Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Fivalco Inc.
 - c. Global Safety Products, Inc.
 - d. Kennedy Valve; a division of McWane, Inc.
 - e. Milwaukee Valve Company.
 - f. NIBCO INC.
 - g. Shurjoint Piping Products.
 - h. Tyco Fire & Building Products LP.
 - i. Victaulic Company.
2. Standard: UL 1091.
3. Pressure Rating: 175 psig minimum.
4. Valves NPS 2 and Smaller:
 - a. Valve Type: Ball or butterfly.
 - b. Body Material: Bronze.
 - c. End Connections: Threaded.
5. Valves NPS 2-1/2 and Larger:
 - a. Valve Type: Butterfly.
 - b. Body Material: Cast or ductile iron.
 - c. End Connections: Flanged, grooved, or wafer.
6. Valve Operation: Integral electrical, 115-V ac, prewired, single-circuit, supervisory switch indicating device.

2.6 TRIM AND DRAIN VALVES

A. General Requirements:

1. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
2. Pressure Rating: 175 psig minimum.

B. Angle Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire Protection Products, Inc.
 - b. United Brass Works, Inc.

C. Ball Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Affiliated Distributors.
 - b. Anvil International, Inc.
 - c. Barnett.
 - d. Conbraco Industries, Inc.; Apollo Valves.
 - e. Fire-End & Croker Corporation.
 - f. Fire Protection Products, Inc.
 - g. Flowserve.
 - h. FNW.
 - i. Jomar International, Ltd.
 - j. Kennedy Valve; a division of McWane, Inc.
 - k. Kitz Corporation.
 - l. Legend Valve.
 - m. Metso Automation USA Inc.
 - n. Milwaukee Valve Company.
 - o. NIBCO INC.
 - p. Potter Roemer.
 - q. Red-White Valve Corporation.
 - r. Southern Manufacturing Group.
 - s. Stewart, M. A. and Sons Ltd.
 - t. Tyco Fire & Building Products LP.
 - u. Victaulic Company.
 - v. Watts Water Technologies, Inc.

D. Globe Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire Protection Products, Inc.
 - b. United Brass Works, Inc.

2.7 SPECIALTY VALVES

A. General Requirements:

1. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
2. Pressure Rating:
 - a. Standard-Pressure Piping Specialty Valves: 175 psig minimum.
 - b. High-Pressure Piping Specialty Valves: 250 psig minimum.
3. Body Material: Cast or ductile iron.
4. Size: Same as connected piping.
5. End Connections: Flanged or grooved.

B. Dry-Pipe Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
 - c. Victaulic Company.
 - d. Viking Corporation.

 2. Standard: UL 260
 3. Design: Differential-pressure type.
 4. Include UL 1486, quick-opening devices, trim sets for air supply, drain, priming level, alarm connections, ball drip valves, pressure gages, priming chamber attachment, and fill-line attachment.
 5. Air-Pressure Maintenance Device:
 - a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1) Reliable Automatic Sprinkler Co., Inc.
 - 2) Tyco Fire & Building Products LP.
 - 3) Victaulic Company.
 - 4) Viking Corporation.
 - b. Standard: UL 260.
 - c. Type: Automatic device to maintain minimum air pressure in piping.
 - d. Include shutoff valves to permit servicing without shutting down sprinkler piping, bypass valve for quick filling, pressure regulator or switch to maintain pressure, strainer, pressure ratings with 14- to 60-psig adjustable range, and 175-psig outlet pressure.

 6. Air Compressor:
 - a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1) Gast Manufacturing Inc.
 - 2) General Air Products, Inc,
 - 3) Viking Corporation.
 - b. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
 - c. Motor Horsepower: Fractional.
 - d. Power: 115-V ac, 60 Hz, single phase.
- C. Automatic (Ball Drip) Drain Valves:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.

 2. Standard: UL 1726.

3. Pressure Rating: 175 psig minimum.
4. Type: Automatic draining, ball check.
5. Size: NPS 3/4.
6. End Connections: Threaded.

2.8 SPRINKLER SPECIALTY PIPE FITTINGS

- A. General Requirements for Dry-Pipe-System Fittings: UL listed for dry-pipe service.
- B. Branch Outlet Fittings:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. National Fittings, Inc.
 - c. Shurjoint Piping Products.
 - d. Tyco Fire & Building Products LP.
 - e. Victaulic Company.
 2. Standard: UL 213.
 3. Pressure Rating: 175 psig minimum.
 4. Body Material: Ductile-iron housing with EPDM seals and bolts and nuts.
 5. Type: Mechanical-T and -cross fittings.
 6. Configurations: Snap-on and strapless, ductile-iron housing with branch outlets.
 7. Size: Of dimension to fit onto sprinkler main and with outlet connections as required to match connected branch piping.
 8. Branch Outlets: Grooved, plain-end pipe, or threaded.
- C. Flow Detection and Test Assemblies:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AGF Manufacturing Inc.
 - b. Reliable Automatic Sprinkler Co., Inc.
 - c. Tyco Fire & Building Products LP.
 - d. Victaulic Company.
 2. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
 3. Pressure Rating: 175 psig minimum.
 4. Body Material: Cast- or ductile-iron housing with orifice, sight glass, and integral test valve.
 5. Size: Same as connected piping.
 6. Inlet and Outlet: Threaded.
- D. Branch Line Testers:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Elkhart Brass Mfg. Company, Inc.

- b. Fire-End & Croker Corporation.
 - c. Potter Roemer.
 - 2. Standard: UL 199.
 - 3. Pressure Rating: 175 psig minimum.
 - 4. Body Material: Brass.
 - 5. Size: Same as connected piping.
 - 6. Inlet: Threaded.
 - 7. Drain Outlet: Threaded and capped.
 - 8. Branch Outlet: Threaded, for sprinkler.
- E. Sprinkler Inspector's Test Fittings:
- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AGF Manufacturing Inc.
 - b. Triple R Specialty.
 - c. Tyco Fire & Building Products LP.
 - d. Victaulic Company.
 - e. Viking Corporation.
 - 2. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
 - 3. Pressure Rating: 175 psig minimum.
 - 4. Body Material: Cast- or ductile-iron housing with sight glass.
 - 5. Size: Same as connected piping.
 - 6. Inlet and Outlet: Threaded.
- F. Adjustable Drop Nipples:
- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. CECA, LLC.
 - b. Corcoran Piping System Co.
 - c. Merit Manufacturing; a division of Anvil International, Inc.
 - 2. Standard: UL 1474.
 - 3. Pressure Rating: 250 psig minimum.
 - 4. Body Material: Steel pipe with EPDM O-ring seals.
 - 5. Size: Same as connected piping.
 - 6. Length: Adjustable.
 - 7. Inlet and Outlet: Threaded.
- G. Flexible, Sprinkler Hose Fittings:
- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fivalco Inc.
 - b. FlexHead Industries, Inc.
 - c. Gateway Tubing, Inc.

2. Standard: UL 1474.
3. Type: Flexible hose for connection to sprinkler, and with bracket for connection to ceiling grid.
4. Pressure Rating: 175 psig minimum.
5. Size: Same as connected piping, for sprinkler.

2.9 SPRINKLERS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 1. Reliable Automatic Sprinkler Co., Inc.
 2. Tyco Fire & Building Products LP.
 3. Victaulic Company.
 4. Viking Corporation.
- B. General Requirements:
 1. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
 2. Pressure Rating for Automatic Sprinklers: 175 psig minimum.
 3. Pressure Rating for High-Pressure Automatic Sprinklers: 300 psig.
- C. Automatic Sprinklers with Heat-Responsive Element:
 1. Nonresidential Applications: UL 199.
 2. Characteristics: Nominal 1/2-inch orifice with discharge coefficient K of 5.6, and for "Ordinary" temperature classification rating unless otherwise indicated or required by application.
- D. Sprinkler Finishes:
 1. Chrome plated.
 2. Brass.
- E. Sprinkler Escutcheons: Materials, types, and finishes for the following sprinkler mounting applications. Escutcheons for concealed, and recessed-type sprinklers are specified with sprinklers.
 1. Ceiling Mounting (Recessed Type Sprinkler): Chrome-plated steel, two piece, with 1-inch vertical adjustment.
 2. Ceiling Mounting (Concealed Type Sprinkler): Flatplate concealer plate, finish to match ceiling color, with 1-inch vertical adjustment.
 3. Sidewall Mounting: Chrome-plated steel, one piece, flat.
- F. Sprinkler Guards:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
 - c. Victaulic Company.
 - d. Viking Corporation.

2. Standard: UL 199.
3. Type: Wire cage with fastening device for attaching to sprinkler.

2.10 ALARM DEVICES

- A. Alarm-device types shall match piping and equipment connections.
- B. Electrically Operated Alarm Bell:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire-Lite Alarms; a Honeywell company.
 - b. Notifier; a Honeywell company.
 - c. Potter Electric Signal Company.
 2. Standard: UL 464.
 3. Type: Vibrating, metal alarm bell.
 4. Size: 6-inch minimum diameter.
 5. Finish: Red-enamel factory finish, suitable for outdoor use.
- C. Pressure Switches:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. AFAC Inc.
 - b. Barksdale, Inc.
 - c. Detroit Switch, Inc.
 - d. Potter Electric Signal Company.
 - e. System Sensor; a Honeywell company.
 - f. Tyco Fire & Building Products LP.
 - g. United Electric Controls Co.
 - h. Viking Corporation.
 2. Standard: UL 346.
 3. Type: Electrically supervised water-flow switch with retard feature.
 4. Components: Single-pole, double-throw switch with normally closed contacts.
 5. Design Operation: Rising pressure signals water flow.
- D. Valve Supervisory Switches:
 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire-Lite Alarms; a Honeywell company.
 - b. Kennedy Valve; a division of McWane, Inc.
 - c. Potter Electric Signal Company.
 - d. System Sensor; a Honeywell company.
 2. Standard: UL 346.
 3. Type: Electrically supervised.

4. Components: Single-pole, double-throw switch with normally closed contacts.
 5. Design: Signals that controlled valve is in other than fully open position.
- E. Indicator-Post Supervisory Switches:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Potter Electric Signal Company.
 - b. System Sensor; a Honeywell company.
 2. Standard: UL 346.
 3. Type: Electrically supervised.
 4. Components: Single-pole, double-throw switch with normally closed contacts.
 5. Design: Signals that controlled indicator-post valve is in other than fully open position.

2.11 PRESSURE GAGES

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. AMETEK, Inc.; U.S. Gauge Division.
 2. Ashcroft, Inc.
 3. Brecco Corporation.
 4. WIKA Instrument Corporation.
- B. Standard: UL 393.
- C. Dial Size: 3-1/2- to 4-1/2-inch diameter.
- D. Pressure Gage Range: 0 to 300 psig.
- E. Water System Piping Gage: Include "WATER" or "AIR/WATER" label on dial face.
- F. Air System Piping Gage: Include "AIR" or "AIR/WATER" label on dial face.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Perform fire-hydrant flow test according to NFPA 13 and NFPA 291. Use results for system design calculations required in "Quality Assurance" Article.
- B. Report test results promptly and in writing.

3.2 SERVICE-ENTRANCE PIPING

- A. Connect sprinkler piping to water-service piping for service entrance to building. Comply with requirements in Section 02713 "EXTERIOR WATER DISTRIBUTION SYSTEMS" for exterior piping.
- B. Install shutoff valve, backflow preventer, pressure gage, drain, and other accessories indicated at connection to water-service piping. Comply with requirements in Section 002713 "EXTERIOR WATER DISTRIBUTION SYSTEM." for backflow preventors.
- C. Install shutoff valve, check valve, pressure gage, and drain at connection to water service.

3.3 PIPING INSTALLATION

- A. Locations and Arrangements: Drawing plans, schematics, and diagrams indicate general location and arrangement of piping. Install piping as indicated, as far as practical.
 - 1. Deviations from approved working plans for piping require written approval from authorities having jurisdiction. File written approval with Architect before deviating from approved working plans.
- B. Piping Standard: Comply with requirements in NFPA 13 for installation of sprinkler piping.
- C. Install seismic restraints on piping. Comply with requirements in NFPA 13 for seismic-restraint device materials and installation.
- D. Use listed fittings to make changes in direction, branch takeoffs from mains, and reductions in pipe sizes.
- E. Install unions adjacent to each valve in pipes NPS 2 and smaller.
- F. Install flanges, flange adapters, or couplings for grooved-end piping on valves, apparatus, and equipment having NPS 2-1/2 and larger end connections.
- G. Install "Inspector's Test Connections" in sprinkler system piping, complete with shutoff valve, and sized and located according to NFPA 13.
- H. Install sprinkler piping with drains for complete system drainage.
- I. Install sprinkler control valves, test assemblies, and drain risers adjacent to standpipes when sprinkler piping is connected to standpipes.
- J. Install automatic (ball drip) drain valves to drain piping between fire-department connections and check valves. Drain to floor drain or to outside building.
- K. Connect compressed-air supply to dry-pipe sprinkler piping.
- L. Connect air compressor to the following piping and wiring:
 - 1. Pressure gages and controls.
 - 2. Electrical power system.
 - 3. Fire-alarm devices, including low-pressure alarm.

- M. Install alarm devices in piping systems.
- N. Install hangers and supports for sprinkler system piping according to NFPA 13. Comply with requirements in NFPA 13 for hanger materials.
- O. Install pressure gages on riser or feed main, at each sprinkler test connection, and at top of each standpipe. Include pressure gages with connection not less than NPS 1/4 and with soft metal seated globe valve, arranged for draining pipe between gage and valve. Install gages to permit removal, and install where they will not be subject to freezing.
- P. Drain dry-pipe sprinkler piping.
- Q. Pressurize and check dry-pipe sprinkler system piping, air-pressure maintenance devices and air compressors.
- R. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- S. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- T. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 15052 "BASIC MATERIALS AND METHODS FOR FIRE PROTECTION WORK."

3.4 JOINT CONSTRUCTION

- A. Install couplings, flanges, flanged fittings, unions, nipples, and transition and special fittings that have finish and pressure ratings same as or higher than system's pressure rating for aboveground applications unless otherwise indicated.
- B. Install unions adjacent to each valve in pipes NPS 2 and smaller.
- C. Install flanges, flange adapters, or couplings for grooved-end piping on valves, apparatus, and equipment having NPS 2-1/2 and larger end connections.
- D. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
- E. Remove scale, slag, dirt, and debris from inside and outside of pipes, tubes, and fittings before assembly.
- F. Flanged Joints: Select appropriate gasket material in size, type, and thickness suitable for water service. Join flanges with gasket and bolts according to ASME B31.9.
- G. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.

- H. Twist-Locked Joints: Insert plain end of steel pipe into plain-end-pipe fitting. Rotate retainer lugs one-quarter turn or tighten retainer pin.
- I. Steel-Piping, Cut-Grooved Joints: Cut square-edge groove in end of pipe according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join steel pipe and grooved-end fittings according to AWWA C606 for steel-pipe joints.
- J. Brazed Joints: Join copper tube and fittings according to CDA's "Copper Tube Handbook," "Braze Joints" Chapter.
- K. Copper-Tubing Grooved Joints: Roll rounded-edge groove in end of tube according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join copper tube and grooved-end fittings according to AWWA C606 for steel-pipe grooved joints.
- L. Copper-Tubing, Pressure-Sealed Joints: Join copper tube and copper pressure-seal fittings with tools recommended by fitting manufacturer.
- M. Extruded-Tee Connections: Form tee in copper tube according to ASTM F 2104. Use tool designed for copper tube; drill pilot hole, form collar for outlet, dimple tube to form seating stop, and braze branch tube into collar.
- N. Dissimilar-Material Piping Joints: Make joints using adapters compatible with materials of both piping systems.

3.5 VALVE AND SPECIALTIES INSTALLATION

- A. Install listed fire-protection valves, trim and drain valves, specialty valves and trim, controls, and specialties according to NFPA 13 and authorities having jurisdiction.
- B. Install listed fire-protection shutoff valves supervised open, located to control sources of water supply except from fire-department connections. Install permanent identification signs indicating portion of system controlled by each valve.
- C. Install check valve in each water-supply connection. Install backflow preventers instead of check valves in potable-water-supply sources.
- D. Specialty Valves:
 - 1. General Requirements: Install in vertical position for proper direction of flow, in main supply to system.
 - 2. Dry-Pipe Valves: Install trim sets for air supply, drain, priming level, alarm connections, ball drip valves, pressure gages, priming chamber attachment, and fill-line attachment.
 - a. Install air compressor and compressed-air supply piping.
 - b. Air-Pressure Maintenance Device: Install shutoff valves to permit servicing without shutting down sprinkler system; bypass valve for quick system filling; pressure regulator or switch to maintain system pressure; strainer; pressure ratings with 14- to 60-psig adjustable range; and 175-psig maximum inlet pressure.

3.6 SPRINKLER INSTALLATION

- A. Install sprinklers in suspended ceilings in center of acoustical ceiling panels.
- B. Install standard upright sprinklers and dry-type pendent and sidewall sprinklers..

3.7 IDENTIFICATION

- A. Install labeling and pipe markers on equipment and piping according to requirements in NFPA 13.
- B. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION."

3.8 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
 - 1. Leak Test: After installation, charge systems and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 3. Flush, test, and inspect sprinkler systems according to NFPA 13, "Systems Acceptance" Chapter.
 - 4. Energize circuits to electrical equipment and devices.
 - 5. Start and run air compressors.
 - 6. Coordinate with fire-alarm tests. Operate as required.
 - 7. Coordinate with fire-pump tests. Operate as required.
 - 8. Verify that equipment hose threads are same as local fire-department equipment.
- C. Sprinkler piping system will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.9 CLEANING

- A. Clean dirt and debris from sprinklers.
- B. Remove and replace sprinklers with paint other than factory finish.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain specialty valves.

3.11 PIPING SCHEDULE

- A. Underground piping: High Density Polyethylene Pipe (HDPE) with HDPE fittings, and fused joints.
- B. Aboveground piping between Fire-Department Connections and Check Valves: Galvanized, standard-weight steel pipe with grooved ends; grooved-end fittings; grooved-end-pipe couplings; and grooved joints.
- C. Sprinkler specialty fittings may be used, downstream of control valves, instead of specified fittings.
- D. Standard-pressure, dry-pipe sprinkler system, NPS 2 and smaller, shall be the following:
 - 1. Schedule 40, galvanized-steel pipe with cut-grooved ends; galvanized, grooved-end fittings for steel piping; grooved-end-pipe couplings for steel piping; and grooved joints.
- E. Standard-pressure, dry-pipe sprinkler system, NPS 2-1/2 and larger, shall be the following:
 - 1. Schedule 40, galvanized-steel pipe with cut-grooved ends; galvanized, grooved-end fittings for steel piping; grooved-end-pipe couplings for steel piping; and grooved joints.

3.12 SPRINKLER SCHEDULE

- A. Use sprinkler types in subparagraphs below for the following applications:
 - 1. Rooms without Ceilings: Upright sprinklers.
 - 2. Rooms with Suspended Ceilings: Dry pendent, recessed, flush, and concealed sprinklers as indicated.
 - 3. Wall Mounting: Dry sidewall, recessed sprinklers.
 - 4. Spaces Subject to Freezing: Upright, dry pendent sprinklers; and dry sidewall sprinklers as indicated.
- B. Provide sprinkler types in subparagraphs below with finishes indicated.
 - 1. Concealed Pendent Sprinklers: Rough brass, with factory-painted cover plate to match ceiling, 155 degree °F, quick response, Tyco DS-C or approved other.
 - 2. Recessed Pendent Sprinklers: Bright chrome, with bright chrome escutcheon, 155 degree °F, quick response, Reliable Model F3QR or approved other.
 - 3. Recessed Sidewall Sprinklers: Bright chrome, with bright chrome escutcheon, 155 degree °F, quick response, Reliable Model F3QR or approved other.
 - 4. Upright Sprinklers: Chrome plated in finished spaces exposed to view; rough bronze in unfinished spaces not exposed to view. 155 degree °F, quick response, Viking Microfast or approved other.
 - 5. Notwithstanding the above selections, in areas subject to higher temperatures, including within proximity to radiant heaters or other heat sources, provide high-temperature heads of types and trim to suit the installation.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15940

SEQUENCE OF OPERATION FOR HVAC SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 WORK INCLUDED

- A. This section includes the following:
 - 1. Sequences of Operation for HVAC systems and related systems of other trades.
- B. Related Sections include the following:
 - 1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
 - 2. Section 15077 – IDENTIFICATION FOR PIPING AND EQUIPMENT
 - 3. Section 15739 – SPLIT-SYSTEM AIR-CONDITIONING UNITS
 - 4. Section 15765 – ELECTRIC RESISTANCE AIR COILS
 - 5. Section 15791 –CABINET UNIT HEATERS
 - 6. Section 15792 – PROPELLER UNIT HEATERS
 - 7. Section 15798 – FINNED TUBE RADIATION HEATERS
 - 8. Section 15838 – POWER VENTILATORS
 - 9. Section 15900 "HVAC INSTRUMENTATION AND CONTROLS"
 - 10. Section 15950 – TESTING, ADJUSTING AND BALANCING

1.3 SUMMARY

- A. This Section includes control sequences for HVAC systems, subsystems, and equipment.
- B. This section is not intended to enumerate every system or function possible, but is intended to convey typical principles to be used across the project. The Design-Builder shall be responsible to create, design and deliver appropriate system functions to the convenience and satisfaction of the Owner.
- C. All systems and single-component systems designed and installed for this project shall have associated controls devices, sensors and control sequences applicable to each system, function and schedule, including alarms.
- D. Except for utility rooms and spaces which have stand-alone heaters for minimum baseline heating functions, all systems shall have a timeclock function to enact occupied/unoccupied set-point schedules, optimum start times for energy management and occupant comfort.
- E. All spaces where piped water is located shall have temperature sensors and alarms to broadcast presence of water leakage and low temperatures (40 degrees F. adjustable) via the SCADA system to the Operations Command Center (OCC) at 45 High Street, Boston.

- F. All spaces with requirements for cooling/heat removal shall have appropriate thermostats, sensors, dampers, fans, secondary staging of mechanical cooling and reversal of sequences in stages upon satisfaction. High temperatures outside of range for critical spaces, including substations, electrical closets and tel-data rooms shall be alarmed via the SCADA system to the Operations Command Center (OCC)45 High Street.
- G. Include initiation of redundant systems upon failure of any primary system. Rotate redundant/standby systems to assure equal hours of use on a periodic basis.
- H. Controls for energy efficiency and optimization shall be used. Use outside air for cooling when available. Reserve mechanical cooling for when outside air cooling is insufficient or not compatible with the process. Controls shall optimize energy use while maintaining space conditions. Variable capacity systems shall be favored over staged systems and staged systems shall be favored over fixed-capacity systems. Limit the use of outside ventilation air in mixed air systems, based on carbon dioxide concentrations in the spaces compared to ambient outside carbon dioxide.
- I. All such sequences shall be demonstrated to be repeatable and be integrated with the network and user interface including graphics.

1.4 DEFINITIONS

- A. DDC: Direct digital control.

1.5 SEQUENCE OF OPERATIONS

- A. The Design-Builder shall furnish appropriate sequences of operation for review for each system proposed on the project.
- B. Every system and sub-system including stand-alone heating and cooling units, shall have an associated Sequence of Operation.
- C. Every complex system with separate but cooperative sub-systems (e.g. boilers and related pumps, fans and related terminal units, energy recovery and related dampers and fans), shall have Sequences of Operation in sufficient detail to clearly describe interactions between components including limiting and extending logic arguments and exceptions.

PART 2 - PRODUCTS

Not Used.

PART 3 - EXECUTION

Not Used.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A.** Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15950

TESTING, ADJUSTING, AND BALANCING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

RELATED SECTIONS:

1. Section 15050 – BASIC MATERIALS AND METHODS FOR HVAC WORK
2. Section 15086 – DUCT INSULATION
3. Section 15088 – HVAC PIPING INSULATION
4. Section 15739 – SPLIT SYSTEM AIR CONDITIONING UNITS
5. Section 15765 – ELECTRIC RESISTANCE AIR COILS
6. Section 15791 – CABINET UNIT HEATER
7. Section 15792 – PROPELLER UNIT HEATERS
8. Section 15815 – METAL DUCTS
9. Section 15816 – NONMETAL DUCTS
10. Section 15820 – DUCT ACCESSORIES
11. Section 15838 – POWER VENTILATORS
12. Section 15855 – DIFFUSERS, REGISTERS, AND GRILLES

1.2 SUMMARY

- A. Section Includes:

1. Balancing Air Systems:
 - a. Constant-volume air systems.
 - b. Variable-air-volume systems.
2. Balancing Hydronic Piping Systems:
 - a. Constant-flow hydronic systems.
 - b. Variable-flow hydronic systems.
 - c. Primary-secondary hydronic systems.

1.3 DEFINITIONS

- A. AABC: Associated Air Balance Council.
- B. ASHRAE: American Society of Heating, Refrigeration and Air Conditioning Engineers.
- C. ICB: International Certification Board
- D. NEBB: National Environmental Balancing Bureau.

- E. TAB: Testing, adjusting, and balancing.
- F. TABB: Testing, Adjusting, and Balancing Bureau.
- G. TAB Specialist: An entity engaged to perform TAB Work.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: Within 45 days of Contractor's Notice to Proceed, submit documentation that the TAB contractor and this Project's TAB team members meet the qualifications specified in "Quality Assurance" Article.
- B. Contract Documents Examination Report: Within 45 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.
- C. Strategies and Procedures Plan: Within 90 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.
- D. Certified TAB reports.
- E. Sample report forms.
- F. Instrument calibration reports, to include the following:
 - 1. Instrument type and make.
 - 2. Serial number.
 - 3. Application.
 - 4. Dates of use.
 - 5. Dates of calibration.

1.5 QUALITY ASSURANCE

- A. TAB Contractor Qualifications: Engage a TAB entity certified by AABC, TABB or NEBB.
 - 1. TAB Field Supervisor: Employee of the TAB contractor and certified by AABC, TABB or NEBB.
 - 2. TAB Technician: Employee of the TAB contractor and who is certified by AABC, TABB or NEBB as a TAB technician.
- B. TAB Conference: Meet with Commissioning Authority on approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Require the participation of the TAB field supervisor and technicians. Provide seven days' advance notice of scheduled meeting time and location. Coordinate requirements in subparagraphs below with Section 01310 "PROJECT MANAGEMENT AND COORDINATION."
 - 1. Agenda Items:
 - a. The Contract Documents examination report.
 - b. The TAB plan.
 - c. Coordination and cooperation of trades and subcontractors.
 - d. Coordination of documentation and communication flow.

- C. Certify TAB field data reports and perform the following:
 - 1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
 - 2. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.
- D. TAB Report Forms: Use standard TAB contractor's forms approved by Commissioning Authority.
- E. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."
- F. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 7.2.2 - "Air Balancing."
- G. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3 - "System Balancing."

1.6 COORDINATION

- A. Notice: Provide seven days' notice for each test. Include scheduled test dates and times.
- B. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

PART 2 - PRODUCTS

(Not Applicable)

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.
- B. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.
- C. Examine the approved submittals for HVAC systems and equipment.
- D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.
- E. Examine equipment performance data including fan and pump curves.

1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
 2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.
- F. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
- G. Examine test reports specified in individual system and equipment Sections.
- H. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.
- I. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.
- J. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.
- K. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
- L. Examine system pumps to ensure absence of entrained air in the suction piping.
- M. Examine operating safety interlocks and controls on HVAC equipment.
- N. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

- A. Prepare a TAB plan that includes strategies and step-by-step procedures.
- B. Complete system-readiness checks and prepare reports. Verify the following:
1. Permanent electrical-power wiring is complete.
 2. Hydronic systems are filled, clean, and free of air.
 3. Automatic temperature-control systems are operational.
 4. Equipment and duct access doors are securely closed.
 5. Balance, smoke, and fire dampers are open.
 6. Isolating and balancing valves are open and control valves are operational.
 7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
 8. Windows and doors can be closed so indicated conditions for system operations can be met.

3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

- A. Perform testing and balancing procedures on each system according to the procedures contained in the TAB specialist's parent governing organization, including AABC's "National Standards for Total System Balance" or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems", ICB/TABB and in this Section. The selected standards shall be stated in the submittal of sample forms and qualifications.
- B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.
 - 1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
 - 2. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Section 15086 "DUCT INSULATION," Section 15087 "HVAC EQUIPMENT INSULATION," and Section 15088 "HVAC PIPING INSULATION."
- C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
- D. Take and report testing and balancing measurements in inch-pound (IP) units.

3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

- A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.
- B. Prepare schematic diagrams of systems' "as-built" duct layouts.
- C. For variable-air-volume systems, develop a plan to simulate diversity.
- D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.
- E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.
- F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
- G. Verify that motor starters are equipped with properly sized thermal protection.
- H. Check dampers for proper position to achieve desired airflow path.
- I. Check for airflow blockages.
- J. Check condensate drains for proper connections and functioning.
- K. Check for proper sealing of air-handling-unit components.
- L. Verify that air duct system is sealed as specified in Section 15815 "METAL DUCTS."

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

- A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
1. Measure total airflow.
 - a. Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.
 2. Measure fan static pressures as follows to determine actual static pressure:
 - a. Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
 - b. Measure static pressure directly at the fan outlet or through the flexible connection.
 - c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
 - d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.
 3. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.
 - a. Report the cleanliness status of filters and the time static pressures are measured.
 4. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
 5. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
 6. Obtain approval from Commissioning Authority for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
 7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.
- B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.
1. Measure airflow of submain and branch ducts.
 - a. Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.
 2. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.

3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.
- C. Measure air outlets and inlets without making adjustments.
1. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.
- D. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.
1. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
 2. Adjust patterns of adjustable outlets for proper distribution without drafts.

3.6 PROCEDURES FOR VARIABLE-AIR-VOLUME SYSTEMS

- A. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
- B. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
1. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.
 2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
 3. Measure total system airflow. Adjust to within indicated airflow.
 4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
 5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.
 - a. If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
 6. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.

- a. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.
- 7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
- 8. Record final fan-performance data.

3.7 GENERAL PROCEDURES FOR HYDRONIC SYSTEMS

- A. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate. Correct variations that exceed plus or minus 5 percent.
- B. Prepare schematic diagrams of systems' "as-built" piping layouts.
- C. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:
 - 1. Open all manual valves for maximum flow.
 - 2. Check liquid level in expansion tank.
 - 3. Check makeup water-station pressure gage for adequate pressure for highest vent.
 - 4. Check flow-control valves for specified sequence of operation, and set at indicated flow.
 - 5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
 - 6. Set system controls so automatic valves are wide open to heat exchangers.
 - 7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
 - 8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

3.8 PROCEDURES FOR CONSTANT-FLOW HYDRONIC SYSTEMS

- A. Measure water flow at pumps. Use the following procedures except for positive-displacement pumps:
 - 1. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
 - a. If impeller sizes must be adjusted to achieve pump performance, obtain approval from Commissioning Authority and comply with requirements in Section 15185 "HYDRONIC PUMPS."
 - 2. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
 - a. Monitor motor performance during procedures and do not operate motors in overload conditions.

3. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
 4. Report flow rates that are not within plus or minus 10 percent of design.
- B. Measure flow at all automatic flow control valves to verify that valves are functioning as designed.
 - C. Measure flow at all pressure-independent characterized control valves, with valves in fully open position, to verify that valves are functioning as designed.
 - D. Set calibrated balancing valves, if installed, at calculated presettings.
 - E. Measure flow at all stations and adjust, where necessary, to obtain first balance.
 1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.
 - F. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than indicated flow.
 - G. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:
 1. Determine the balancing station with the highest percentage over indicated flow.
 2. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
 3. Record settings and mark balancing devices.
 - H. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.
 - I. Measure the differential-pressure-control-valve settings existing at the conclusion of balancing.
 - J. Check settings and operation of each safety valve. Record settings.

3.9 PROCEDURES FOR VARIABLE-FLOW HYDRONIC SYSTEMS

- A. Balance systems with automatic two-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

3.10 PROCEDURES FOR PRIMARY-SECONDARY HYDRONIC SYSTEMS

- A. Balance the primary circuit flow first and then balance the secondary circuits.

3.11 PROCEDURES FOR HEAT EXCHANGERS

- A. Measure water flow through all circuits.

- B. Adjust water flow to within specified tolerances.
- C. Measure inlet and outlet water temperatures.
- D. Check settings and operation of safety and relief valves. Record settings.

3.12 PROCEDURES FOR MOTORS

- A. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:
 - 1. Manufacturer's name, model number, and serial number.
 - 2. Motor horsepower rating.
 - 3. Motor rpm.
 - 4. Efficiency rating.
 - 5. Nameplate and measured voltage, each phase.
 - 6. Nameplate and measured amperage, each phase.
 - 7. Starter thermal-protection-element rating.
- B. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

3.13 PROCEDURES FOR CONDENSING UNITS

- A. Verify proper rotation of fans.
- B. Measure entering- and leaving-air temperatures.
- C. Record compressor data.

3.14 PROCEDURES FOR BOILERS

- A. Hydronic Boilers: Measure and record entering- and leaving-water temperatures and water flow, pressures, pressure drops.

3.15 PROCEDURES FOR HEAT-TRANSFER COILS

- A. Measure, adjust, and record the following data for each water coil:
 - 1. Entering- and leaving-water temperature.
 - 2. Water flow rate.
 - 3. Water pressure drop.
 - 4. Dry-bulb temperature of entering and leaving air.
 - 5. Wet-bulb temperature of entering and leaving air for cooling coils.
 - 6. Airflow.
 - 7. Air pressure drop.
- B. Measure, adjust, and record the following data for each electric heating coil:

1. Nameplate data.
2. Airflow.
3. Entering- and leaving-air temperature at full load.
4. Voltage and amperage input of each phase at full load and at each incremental stage.
5. Calculated kilowatt at full load.
6. Fuse or circuit-breaker rating for overload protection.

C. Measure, adjust, and record the following data for each refrigerant coil:

1. Dry-bulb temperature of entering and leaving air.
2. Wet-bulb temperature of entering and leaving air.
3. Airflow.
4. Air pressure drop.
5. Refrigerant suction pressure and temperature.

3.16 TOLERANCES

A. Set HVAC system's air flow rates and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 5 percent.
2. Air Outlets and Inlets: Plus or minus 5 percent.
3. Heating-Water Flow Rate: Plus or minus 5 percent.

3.17 REPORTING

- A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.
- B. Status Reports: Prepare biweekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.18 FINAL REPORT

- A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.
1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
 2. Include a list of instruments used for procedures, along with proof of calibration.
- B. Final Report Contents: In addition to certified field-report data, include the following:
1. Pump curves.
 2. Fan curves.
 3. Manufacturers' test data.

4. Field test reports prepared by system and equipment installers.
 5. Other information relative to equipment performance; do not include Shop Drawings and product data.
- C. General Report Data: In addition to form titles and entries, include the following data:
1. Title page.
 2. Name and address of the TAB contractor.
 3. Project name.
 4. Project location.
 5. Architect's name and address.
 6. Engineer's name and address.
 7. Contractor's name and address.
 8. Report date.
 9. Signature of TAB supervisor who certifies the report.
 10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
 11. Summary of contents including the following:
 - a. Indicated versus final performance.
 - b. Notable characteristics of systems.
 - c. Description of system operation sequence if it varies from the Contract Documents.
 12. Nomenclature sheets for each item of equipment.
 13. Data for terminal units, including manufacturer's name, type, size, and fittings.
 14. Notes to explain why certain final data in the body of reports vary from indicated values.
 15. Test conditions for fans and pump performance forms including the following:
 - a. Settings for outdoor-, return-, and exhaust-air dampers.
 - b. Conditions of filters.
 - c. Cooling coil, wet- and dry-bulb conditions.
 - d. Face and bypass damper settings at coils.
 - e. Fan drive settings including settings and percentage of maximum pitch diameter.
 - f. Inlet vane settings for variable-air-volume systems.
 - g. Settings for supply-air, static-pressure controller.
 - h. Other system operating conditions that affect performance.
- D. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
1. Quantities of outdoor, supply, return, and exhaust airflows.
 2. Water and steam flow rates.
 3. Duct, outlet, and inlet sizes.
 4. Pipe and valve sizes and locations.
 5. Terminal units.
 6. Balancing stations.
 7. Position of balancing devices.
- E. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:
1. Unit Data:
 - a. Unit identification.

- b. Location.
- c. Make and type.
- d. Model number and unit size.
- e. Manufacturer's serial number.
- f. Unit arrangement and class.
- g. Discharge arrangement.
- h. Sheave make, size in inches, and bore.
- i. Center-to-center dimensions of sheave, and amount of adjustments in inches.
- j. Number, make, and size of belts.
- k. Number, type, and size of filters.

2. Motor Data:

- a. Motor make, and frame type and size.
- b. Horsepower and rpm.
- c. Volts, phase, and hertz.
- d. Full-load amperage and service factor.
- e. Sheave make, size in inches, and bore.
- f. Center-to-center dimensions of sheave, and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):

- a. Total air flow rate in cfm.
- b. Total system static pressure in inches wg.
- c. Fan rpm.
- d. Discharge static pressure in inches wg.
- e. Filter static-pressure differential in inches wg.
- f. Preheat-coil static-pressure differential in inches wg.
- g. Cooling-coil static-pressure differential in inches wg.
- h. Heating-coil static-pressure differential in inches wg.
- i. Outdoor airflow in cfm.
- j. Return airflow in cfm.
- k. Outdoor-air damper position.
- l. Return-air damper position.
- m. Vortex damper position.

F. Apparatus-Coil Test Reports:

1. Coil Data:

- a. System identification.
- b. Location.
- c. Coil type.
- d. Number of rows.
- e. Fin spacing in fins per inch o.c.
- f. Make and model number.
- g. Face area in sq. ft..
- h. Tube size in NPS.
- i. Tube and fin materials.
- j. Circuiting arrangement.

2. Test Data (Indicated and Actual Values):

- a. Air flow rate in cfm.
- b. Average face velocity in fpm.
- c. Air pressure drop in inches wg.
- d. Outdoor-air, wet- and dry-bulb temperatures in deg F.
- e. Return-air, wet- and dry-bulb temperatures in deg F.
- f. Entering-air, wet- and dry-bulb temperatures in deg F.
- g. Leaving-air, wet- and dry-bulb temperatures in deg F.
- h. Water flow rate in gpm.
- i. Water pressure differential in feet of head or psig.
- j. Entering-water temperature in deg F.
- k. Leaving-water temperature in deg F.
- l. Refrigerant expansion valve and refrigerant types.
- m. Refrigerant suction pressure in psig.
- n. Refrigerant suction temperature in deg F.
- o. Inlet steam pressure in psig.

G. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:

1. Unit Data:

- a. System identification.
- b. Location.
- c. Make and type.
- d. Model number and unit size.
- e. Manufacturer's serial number.
- f. Fuel type in input data.
- g. Output capacity in Btu/h.
- h. Ignition type.
- i. Burner-control types.
- j. Motor horsepower and rpm.
- k. Motor volts, phase, and hertz.
- l. Motor full-load amperage and service factor.
- m. Sheave make, size in inches, and bore.
- n. Center-to-center dimensions of sheave, and amount of adjustments in inches.

2. Test Data (Indicated and Actual Values):

- a. Total air flow rate in cfm.
- b. Entering-air temperature in deg F.
- c. Leaving-air temperature in deg F.
- d. Air temperature differential in deg F.
- e. Entering-air static pressure in inches wg.
- f. Leaving-air static pressure in inches wg.
- g. Air static-pressure differential in inches wg.
- h. Low-fire fuel input in Btu/h.
- i. High-fire fuel input in Btu/h.
- j. Manifold pressure in psig.
- k. High-temperature-limit setting in deg F.
- l. Operating set point in Btu/h.
- m. Motor voltage at each connection.
- n. Motor amperage for each phase.

- o. Heating value of fuel in Btu/h.
- H. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:
- 1. Unit Data:
 - a. System identification.
 - b. Location.
 - c. Coil identification.
 - d. Capacity in Btu/h.
 - e. Number of stages.
 - f. Connected volts, phase, and hertz.
 - g. Rated amperage.
 - h. Air flow rate in cfm.
 - i. Face area in sq. ft..
 - j. Minimum face velocity in fpm.
 - 2. Test Data (Indicated and Actual Values):
 - a. Heat output in Btu/h.
 - b. Air flow rate in cfm.
 - c. Air velocity in fpm.
 - d. Entering-air temperature in deg F.
 - e. Leaving-air temperature in deg F.
 - f. Voltage at each connection.
 - g. Amperage for each phase.
- I. Fan Test Reports: For supply, return, and exhaust fans, include the following:
- 1. Fan Data:
 - a. System identification.
 - b. Location.
 - c. Make and type.
 - d. Model number and size.
 - e. Manufacturer's serial number.
 - f. Arrangement and class.
 - g. Sheave make, size in inches, and bore.
 - h. Center-to-center dimensions of sheave, and amount of adjustments in inches.
 - 2. Motor Data:
 - a. Motor make, and frame type and size.
 - b. Horsepower and rpm.
 - c. Volts, phase, and hertz.
 - d. Full-load amperage and service factor.
 - e. Sheave make, size in inches, and bore.
 - f. Center-to-center dimensions of sheave, and amount of adjustments in inches.
 - g. Number, make, and size of belts.
 - 3. Test Data (Indicated and Actual Values):

- a. Total airflow rate in cfm.
- b. Total system static pressure in inches wg.
- c. Fan rpm.
- d. Discharge static pressure in inches wg.
- e. Suction static pressure in inches wg.

J. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:

1. Report Data:

- a. System and air-handling-unit number.
- b. Location and zone.
- c. Traverse air temperature in deg F.
- d. Duct static pressure in inches wg.
- e. Duct size in inches.
- f. Duct area in sq. ft..
- g. Indicated air flow rate in cfm.
- h. Indicated velocity in fpm.
- i. Actual air flow rate in cfm.
- j. Actual average velocity in fpm.
- k. Barometric pressure in psig.

K. Air-Terminal-Device Reports:

1. Unit Data:

- a. System and air-handling unit identification.
- b. Location and zone.
- c. Apparatus used for test.
- d. Area served.
- e. Make.
- f. Number from system diagram.
- g. Type and model number.
- h. Size.
- i. Effective area in sq. ft..

2. Test Data (Indicated and Actual Values):

- a. Air flow rate in cfm.
- b. Air velocity in fpm.
- c. Preliminary air flow rate as needed in cfm.
- d. Preliminary velocity as needed in fpm.
- e. Final air flow rate in cfm.
- f. Final velocity in fpm.
- g. Space temperature in deg F.

L. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:

1. Unit Data:

- a. System and air-handling-unit identification.
- b. Location and zone.

- c. Room or riser served.
 - d. Coil make and size.
 - e. Flowmeter type.
2. Test Data (Indicated and Actual Values):
- a. Air flow rate in cfm.
 - b. Entering-water temperature in deg F.
 - c. Leaving-water temperature in deg F.
 - d. Water pressure drop in feet of head or psig.
 - e. Entering-air temperature in deg F.
 - f. Leaving-air temperature in deg F.
- M. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:
1. Unit Data:
- a. Unit identification.
 - b. Location.
 - c. Service.
 - d. Make and size.
 - e. Model number and serial number.
 - f. Water flow rate in gpm.
 - g. Water pressure differential in feet of head or psig.
 - h. Required net positive suction head in feet of head or psig.
 - i. Pump rpm.
 - j. Impeller diameter in inches.
 - k. Motor make and frame size.
 - l. Motor horsepower and rpm.
 - m. Voltage at each connection.
 - n. Amperage for each phase.
 - o. Full-load amperage and service factor.
 - p. Seal type.
2. Test Data (Indicated and Actual Values):
- a. Static head in feet of head or psig.
 - b. Pump shutoff pressure in feet of head or psig.
 - c. Actual impeller size in inches.
 - d. Full-open flow rate in gpm.
 - e. Full-open pressure in feet of head or psig.
 - f. Final discharge pressure in feet of head or psig.
 - g. Final suction pressure in feet of head or psig.
 - h. Final total pressure in feet of head or psig.
 - i. Final water flow rate in gpm.
 - j. Voltage at each connection.
 - k. Amperage for each phase.
- N. Instrument Calibration Reports:
1. Report Data:

- a. Instrument type and make.
- b. Serial number.
- c. Application.
- d. Dates of use.
- e. Dates of calibration.

3.19 INSPECTIONS

A. Initial Inspection:

- 1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
- 2. Check the following for each system:
 - a. Measure airflow of at least 10 percent of air outlets.
 - b. Measure water flow of at least 5 percent of terminals.
 - c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
 - d. Verify that balancing devices are marked with final balance position.
 - e. Note deviations from the Contract Documents in the final report.

B. Final Inspection:

- 1. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by Construction Manager.
- 2. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of Construction Manager.
- 3. Construction Manager shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.
- 4. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
- 5. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

C. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

- 1. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
- 2. If the second final inspection also fails, Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

D. Prepare test and inspection reports.

3.20 ADDITIONAL TESTS

- A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.
- B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 15967

CLEAN-AGENT FIRE-EXTINGUISHING SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Piping and piping specialties.
 - 2. Extinguishing-agent containers.
 - 3. Extinguishing agent.
 - 4. Detection and alarm devices.
 - 5. Control and alarm panels.
 - 6. Accessories.
 - 7. Connection devices for and wiring between system components.
 - 8. Connection devices for power and integration into building's fire-alarm system.

1.3 DEFINITIONS

- A. ATS: Acceptance Testing Specifications.
- B. EPO: Emergency Power Off.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For clean-agent fire-extinguishing system designed by a NICET III certified individual and signed and sealed by a qualified professional engineer.
 - 1. Include plans, elevations, sections, details, and attachments to other work.
 - 2. Include design calculations.
 - 3. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 4. Wiring Diagrams: For power, signal, and control wiring.
- C. Delegated-Design Submittal: For clean-agent fire-extinguishing system designed by a NICET III certified individual and signed and sealed by a qualified professional engineer.
 - 1. Indicate compliance with performance requirements and design criteria, including analysis data.

2. Include design calculations for weight, volume, and concentration of extinguishing agent required for each hazard area.
3. Indicate the Following on Reflected Ceiling Plans:
 - a. Ceiling penetrations and ceiling-mounted items.
 - b. Extinguishing-agent containers if mounted above floor, piping and discharge nozzles, detectors, and accessories.
 - c. Method of attaching hangers to building structure.
 - d. Other ceiling-mounted items including light fixtures, diffusers, grilles, speakers, sprinklers, and access panels.
4. Indicate the Following on Occupied Work Area Plans:
 - a. Controls and alarms.
 - b. Extinguishing-agent containers, piping and discharge nozzles if mounted in space, detectors, and accessories.
 - c. Equipment and furnishings.
5. Indicate the Following on Access Floor Space Plans:
 - a. Extinguishing-agent containers, piping and discharge nozzles, detectors, and accessories.
 - b. Method of supporting piping.
6. Indicate the Following on Ceiling Plans:
 - a. Extinguishing-agent containers, piping and discharge nozzles, detectors, and accessories.
 - b. Method of supporting piping.
 - c. Other equipment located in the ceiling space that is being protected including sprinkler piping, HVAC equipment, raceways, or conduit.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Sprinkler systems, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
 1. Domestic water piping.
 2. Items Penetrating Finished Ceiling Include the Following:
 - a. Lighting fixtures.
 - b. Air outlets and inlets.
- B. Permit Approved Drawings: Working plans, prepared according to NFPA 2001, that have been approved by authorities having jurisdiction. Include design calculations.
- C. Seismic Qualification Certificates: For extinguishing-agent containers and control panels from manufacturer.
 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For special agent system to include in emergency, operation, and maintenance manuals.
- B. As-Built Record Drawings: Update shop drawings to include all changes made during installation to provide as-built record drawings of all piping, equipment and systems installed.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents. Deliver extra materials to Owner.
 1. Detection Devices: Not less than 20 percent of amount of each type installed.
 2. Container Valves: Not less than 10 percent of amount of each size and type installed.
 3. Nozzles: Not less than 20 percent of amount of each type installed.
 4. Extinguishing Agent: Not less than 100 percent of amount installed in largest hazard area. Include pressure-rated containers with valves.

1.8 QUALITY ASSURANCE

- A. Installer Qualifications:
 1. Installer's responsibilities include designing, fabricating, and installing clean agent systems and providing professional engineering services needed to assume engineering responsibility.
 - a. Engineering Responsibility: Preparation of working plans, calculations, and field test reports by a NICET Level III certified individual and signed and sealed by a qualified professional engineer.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. NFPA Standards: Sprinkler system equipment, specialties, accessories, installation, and testing shall comply with the following:
 1. NFPA 2001, "Standard on Clean Agent Fire Extinguishing Systems."
- D. UL Compliance: Provide equipment listed in UL's "Fire Protection Equipment Directory."

PART 2 - PRODUCTS

2.1 CLEAN-AGENT SYSTEMS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. Ansul Incorporated.
 2. Chemetron Fire Systems; a UTC Fire & Security company.
 3. Fike Corporation.
 4. Pem All Fire Extinguisher Corporation; a division of Pem Systems Inc.
 5. Pyro-Chem.
 6. Siemens Building Technologies, Inc.; Fire Safety Division.
 7. Minimax USA LLC
- B. Description: Clean-agent fire-extinguishing system shall be an engineered system for total flooding of the hazard area including the room cavity above the ceiling, below the ceiling, and below a raised floor, depending on final facility configuration. System includes separate zones above and below the ceiling and beneath the raised floor. If smoke is detected below the raised floor, extinguishing agent shall be discharged in the underfloor zone only. If smoke is detected below the ceiling, extinguishing agent shall be discharged in zones above and below the ceiling and below the floor. If smoke is detected above the ceiling, extinguishing agent shall be discharged in the zone above the ceiling only.
- C. Delegated Design: Design clean-agent fire-extinguishing system and obtain approval from authorities having jurisdiction. Design system for Class C fires as appropriate for areas being protected, and include safety factor. Use clean agent indicated and in concentration suitable for normally occupied areas.
- D. Performance Requirements: Discharge FK-5-1-12 within 10 seconds and maintain 6.6 percent concentration by volume at 70 deg F for 10-minute holding time in hazard areas.
1. FK-5-1-12 concentration in hazard areas greater than 10.0 percent immediately after discharge or less than 6.5 percent throughout holding time will not be accepted without written authorization from Owner and authorities having jurisdiction.
 2. System Capabilities: Minimum 620-psig calculated working pressure and 360-psig initial charging pressure.
- E. Cross-Zoned Detection: Devices located in two separate zones. Sound alarm on activating single-detection device, and discharge extinguishing agent on actuating single-detection device in other zone.
- F. System Operating Sequence:
1. Actuating First Detector: Visual indication on annunciator panel. Energize audible and visual alarms (slow pulse), shut down air-conditioning and ventilating systems serving protected area, close doors in protected area, and send signal to fire-alarm system.
 2. Actuating Second Detector: Visual indication on annunciator panel. Energize audible and visual alarms (fast pulse), start time delay for extinguishing-agent discharge for 30 seconds, and discharge extinguishing agent.
 3. Extinguishing-agent discharge will operate audible alarms and strobe lights inside and outside the protected area.

- G. Manual stations shall immediately discharge extinguishing agent when activated.
- H. Operating abort switches will delay extinguishing-agent discharge while being activated, and switches must be reset to prevent agent discharge. Release of hand pressure on the switch will cause agent discharge if the time delay has expired.
- I. EPO: Will terminate power to protected equipment immediately on actuation.
- J. Low-Agent Pressure Switch: Initiate trouble alarm if sensing less than set pressure.
- K. Power Transfer Switch: Transfer from normal to stand-by power source.
- L. Seismic Performance: Fire-suppression piping and containers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2.2 PIPE AND FITTINGS

- A. Steel Pipe: ASTM A 53/A 53M, Type S, Grade B or ASTM A 106/A 106M, Grade B; Schedule 40, Schedule 80, and Schedule 160, seamless steel pipe.
 - 1. Threaded Fittings:
 - a. Malleable-Iron Fittings: ASME B16.3, Class 300.
 - b. Flanges and Flanged Fittings: ASME B16.5, Class 300 unless Class 600 is indicated.
 - c. Fittings Working Pressure: 620 psig minimum.
 - d. Flanged Joints: Class 300 minimum.
 - 2. Forged-Steel Welding Fittings: ASME B16.11, Class 3000, socket pattern.
 - 3. Steel, Grooved-End Fittings: FM Approved and NRTL listed, ASTM A 47/A 47M malleable iron or ASTM A 536 ductile iron, with dimensions matching steel pipe and ends factory grooved according to AWWA C606.
- B. Pipe-Flange Gasket Materials: Suitable for chemical and thermal conditions of piping system contents.
 - 1. ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.
- C. Flange Bolts and Nuts: ASME B18.2.1, carbon steel.
- D. Welding Filler Metals: Comply with AWS D10.12M/D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
- E. Steel, Keyed Couplings: UL 213, AWWA C606, approved or listed for clean-agent service, and matching steel-pipe dimensions. Include ASTM A 536, ductile-iron housing, rubber gasket, and steel bolts and nuts.

2.3 VALVES

- A. General Valve Requirements:
 - 1. UL listed or FM Approved for use in the designed fire-protection system.
 - 2. Compatible with type of clean agent used.
- B. Container Valves: With rupture disc or solenoid and manual-release lever, capable of immediate and total agent discharge and suitable for intended flow capacity.
- C. Valves in Sections of Closed Piping and Manifolds: Fabricate to prevent entrapment of liquid, or install valve and separate pressure relief device.
- D. Valves in Manifolds: Check valve; installed to prevent loss of extinguishing agent when container is removed from manifold.

2.4 EXTINGUISHING-AGENT CONTAINERS

- A. Description: Steel tanks complying with ASME Boiler and Pressure Vessel Code: Section VIII, for unfired pressure vessels. Include minimum working-pressure rating that matches system charging pressure, valve, pressure switch, and pressure gage.
 - 1. Finish: Manufacturer's standard color, enamel or epoxy paint.
 - 2. Manifold: Fabricate with valves, pressure switches, selector switch, and connections for main- and reserve-supply banks of multiple storage containers.
 - 3. Storage-Tank Brackets: Factory- or field-fabricated retaining brackets consisting of steel straps and channels; suitable for container support, maintenance, and tank refilling or replacement.

2.5 FIRE-EXTINGUISHING CLEAN AGENT

- A. FK-5-1-12 Clean Agent: Dodecafluoro-2-methylpentan-3-one.
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. 3M.

2.6 DISCHARGE NOZZLES

- A. Equipment manufacturer's standard one-piece brass or aluminum alloy of type, size, discharge pattern, and capacity required for application.

2.7 CONTROL PANELS

- A. Description: FM Approved or NRTL listed, including equipment and features required for testing, supervising, and operating fire-extinguishing system.

- B. Power Requirements: 120/240-V ac; with electrical contacts for connection to system components and fire-alarm system, and transformer or rectifier as needed to produce power at voltage required for accessories and alarm devices.
- C. Enclosure: NEMA ICS 6, Type 1, enameled-steel cabinet.
 - 1. Mounting: Surface.
- D. Supervised Circuits: Separate circuits for each independent hazard area.
 - 1. Detection circuits equal to the required number of zones, or addressable devices assigned to the required number of zones.
 - 2. Manual pull-station circuit.
 - 3. Alarm circuit.
 - 4. Release circuit.
 - 5. Abort circuit.
 - 6. EPO circuit.
- E. Control-Panel Features:
 - 1. Electrical contacts for shutting down fans, activating dampers, and operating system electrical devices.
 - 2. Automatic switchover to standby power at loss of primary power.
 - 3. Storage container, low-pressure indicator.
 - 4. Service disconnect to interrupt system operation for maintenance with visual status indication on the annunciator panel.
- F. Annunciator Panel: Graphic type showing protected, hazard-area plans, as well as locations of detectors and abort, EPO, and manual stations. Include lamps to indicate device-initiating alarm, electrical contacts for connection to control panel, and stainless-steel or aluminum enclosure.
- G. Standby Power: Sealed, valve-regulated, recombinant lead acid batteries with capacity to operate system for 24 hours and alarm for minimum of 15 minutes. Include automatic battery charger that has a varying charging rate between trickle and high depending on battery voltage, and that is capable of maintaining batteries fully charged. Include manual voltage control, dc voltmeter, dc ammeter, electrical contacts for connection to control panel, automatic transfer switch, and suitable enclosure.

2.8 DETECTION DEVICES

- A. General Requirements for Detection Devices:
 - 1. Comply with NFPA 2001, NFPA 72, and UL 268.
 - 2. 24-V dc, nominal.
- B. Photoelectric Detectors: LED light source and silicon photodiode receiving element.
- C. Signals to the Building Fire Alarm Control Panel: Any type of local system trouble is reported to the building fire alarm control panel as a composite "trouble" signal. Alarms on each system zone are individually reported to the central fire alarm control panel as separately identified zones.

2.9 MANUAL STATIONS

- A. General Description: Semirecessed FM Approved or NRTL listed, with clear plastic hinged cover, 120-V ac or low voltage compatible with controls. Include contacts for connection to control panel.
- B. Manual Release: "MANUAL RELEASE" caption, and red finish. Unit can manually discharge extinguishing agent with operating device that remains engaged until unlocked.
- C. Abort Switch: "ABORT" caption, momentary contact, with green finish.

2.10 SWITCHES

- A. Description: FM Approved or NRTL listed, where available, 120-V ac or low voltage compatible with controls. Include contacts for connection to control panel.
 - 1. Low-Agent Pressure Switches: Pneumatic operation.
 - 2. Power Transfer Switches: Key-operation selector, for transfer of release circuit signal from main supply to reserve supply.

2.11 ALARM DEVICES

- A. Description: Listed and labeled by an NRTL or FM Approved, low voltage, and surface mounting. Comply with requirements in Section 16705 "STATION FIRE ALARM SYSTEM" for alarm and monitoring devices.
- B. Bells: Minimum 6-inch diameter.
- C. Horns: 15 dBA above average ambient or 5 dBA above maximum ambient sound level, whichever is greater.
- D. Strobe Lights: Translucent lens, with "AGENT" or similar caption.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with hazard-area leakage requirements, installation tolerances, and other conditions affecting work performance.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 FK-5-1-12 AGENT PIPING APPLICATIONS

- A. Flanged pipe and fittings and flanged joints may be used to connect to specialties and accessories and where required for maintenance.
- B. NPS 2 and Smaller: Schedule 40, steel pipe; malleable-iron threaded fittings; and threaded joints.

- C. NPS 2-1/2 and Larger: Schedule 40, steel pipe; steel, grooved-end fittings; steel, keyed couplings; and grooved joints.

3.3 CLEAN-AGENT PIPING INSTALLATION

- A. Install clean-agent extinguishing piping and other components level and plumb, according to manufacturers' written instructions.
- B. Grooved Piping Joints: Groove pipe ends according to AWWA C606 dimensions. Assemble grooved-end steel pipe and steel, grooved-end fittings with steel, keyed couplings and lubricant according to manufacturer's written instructions.
- C. Install extinguishing-agent containers anchored to substrate.
- D. Install pipe and fittings, valves, and discharge nozzles according to requirements listed in NFPA 2001, Section "Distribution."
 - 1. Install valves designed to prevent entrapment of liquid, or install pressure relief devices in valved sections of piping systems.
 - 2. Support piping using supports and methods according to NFPA 13.
 - 3. Install seismic restraints for extinguishing-agent containers and piping systems.
 - 4. Install control panels, detection system components, alarms, and accessories, complying with requirements of NFPA 2001, Section "Detection, Actuation, and Control Systems," as required for supervised system application.

3.4 CONNECTIONS

- A. Drawings indicate general arrangement of piping, fittings, and specialties.
- B. Where installing piping adjacent to equipment, allow space for service and maintenance.
- C. Connect electrical devices to control panel and to building's fire-alarm system. Electrical power, wiring, and devices are specified in Section 16705 "STATION FIRE-ALARM SYSTEM".

3.5 IDENTIFICATION

- A. Identify system components and equipment. Comply with requirements for identification specified in Section 161195 "ELECTRICAL IDENTIFICATION."
- B. Identify piping, extinguishing-agent containers, other equipment, and panels according to NFPA 2001.
- C. Install signs at entry doors for protected areas to warn occupants that they are entering a room protected with a clean-agent fire-extinguishing system.
- D. Install signs at entry doors to advise persons outside the room the meaning of the horn(s), bell(s), and strobe light(s) outside the protected space.

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections.
 - 1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
- D. Tests and Inspections:
 - 1. After installing clean-agent extinguishing piping system and after electrical circuitry has been energized, test for compliance with requirements.
 - 2. Perform each electrical test and visual and mechanical inspection stated in NETA ATS, Sections "Inspection and Test Procedures" and "System Function Tests." Certify compliance with test parameters.
 - 3. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
 - 4. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Remove malfunctioning units, replace with new units, and retest.
 - 5. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- E. Units will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports.

3.7 CLEANING

- A. Each pipe section shall be cleaned internally after preparation and before assembly by means of swabbing, using a suitable nonflammable cleaner. Pipe network shall be free of particulate matter and oil residue before installing nozzles or discharge devices.

3.8 SYSTEM FILLING

- A. Preparation:
 - 1. Verify that piping system installation is completed and cleaned.
 - 2. Check for complete enclosure integrity.
 - 3. Check operation of ventilation and exhaust systems.
- B. Filling Procedures:
 - 1. Fill extinguishing-agent containers with extinguishing agent, and pressurize to indicated charging pressure.
 - 2. Install filled extinguishing-agent containers.

3. Energize circuits.
4. Adjust operating controls.

3.9 ENCLOSURE EVALUATION

A. Enclosure Integrity

1. Perform a visual survey of enclosure and correct any obvious points of failure prior to integrity test.
2. Perform a room integrity test in accordance with Annex C of NFPA 2001 to demonstrate acceptable leakage rates.
3. Correct any points of failure and repeat integrity test until acceptable results are achieved.
4. Provide documentation of test as part of closeout documentation.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain clean-agent fire-extinguishing systems.

PART 4 - MEASUREMENTS AND PAYMENTS

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment" .

END OF SECTION

SECTION 15974

FIRE-SUPPRESSION STANDPIPES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:

1. Pipes, fittings, and specialties.
2. Fire-protection specialty valves.
3. Hose connections.
4. Alarm devices.
5. Pressure gages.

- B. Related Requirements:

1. Section 16705 "STATION FIRE-ALARM SYSTEM" for connections to alarm devices.
2. Section 15930 "WET-PIPE FIRE-SUPPRESSION SPRINKLERS" for wet-pipe sprinkler piping.
3. Section 15935 "DRY-PIPE FIRE-SUPPRESSION SPRINKLERS" for dry-pipe sprinkler piping.

1.3 DEFINITIONS

- A. High-Pressure Standpipe Piping: Fire-suppression standpipe piping designed to operate at working pressure higher than standard 175 psig, but not higher than 300 psig.
- B. Standard-Pressure Standpipe Piping: Fire-suppression standpipe piping designed to operate at working pressure 175 psig maximum.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Shop Drawings: For fire-suppression standpipes.
 1. Include plans, elevations, sections, and attachment details.
 2. Include diagrams for power, signal, and control wiring.

- C. Delegated-Design Submittal: For standpipe systems indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Fire-suppression standpipes, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 - 1. Domestic water piping.
 - 2. Compressed-air piping.
 - 3. HVAC hydronic piping.
 - 4. Nitrogen piping.
 - 5. Architectural elements.
 - 6. Structural elements.
- B. Qualification Data: For Installer and professional engineer.
- C. Approved Standpipe Drawings: Working plans, prepared according to NFPA 14, that have been approved by authorities having jurisdiction, including hydraulic calculations.
- D. Welding certificates.
- E. Fire-hydrant flow test report.
- F. Field Test Reports and Certificates: Indicate and interpret test results for compliance with performance requirements and as described in NFPA 14. Include "Design-Builder's Material and Test Certificate for Aboveground Piping" and "Design-Builder's Material and Test Certificate for Underground Piping."
- G. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fire-suppression standpipes specialties to include in emergency, operation, and maintenance manuals.

1.7 QUALITY ASSURANCE

- A. Installer Qualifications:
 - 1. Installer's responsibilities include designing, fabricating, and installing fire-suppression standpipes and providing professional engineering services needed to assume engineering responsibility. Base calculations on results of fire-hydrant flow test.
 - a. Engineering Responsibility: Preparation of working plans, calculations, and field test reports by a NICET Level III certified individual and signed and sealed by a qualified professional engineer.

- B. Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- D. NFPA Standards: Fire-suppression standpipe equipment, specialties, accessories, installation, and testing shall comply with NFPA 14.

1.8 PROJECT CONDITIONS

- A. Interruption of Existing Services: Do not interrupt existing service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary fire-suppression standpipe service according to requirements indicated:
 - 1. Notify Owner no fewer than seven days in advance of proposed interruption of existing services.
 - 2. Do not proceed with interruption of existing services without Owner's written permission.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTIONS

- A. Manual Dry-Type, Class I Standpipe System: Includes NPS 2-1/2 hose connections. Does not have permanent water supply. Piping is dry. Water must be pumped into standpipes to satisfy demand.

2.2 PERFORMANCE REQUIREMENTS

- A. Standard-Pressure, Fire-Suppression Standpipe System Component: Listed for 175-psig minimum working pressure.
- B. High-Pressure, Fire-Suppression Standpipe System Component: Listed for 300-psig working pressure.
- C. Delegated Design: Design fire-suppression standpipes, including comprehensive engineering analysis by a NICET Level III certified individual and approved by a qualified professional engineer, using performance requirements and design criteria indicated.
 - 1. Design-Builder shall obtain hydrant flow data from the local water authority. Test shall have been performed within the last 12 months.
- D. Fire-suppression standpipe design shall be approved by authorities having jurisdiction.
 - 1. Minimum design flow of standpipe system:
 - a. 250 gallons per minute at the three most remote hose connections.
 - 2. Minimum residual pressure at each hose-connection outlet is as follows:
 - a. NPS 2-1/2 Hose Connections: 100 psig.

- E. Seismic Performance: Fire-suppression standpipes shall withstand the effects of earthquake motions determined according to NFPA 13 and ASCE/SEI 7.

2.3 PIPING MATERIALS

- A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, and fitting materials and for joining methods for specific services, service locations, and pipe sizes.

2.4 GALVANIZED-STEEL PIPE AND ASSOCIATED FITTINGS

- A. Schedule 40: ASTM A 53/A 53M, Type E, Grade B; with factory- or field-formed ends to accommodate joining method.
- B. Galvanized-Steel Pipe Nipples: ASTM A 733, made of ASTM A 53/A 53M or ASTM A 106/A 106M, Standard Weight, seamless steel pipe with threaded ends.
- C. Galvanized, Gray-Iron Threaded Fittings: ASME B16.4, Class 125, standard pattern.
- D. Malleable-Iron Unions:
 - 1. ASME B16.39, Class 150.
 - 2. Hexagonal-stock body.
 - 3. Ball-and-socket, metal-to-metal, bronze seating surface.
 - 4. Threaded ends.
- E. Flanges: ASME B16.1, Class 125, cast iron.
- F. Appurtenances for Grooved-End, Galvanized-Steel Pipe:
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Anvil International, Inc.
 - b. Grinnell Mechanical Products; Tyco Fire Products LP.
 - c. Shurjoint Piping Products.
 - d. Victaulic Company.
 - 2. Fittings for Grooved-End, Galvanized-Steel Pipe: Galvanized, ASTM A 47/A 47M, malleable-iron casting; ASTM A 106/A 106M, steel pipe; or ASTM A 536, ductile-iron casting; with dimensions matching steel pipe.
 - 3. Fittings for Grooved-End, Galvanized-Steel Pipe:
 - a. AWWA C606 for steel-pipe dimensions.
 - b. Ferrous housing sections.
 - c. EPDM-rubber gaskets suitable for hot and cold water.
 - d. Bolts and nuts.
 - e. Minimum Pressure Rating:
 - 1) NPS 8 and Smaller: 600 psig.
 - 2) NPS 10 and NPS 12: 400 psig.
 - NPS 14 to NPS 24: 250 psig.

2.5 HIGH DENSITY POLY ETHYLENE (HDPE)

- A. HDPE Pipe: FM Approved, ASTM 3350-02 with cell classification of 34554642, Class 200.
- B. HDPE Fittings: FM Approved, ASTM 3350-02 with cell classification of 34554642, Class 200.

2.6 PIPING JOINING MATERIALS

- A. Pipe-Flange Gasket Materials: AWWA C110, rubber, flat face, 1/8 inch thick or ASME B16.21, nonmetallic and asbestos free.
 - 1. Class 125, Cast-Iron Flanges and Class 150, Bronze Flat-Face Flanges: Full-face gaskets.
 - 2. Class 250, Cast-Iron Flanges and Class 300, Steel Raised-Face Flanges: Ring-type gaskets.
- B. Metal, Pipe-Flange Bolts and Nuts: ASME B18.2.1, carbon steel unless otherwise indicated.
- C. Brazing Filler Metals: AWS A5.8/A5.8M, BCuP Series, copper-phosphorus alloys for general-duty brazing unless otherwise indicated.
- D. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.

2.7 SPECIALTY VALVES

- A. General Requirements:
 - 1. Standard: UL's "Fire Protection Equipment Directory" listing or FM Global's "Approval Guide."
 - 2. Pressure Rating:
 - a. Standard-Pressure Piping Specialty Valves: 175 psig minimum.
 - b. High-Pressure Piping Specialty Valves: 250 psig minimum.
 - 3. Body Material: Cast or ductile iron.
 - 4. Size: Same as connected piping.
 - 5. End Connections: Flanged or grooved.
- B. Pressure-Reducing Valves:
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. CLA-VAL Automatic Control Valves.
 - b. Fire-End & Croker Corporation.
 - c. Fire Protection Products, Inc.
 - d. Guardian Fire Equipment, Inc.
 - e. OCV Control Valves.
 - f. Potter Roemer.
 - g. Zurn Plumbing Products Group; Wilkins Water Control Products Division.
 - 2. UL 668 hose valve, with integral UL 1468 reducing device.
 - 3. Pressure Rating: 300 psig minimum.

4. Material: Brass or bronze.
5. Inlet: Female pipe threads.
6. Outlet: Threaded with or without adapter having male hose threads.
7. Pattern: Angle.
8. Finish: Polished chrome-plated.

C. Automatic (Ball Drip) Drain Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
2. Standard: UL 1726.
3. Pressure Rating: 175 psig minimum.
4. Type: Automatic draining, ball check.
5. Size: NPS 3/4.
6. End Connections: Threaded.

2.8 HOSE CONNECTIONS

A. Nonadjustable-Valve Hose Connections:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Brooks Equipment Co., Inc.
 - b. Elkhart Brass Mfg. Company, Inc.
 - c. Fire-End & Croker Corporation.
 - d. Fire Protection Products, Inc.
 - e. GMR International Equipment Corporation.
 - f. Guardian Fire Equipment, Inc.
 - g. Kennedy Valve; a division of McWane, Inc.
 - h. Mueller Co.; Water Products Division.
 - i. NIBCO INC.
 - j. Potter Roemer.
 - k. Tyco Fire & Building Products LP.
 - l. Viking Corporation.
 - m. Wilson & Cousins Inc.
2. Standard: UL 668 hose valve for connecting fire hose.
3. Pressure Rating: 300 psig minimum.
4. Material: Brass or bronze.
5. Size: NPS 1-1/2 or NPS 2-1/2, as indicated.
6. Inlet: Female pipe threads.
7. Outlet: Male hose threads with lugged cap, gasket, and chain. Include hose valve threads according to NFPA 1963 and matching local fire-department threads.
8. Pattern: Angle.
9. Finish: Polished chrome-plated with red valve handle.

2.9 AIR RELEASE VALVE

A. Air Release Valves:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Cla-Val
 - b. Val-Matic
2. Standard: ANSI/AWWA C512-04 and FM Approved.
3. Pressure Rating: 300 psig minimum.
4. Body Material: Cast Iron, ASTM A-126, Class B.
5. Float and Internal Part Material: Stainless Steel T316.
6. Size: NPS 1-1/2 or NPS 2-1/2, as indicated.
 - a. Orifice: 3/32"
 - b. Inlet: 1"
 - c. Outlet: 1/2"
7. Inlet: Female pipe threads.
8. Outlet: Female pipe threads
9. Finish: Chrome.

2.10 ALARM DEVICES

A. Alarm-device types shall match piping and equipment connections.

B. Electrically Operated Alarm Bell:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire-Lite Alarms, Inc.; a Honeywell company.
 - b. Notifier; a Honeywell company.
 - c. Potter Electric Signal Company.
2. Standard: UL 464.
3. Type: Vibrating, metal alarm bell.
4. Size: 6-inch minimum diameter.
5. Finish: Red-enamel factory finish, suitable for outdoor use.

C. Pressure Switches:

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Barksdale, Inc.
 - b. Detroit Switch, Inc.
 - c. Potter Electric Signal Company.
 - d. System Sensor; a Honeywell company.
 - e. Tyco Fire & Building Products LP.

- f. United Electric Controls Co.
 - g. Viking Corporation.
2. Standard: UL 346.
 3. Type: Electrically supervised water-flow switch with retard feature.
 4. Components: Single-pole, double-throw switch with normally closed contacts.
 5. Design Operation: Rising pressure signals water flow.
- D. Valve Supervisory Switches:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Fire-Lite Alarms, Inc.; a Honeywell company.
 - b. Kennedy Valve; a division of McWane, Inc.
 - c. Potter Electric Signal Company.
 - d. System Sensor; a Honeywell company.
 2. Standard: UL 346.
 3. Type: Electrically supervised.
 4. Components: Single-pole, double-throw switch with normally closed contacts.
 5. Design: Signals that controlled valve is in other than fully open position.
- E. Indicator-Post Supervisory Switches:
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Potter Electric Signal Company.
 - b. System Sensor; a Honeywell company.
 2. Standard: UL 346.
 3. Type: Electrically supervised.
 4. Components: Single-pole, double-throw switch with normally closed contacts.
 5. Design: Signals that controlled indicator-post valve is in other than fully open position.

2.11 PRESSURE GAGES

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. AMETEK; U.S. Gauge Division.
 2. Ashcroft Inc.
 3. Brecco Corporation.
 4. WIKA Instrument Corporation.
- B. Standard: UL 393.
- C. Dial Size: 3-1/2- to 4-1/2-inch diameter.
- D. Pressure Gage Range: Zero to 300 psig.

- E. Water System Piping Gage: Include "WATER" or "AIR/WATER" label on dial face.
- F. Air System Piping Gage: Include "AIR" or "AIR/WATER" label on dial face.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Perform fire-hydrant flow test according to NFPA 14 and NFPA 291. Use results for system design calculations required in "Quality Assurance" Article.
- B. Report test results promptly and in writing.

3.2 EXAMINATION

- A. Examine roughing-in for hose connections and stations to verify actual locations of piping connections before installation.
- B. Examine walls and partitions for suitable thickness, fire- and smoke-rated construction, framing for hose-station cabinets, and other conditions where hose connections and stations are to be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.3 PIPING INSTALLATION

- A. Locations and Arrangements: Drawing plans, schematics, and diagrams indicate general location and arrangement of piping. Install piping as indicated, as far as practical.
 - 1. Deviations from approved working plans for piping require written approval from authorities having jurisdiction. File written approval with Architect before deviating from approved working plans.
- B. Piping Standard: Comply with requirements in NFPA 14 for installation of fire-suppression standpipe piping.
- C. Install seismic restraints on piping. Comply with requirements in NFPA 13 for seismic-restraint device materials and installation.
- D. Install listed fittings to make changes in direction, branch takeoffs from mains, and reductions in pipe sizes.
- E. Install drain valves on standpipes. Extend drain piping to approved drains.
- F. Install automatic (ball drip) drain valves to drain piping between fire-department connections and check valves. Drain to floor drain or outside building.
- G. Install alarm devices in piping systems.

- H. Install hangers and supports for standpipe system piping according to NFPA 14. Comply with requirements in NFPA 13 for hanger materials.
- I. Install pressure gages on riser or feed main and at top of each standpipe. Include pressure gages with connection not less than NPS 1/4 and with soft-metal seated globe valve, arranged for draining pipe between gage and valve. Install gages to permit removal, and install where they are not subject to freezing.
- J. Drain dry-type standpipe system piping.
- K. Pressurize and check dry-type standpipe system piping, air-pressure maintenance devices and air compressors.
- L. Connect compressed-air supply to dry-pipe standpipe piping.
- M. Connect air compressor to the following piping and wiring:
 - 1. Pressure gages and controls.
 - 2. Electrical power system.
 - 3. Fire-alarm devices, including low-pressure alarm.
- N. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- O. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 15093 "SLEEVES AND SLEEVE SEALS FOR PIPING."
- P. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 15052 "BASIC MATERIALS AND METHODS FOR FIRE PROTECTION WORK."

3.4 JOINT CONSTRUCTION

- A. Install couplings, flanges, flanged fittings, unions, nipples, and transition and special fittings that have finish and pressure ratings same as or higher than system's pressure rating for aboveground applications unless otherwise indicated.
- B. Install unions adjacent to each valve in pipes NPS 2 and smaller.
- C. Install flanges, flange adapters, or couplings for grooved-end piping on valves, apparatus, and equipment having NPS 2-1/2 and larger end connections.
- D. Ream ends of pipes and tubes, and remove burrs. Bevel plain ends of steel pipe.
- E. Remove scale, slag, dirt, and debris from inside and outside of pipes, tubes, and fittings before assembly.
- F. Flanged Joints: Select appropriate gasket material in size, type, and thickness suitable for water service. Join flanges with gasket and bolts according to ASME B31.9.

- G. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
 - 1. Apply appropriate tape or thread compound to external pipe threads.
 - 2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.
- H. Steel-Piping, Cut-Grooved Joints: Cut square-edge groove in end of pipe according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join steel pipe and grooved-end fittings according to AWWA C606 for steel-pipe joints.
- I. Steel-Piping, Roll-Grooved Joints: Roll rounded-edge groove in end of pipe according to AWWA C606. Assemble coupling with housing, gasket, lubricant, and bolts. Join steel pipe and grooved-end fittings according to AWWA C606 for steel-pipe grooved joints.
- J. Welded Joints: Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators according to "Quality Assurance" Article.
 - 1. Shop weld pipe joints where welded piping is indicated. Do not use welded joints for galvanized-steel pipe.
- K. Dissimilar-Material Piping Joints: Make joints using adapters compatible with materials of both piping systems.

3.5 VALVE AND SPECIALTIES INSTALLATION

- A. Install listed fire-protection valves, trim and drain valves, specialty valves and trim, controls, and specialties according to NFPA 14 and authorities having jurisdiction.
- B. Install listed fire-protection shutoff valves supervised-open, located to control sources of water supply except from fire-department connections. Install permanent identification signs indicating portion of system controlled by each valve.
- C. Install check valve in each water-supply connection. Install backflow preventers instead of check valves in potable-water-supply sources.
- D. Specialty Valves:
 - 1. Air-Pressure Maintenance Device:
 - a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1) Reliable Automatic Sprinkler Co., Inc.
 - 2) Tyco Fire & Building Products LP.
 - 3) Victaulic Company.
 - 4) Viking Corporation.
 - b. Standard: UL 260.
 - c. Type: Automatic device to maintain minimum air pressure in piping.

- d. Include shutoff valves to permit servicing without shutting down sprinkler piping, bypass valve for quick filling, pressure regulator or switch to maintain pressure, strainer, pressure ratings with 14- to 60-psig adjustable range, and 175-psig outlet pressure.

2. Air Compressor:

- a. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1) Gast Manufacturing Inc.
 - 2) General Air Products, Inc,
 - 3) Viking Corporation.
- b. Standard: UL's "Fire Protection Equipment Directory" listing or "Approval Guide," published by FM Global, listing.
- c. Motor Horsepower: Fractional.
- d. Power: 115-V ac, 60 Hz, single phase.

E. Automatic (Ball Drip) Drain Valves:

- 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Reliable Automatic Sprinkler Co., Inc.
 - b. Tyco Fire & Building Products LP.
- 2. Standard: UL 1726.
- 3. Pressure Rating: 175 psig minimum.
- 4. Type: Automatic draining, ball check.
- 5. Size: NPS 3/4.
- 6. End Connections: Threaded.

3.6 HOSE-CONNECTION INSTALLATION

- A. Install hose connections adjacent to standpipes.
- B. Install freestanding hose connections for access and minimum passage restriction.
- C. Install wall-mounted-type hose connections in cabinets. Include pipe escutcheons, with finish matching valves, inside cabinet where water-supply piping penetrates cabinet. Install valves at angle required for connection of fire hose.

3.7 AIR RELEASE VALVE

- A. Install air release valves at the top of each hose connection.
- B. Pipe air release valve outlet to discharge downward.

3.8 FIRE-DEPARTMENT CONNECTION INSTALLATION

- A. Install wall-type fire-department connections.
- B. Install yard-type fire-department connections in concrete slab support. Comply with requirements for concrete in Section 03300 "CAST-IN-PLACE CONCRETE."
 - 1. Install three protective pipe bollards around each fire-department connection. Comply with requirements for bollards in Section 05500 "MISCELLANEOUS METALS."
- C. Install automatic (ball drip) drain valve at each check valve for fire-department connection.

3.9 IDENTIFICATION

- A. Install labeling and pipe markers on equipment and piping according to requirements in NFPA 14.
- B. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION."

3.10 FIELD QUALITY CONTROL

- A. Perform tests and inspections.
- B. Tests and Inspections:
 - 1. Leak Test: After installation, charge systems and test for leaks. Repair leaks and retest until no leaks exist.
 - 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
 - 3. Flush, test, and inspect standpipe systems according to NFPA 14, "System Acceptance" Chapter.
 - 4. Energize circuits to electrical equipment and devices.
 - 5. Start and run air compressors.
 - 6. Coordinate with fire-alarm tests. Operate as required.
 - 7. Coordinate with fire-pump tests. Operate as required.
 - 8. Verify that equipment hose threads are same as local fire-department equipment.
- C. Fire-suppression standpipe system will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

3.11 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain specialty valves.

3.12 PIPING SCHEDULE

- A. Underground Piping: High Density Polyethylene Pipe (HDPE) with HDPE fittings, and fused joints.
- B. Aboveground piping between Fire-Department Connections and Check Valves: Galvanized, standard-weight steel pipe with grooved ends; grooved-end fittings; grooved-end-pipe couplings; and grooved joints.
- C. Standard-pressure, dry-type fire-suppression standpipe piping, NPS 2 and smaller, shall be the following:
 - 1. Schedule 40, galvanized-steel pipe with threaded ends; galvanized, gray-iron threaded fittings; and threaded joints.
- D. Standard-pressure, dry-type fire-suppression standpipe piping, NPS 2 ½” and larger, shall be the following:
 - 1. Schedule 40, galvanized-steel pipe with cut-grooved ends; galvanized, grooved-end fittings for steel piping; grooved-end-pipe couplings for steel piping; and grooved joints.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 15976

FIRE-DEPARTMENT CONNECTIONS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS'

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Flush-type fire-department connections.
 - 2. Yard-type fire-department connections.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each fire-department connection.

PART 2 - PRODUCTS

2.1 FLUSH-TYPE FIRE-DEPARTMENT CONNECTION

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. American Fire Hose & Cabinet.
 - 2. Elkhart Brass Mfg. Company, Inc.
 - 3. GMR International Equipment Corporation.
 - 4. Guardian Fire Equipment, Inc.
 - 5. Potter Roemer.
 - 6. Venus Fire Protection Ltd.
- B. Standard: UL 405.
- C. Type: Flush, for wall mounting.
- D. Pressure Rating: 175 psig minimum.
- E. Body Material: Corrosion-resistant metal.
- F. Inlets: Brass with threads according to NFPA 1963 and matching local fire-department sizes and threads. Include extension pipe nipples, brass lugged swivel connections, and check devices or clappers.

- G. Caps: Brass, lugged type, with gasket and chain.
- H. Escutcheon Plate: Rectangular, brass, wall type.
- I. Outlet: With pipe threads.
- J. Body Style: As determined by system design.
- K. Number of Inlets: One inlet per 250 gpm system demand.
- L. Outlet Location: As determined by system design
- M. Escutcheon Plate Marking: Similar to "AUTO SPKR" or "STANDPIPE", coordinated with local fire department and AHJ.
- N. Finish: Polished chrome plated.
- O. Outlet Size: As determined by system design.

2.2 YARD-TYPE FIRE-DEPARTMENT CONNECTION

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Elkhart Brass Mfg. Company, Inc.
 - 2. Fire-End & Croker Corporation.
 - 3. Fire Protection Products, Inc.
 - 4. GMR International Equipment Corporation.
 - 5. Guardian Fire Equipment, Inc.
 - 6. Potter Roemer.
 - 7. Wilson & Cousins Inc.
- B. Standard: UL 405.
- C. Type: Exposed, freestanding.
- D. Pressure Rating: 175 psig minimum.
- E. Body Material: Corrosion-resistant metal.
- F. Inlets: Brass with threads according to NFPA 1963 and matching local fire-department sizes and threads. Include extension pipe nipples, brass lugged swivel connections, and check devices or clappers.
- G. Caps: Brass, lugged type, with gasket and chain.
- H. Escutcheon Plate: Round, brass, floor type.
- I. Outlet: Bottom, with pipe threads.
- J. Number of Inlets: One inlet per 250 gpm system demand.

- K. Sleeve: Chrome.
- L. Sleeve Height: 18 inches.
- M. Escutcheon Plate Marking: Similar to "AUTO SPKR" or "STANDPIPE."
- N. Finish, Including Sleeve: Polished chrome plated.
- O. Outlet Size: As determined by system design.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of fire-department connections.
- B. Examine roughing-in for fire-suppression standpipe system to verify actual locations of piping connections before fire-department connection installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install flush-type fire-department connections.
- B. Install yard-type fire-department connections in concrete slab support. Comply with requirements for concrete in Section 03300 "Cast-in-Place Concrete."
- C. Install three protective pipe bollards around each fire-department connection. Comply with requirements for bollards in Section 05500 "Metal Fabrications."
- D. Install automatic (ball-drip) drain valve at each check valve for fire-department connection.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment"

END OF SECTION

SECTION 16050

BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 DESCRIPTION OF WORK

- A. Work Included: This Section includes basic materials and methods for electrical work.
- B. The purpose of these specifications is to yield complete operable systems at all stations, TPSS, Transportation Building, Community Path, Two pump Stations (Red Bridge and East Somerville) and VMF.

1.3 CODES AND STANDARDS

- A. The electrical installation shall conform to all requirements of the following:
 - 1. Massachusetts Building Code (780 CMR-MA)
 - 2. MBTA standards, including MASS DOT-Design of Lighting Levels and Fixtures Directive
 - 3. Massachusetts Electrical Code (MEC).
 - 4. Local town ordinances that do supersede the Massachusetts Building codes.
 - 5. Massachusetts Architectural Access Board (521CMR).
 - 6. MBTA's Underwriters
 - 7. Underwriters Laboratories (UL)
- B. In case of conflict between provisions of codes, laws, and ordinances, the more stringent requirement shall apply.

1.4 SUBMITTALS

- A. Submit shop drawings for review showing fabricated work being furnished and installed under these Specifications. Submit such drawings prior to fabrication and within ample time to prevent delays in the work. Submit 4 sets of each submittal.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Equipment and materials furnished shall be new. Equipment shall be first grade commercial quality and shall be essentially the standard cataloged products of a manufacturer regularly engaged in the manufacture of the products. Rebuilt or remanufactured equipment shall not be permitted.
- B. Furnish materials and equipment bearing evidence of UL listing where UL standards exist and such product listing is available.
- C. Methods of fabrication, assembly and installation are optional unless otherwise specifically indicated.
- D. Provide products that are free from defects impairing performance, durability, or appearance, and of the commercial quality best suited for the purpose as specified herein.
- E. Steel conduit and accessories specified shall be zinc coated: Hot-dipped galvanized after fabrication in accordance with ASTM A123/A123M.
- F. Conform to applicable requirements of Insulation Power Cable Engineers' Association (ICEA).

2.2 RIGID GALVANIZED STEEL (RGS) CONDUIT AND ACCESSORIES

- A. Conduit, couplings, elbows, bends, and nipples: ANSI C80.1 and UL 6, with each length bearing manufacturer's stamp and UL label.
- B. Method used to determine the thickness of zinc coating: ANSI C80.1, Chapter 7.2.
- C. Fittings and Accessories:
 - 1. Malleable iron, ANSI C80.4.
 - 2. Provide separable watertight hub fittings with a gasket, separate nylon insulated throat and a case hardened locknut, Myers hubs.
 - 3. Bushings: Nylon insulated metallic and grounding type.
 - 4. Furnish conduit straps, clamps, and clamp backs made of galvanized malleable iron.
- D. PVC Externally Coated Galvanized Rigid Steel Conduit
 - 1. NEMA Standard No. RN1, Coating Type A-40.
 - 2. Thread protectors installed on both ends of conduit for shipment and handling, couplings packaged separately.
- E. RGS conduit or schedule 40 PVC concrete encased with a minimum of 2" of concrete all around shall be provided in all below grade installations.
- F. All conduits penetrating floors and slabs shall be RGS and have brass labels for ease of tracing circuits.
- G. Buried conduits shall not have buried pull boxes.

2.3 LIQUID-TIGHT FLEXIBLE METALLIC CONDUIT AND FITTINGS

- A. Furnish conduit consisting of a core of flexible galvanized steel with a low smoke, no halogen jacket overall, in compliance with NFPA 130. Jacket shall be moisture and oil-proof, capable of conforming to the minimum radius bends of flexible conduit without cracking.
 - 1. UL 360, NEMA FB 1.
- B. Furnish conduits with a continuous copper bonding conductor spiral wound between the convolutions, as required by NEC, and as indicated.
- C. Fittings: UL Standard 514, B cadmium or zinc-coated, NEMA FB 1.
- D. Maximum length: 3 feet.

2.4 PVC ELECTRICAL CONDUIT AND FITTINGS

- A. Heavy wall, high impact strength, rigid PVC conforming to the requirements of EPC-40-PVC conduit of NEMA TC2 and fittings for EPC-40-PVC conduit of NEMA TC3.
- B. UL 651 listed in accordance with Article 352 of the MEC for underground and exposed use.
- C. Flammability rated as self-extinguishing, and having the following minimum properties:
 - 1. Tensile strength, ASTM D638 at 78°F: 6,000 psi.
 - 2. Flexural strength, ASTM D790: 11,000 psi.
 - 3. Compressive strength, ASTM D695: 8,500 psi.
 - 4. Hardness (Durometer D), ASTM D2240: 77.
 - 5. Water absorption, % maximum, in 24 hours at 72°F. ASTM D570: 0.03.
 - 6. Dielectric strength, volts per mil, ASTM D149: 1,100.
 - 7. Thermal conductivity: 1.3 BTU per square foot per degree F per inch.
- D. Schedule 40 PVC conduit, NEC Type may be used underground when installed in a minimum 2" concrete enclosure all around.

2.5 CONDUIT EXPANSION FITTINGS

- A. Fabricate from material like the type of conduit with which they are to be used.
- B. Include a factory installed packing ring, designed to prevent the entrance of moisture, and a pressure ring.
- C. Include a grounding ring or a grounding conductor for metallic expansion couplings.

2.6 MULTIPLE PIPE HANGERS (TRAPEZE TYPE)

- A. All components shall be type 316 stainless steel as approved by MBTA.
- B. Fabricate of two or more steel hanger rods, a horizontal member and all U-bolts, clamps, and other attachments necessary for securing hanger rods and conduits.

- C. Hanger Rod: Not smaller than 3/8-inch diameter, threaded either full length or for a sufficient distance at each end to permit at least 1-1/2 inches of adjustment.
- D. Horizontal Member
 - 1. Standard structural steel shapes such as angles or channels, 1-1/2 by 1-1/2 or 1-5/8 by 1-5/8 inches, 12 gauge, lipped channel, and designed to accept special spring-held stainless steel nuts for securing hanger rods and other attachments.
 - 2. Two or more channels may be welded together to form horizontal members of greater strength than single channels.
- E. Design
 - 1. Capable of supporting a load equal to the sum of the weights of the conduits and wires, the weight of the hanger itself, plus 200 pounds.
 - 2. The stress at the root of the thread of the hanger rods; not more than 9,000 psi at design load.
 - 3. Size the horizontal member such that the maximum stress will be not more than 12,500 psi at design load.

2.7 INSERTS

- A. Channel Inserts. Fabricate from not less than 12 gauge steel channel having an overall size of 1-1/2 by 1-1/2 or 1-5/8 by 1-5/8 inches with continuous 7/8 inch wide slot, in lengths as indicated. Galvanize after fabrication.
- B. Channel Inserts for Embedding in Concrete
 - 1. Fabricate from channels having a solid base.
 - 2. Weld concrete anchors to the channel during fabrication and before coating.
 - 3. Galvanize after fabrication
 - 4. Provide assemblies with a minimum pull-out load rating of 4,500 pounds per linear foot uniformly distributed.
 - 5. Furnish all channel inserts for installation embedded in concrete with the channel interior completely filled with styrofoam to prevent seepage of concrete into the channel during installation.
- C. Channel Inserts for Surface Mounting
 - 1. Fabricate from channel having 3/8 inch by 3-inch slots on 4-inch centers in the base.
 - 2. Galvanize inserts for surface mounting on concrete surfaces or for installation in damp or wet areas.
- D. Spot Inserts for Embedding in Concrete
 - 1. Steel, galvanized after fabrication
 - 2. Designed for a maximum loading of 800 pounds with safety factor of three.
 - 3. Knockout openings to accommodate either square or rectangular nuts.

2.8 OUTLET, JUNCTION AND PULL BOXES

- A. Conform to NEC Article 314. Electrical boxes shall conform to UL-50, "Standard for Electrical Equipment, Non-Environmental Considerations", and UL-514 B, "Conduit Tubing and Cable Fittings."
- B. Provide electrical boxes of the material, finish, type and size indicated and required for the location, kind of service, number of wires, and function. Boxes shall have mounting holes retapped for 10-24 machine screws.
- C. Provide boxes complete with accessible covers designed for quick removal and suitable for the purpose for which they will be used, except that boxes in which or on which no devices or fixtures are to be installed, shall be equipped with flat or raised blank covers as required. All ceiling fixture outlet boxes shall be equipped with 3/8-inch boltless fixture studs.
- D. Boxes not over 100 cubic inches in size shall be cast. Boxes over 100 cubic inches in size shall conform to the requirements for cabinets.
- E. Covers: Same thickness as boxes and secured in position by means of No. 10-24 stainless steel machine screws. Arrange covers to be readily and conveniently removed.
- F. Coat junction boxes inside and outside to prevent oxidation. Where outlet boxes are used as junction boxes they shall be cast malleable iron and not be smaller than 4 inch square by 1-1/2 inches deep. Provide such boxes with flat blank covers.
- G. Outlet Boxes: Malleable iron, not be smaller than 4 inches square by 2-1/8 inches deep.
- H. Concealed Switch Boxes: Malleable iron, not less than 4 inches square by 2/1/8 inches deep for two devices unless otherwise indicated. Provide covers with rectangular openings of proper size and shape. Furnish and install special boxes required to suit the kind of service and location requirements, as indicated, and as may be directed by MBTA.
- I. Cast metal boxes shall be of malleable iron, with compatible conduit fittings.
- J. Boxes for exposed switches and receptacles: Cast metal, FS and FD Types.
- K. Furnish brackets, supports, hangers, fittings, bonding jumpers and all other accessories required.
- L. Provide neoprene gaskets 1/8 inch thick with boxes subjected to weather, and as directed by MBTA.
- M. Grounding. Provide each box to which a lighting fixture or receptacle is to be attached with a grounding terminal.
 - 1. Grounding Terminal: Either a green-colored washer-in-head machine screw not smaller than No. 10-32 in a drilled and tapped hole in the back of the box, or a grounding bushing with green-colored machine screw terminal attached to one of the conduits.
 - 2. Provide suitable grounding terminals in motor connection boxes.
 - 3. Install grounding jumpers as specified in Section 16060 – GROUNDING AND BONDING.

- N. Junction and pull boxes shall be accessible.

2.9 CABLE TRAYS

- A. General: Provide cable tray systems conforming to the requirements of NEMA VE1, except for modifications indicated. Cable tray system shall be designed to withstand Seismic Zone 3 earthquake.
- B. Cable Tray System Components: Hot-dipped, galvanized steel with PVC coating; or, stainless steel.
 - 1. Hot-dipped galvanized after fabrication in accordance with ASTM A123/A123M. PVC coating of 20 mils minimum having Shore A durometer hardness of 75.
 - 2. Stainless steel as indicated.
- C. Dimensions
 - 1. Straight sections and fittings: Inside clear width as indicated, measured between the rails. Overall width not exceeding inside depth by more than 2-1/2 inches. Inside nominal depth: 4 inches. Overall tray depth not exceeding inside depth by more than 3/4 inch.
 - 2. Rung spacing for ladder-type straight sections: 9 inches on centers maximum.
- D. Fabrication
 - 1. Straight sections and fittings consisting of stiffened channel rungs located between channel-shaped side rails having outward projecting flanges.
 - 2. Straight-section side rails shall have a top flange at least 1-1/4 inches wide and minimum 3/8-inch vertical stiffening lip.
 - 3. Rungs shall be positioned to provide a flat, cable support surface at least 1-1/8 inches wide, excluding corner radii, and shall be 0.060 inch thick. MIG-weld rungs to side rails and clean welds.
- E. Test Requirements
 - 1. Cable tray system shall be capable of supporting a total cable load of 55 pounds per linear foot on a maximum span of 8 feet with a safety factor of 2 based on the destructive load, regardless of the type of splice plates or type of span, when tested in accordance with load test procedure described in NEMA VE1.
 - 2. Straight sections and fittings shall not permanently deform under a 202 pound static concentrated load applied vertically along a 4-inch length for both of the following conditions:
 - a. Load applied to one side rail of tray section having specified cable load and support spacing. Load shall be applied at midpoint between supports over a splice connection.
 - b. Load applied to one rung of empty tray section having specified support spacing. Load shall be located at midpoint between side rails and supports. Cable tray support shall be capable of supporting 0.625 of the sum of the total load on both spans adjacent to support with safety factor of 2.

2.10 CABLE TRAY CHANNEL SUPPORTS

- A. Fabricate from minimum 12 gauge steel channel, 1-5/8-by-1-5/8 inches, with a continuous 7/8-inch wide slot. Hot-dipped galvanized.
- B. Hardware, Fittings, and Brackets: Zinc or cadmium coated.
- C. Design assembled supports, fittings, brackets, and hardware to carry the loads shown on the Contract Drawings with a factor of safety of three or greater.
- D. Supports shall provide at least 1-1/8 inch bearing length for each rail and shall have provision for tray hold-down clamps and fasteners.

2.11 UNDERFLOOR DUCTS, TRENCHES, AND FITTINGS

- A. Manufacture ducts and trenches from 14 gauge galvanized steel, furnished with a UL listed corrosion-resistant coating.
- B. Design fittings for use with the duct or trench to form a complete underfloor raceway system.
- C. Ducts for Power Service: 3-1/8 inches wide by a minimum 1-1/4 inches deep, or 6 inches wide by 1-1/2 inches deep, as indicated, with threaded 2 inch IPS inserts spaced on 2-foot centers.
- D. Ducts for Low Voltage, Communication, or Signal Use; Six inches wide by 1-1/2 inches deep with 2-inch IPS inserts spaced on 2-inch centers.
- E. Floor Trenches: 18 inches wide by 4 inches deep with 5/16-inch thick floor plate. Cover plates of maximum length, as indicated.
- F. Equip inserts with caps and countersunk-head floor marking screws.
- G. Size junction boxes for underfloor ducts to accommodate the ducts, and finish similar to the duct.
- H. Provide approximate tile holders of a depth as required for installation of the floor finish.
- I. Provide service fittings where required, complete with adapters and locking nipples suitable for use with the duct.

2.12 WIRE AND CABLE (600 VOLT)

- A. Conductors: Conform to the requirements of the MEC.
 - 1. Feeder and Branch Circuit Conductors: Soft-drawn copper.
 - 2. Control Circuits: Soft-drawn copper.
 - 3. Conductor Sizes: Standard American Wire gauge sizes. All conductors, stranded copper.
 - 4. Minimum AWG sizes unless otherwise indicated:
 - a. No. 12 for branch circuits.
 - b. No. 14 for control wire and fixture wire
 - c. No. 16 for low voltage circuit and indication wire.
- B. Wire and Cable 600 volts and Below Installed Raceways: Single conductor, NEC type XHHW-2 (no substitute), conforming to requirements of NEMA WC 7.

C. No asbestos conductor insulation.

D. Color Coding of Conductors

1. Color code supply cables and branch circuit conductors throughout the secondary alternating current wiring system as follows:

Conductor	208/120 Volts	480/277 Volts
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Gray
Ground	Green	Green

2. Branch circuit phase conductors No. 10 and smaller and all neutral and equipment conductors: Solid color insulation or solid color coating.
3. On-site coloring of ends of conductor may be permitted by MBTA upon receipt of satisfactory evidence that the Contractor is unable to order color-coded wire and cable as specified. Provide certification from the cable manufacturer that the paint or dye proposed for field application is non-injurious to the insulation. Colored tape may be used to mark the ends of conductors in lieu of paint or dye.

E. Identification Tags

1. Provide waterproof identification tags of brass, aluminum, plastic, or pressure-sensitive moisture-resistant labels designed for fastening to cables, feeders, and power circuits in vaults, pull boxes, manholes, and switchboard rooms and at all terminations of cable or wire.
2. Stamp or print tags or labels to correspond with markings on the Contract Drawings or accepted Shop Drawings, or mark so that feeder, cable or conductor may be readily identified. Tags on conductors at switches, receptacles, motor control panels, wireways, and junction boxes shall bear the circuit number of the conductor as it appears in the circuit directory. Mark conductors in motor control panels with the terminal number.
3. If suspended type tags are provided, design tie tags with slip-free plastic cable lacing unit or design for attachment by nylon bundling straps.

F. Cable Supports and Fasteners: Design for use with channel inserts.

G. Conductor Bundling Straps

1. Formed from self-extinguishing nylon having a temperature range of minus 65°F to plus 250°F.
2. Equip each strap with a locking hub or head with a stainless steel locking barb on one end and a taper on the other end.
3. Make wire and cable ties for installation outdoors and in exposed locations of ultraviolet resistant nylon material.

H. Splice and Terminal Connectors

1. Design termination fittings for use with the cable furnished, NEMA Standard, and UL approved.
2. Termination and splice fittings for No. 10 and smaller conductors; Screw on, spring pressure-type copper connectors with nonflammable, self-extinguishing insulation of temperature rating equal to that of cable being connected. Terminals to provide a metal insulation grip on the conductor for strain relief.
3. Termination and splice fittings for No. 8 and larger conductors: Tool-applied compression connectors of material and design compatible with the conductors for which they are used.
4. Terminal connectors for conductors Size No. 4/0 and larger: Long-barrel, double compression type, and furnished with two bolting holes in the pad.

I. Insulating Material for Splices and Terminations

1. Of the type approved by the Engineer for the particular use, location and voltage, 3/4 inch nominal width.
2. Plastic electrical insulating tape for general use: Vinyl plastic with rubber-based pressure-sensitive adhesive. Pliable at temperature of minus 18°C to 105°C. When tested in accordance with ASTM D 3005, the tape shall have the following minimum properties:
 - a. Thickness: 7 mils.
 - b. Breaking Strength: 15 pounds per inch.
 - c. Elongation: 200%.
 - d. Dielectric Strength: 10,000 volts/mil
 - e. Insulation Resistance (Direct method of electrolytic corrosion): 1,000,000 megohms.
3. Rubber electrical insulating tape for protective overwrapping: Silicone rubber with a silicone pressure-sensitive adhesive. When tested in accordance with ASTM D1000, the tape shall have the following minimum properties:
 - a. Thickness: 15 mils.
 - b. Tensile Strength: 11 pounds per inch.
 - c. Elongation: 525%.
 - d. Dielectric Strength: 13,000 volts
 - e. Insulation Resistance (Indirect Method of Electrolytic corrosion): 1,000,000 megohms.
4. Arc-proof Tape: Flexible, conformable organic fabric, coated one side with a flame-retardant flexible elastomer-self-extinguishing, with the following minimum properties:
 - a. Thickness, ASTM D1000: 55 mils.
 - b. Tensile strength, ASTM D5034, D5035: 50 pounds per inch.
 - c. Thermal conductivity, ASTM D1518: 0.478 btu/hour/square foot/degrees F.
 - d. Electrical Arc Resistance: Withstand 200 ampere arc for 40 seconds.
5. Mark each tape package to indicate shelf-life expiration date.
6. Glass Cloth Electrical Insulating Tape (for use with arc-proof tape): Woven glass fabric; when tested in accordance with ASTM D1000, the tape shall have the following minimum properties:

- a. Thickness: 7 mils
- b. Breaking Strength: 170 pounds per inch.
- c. Elongation: 5%.
- d. Dielectric Breakdown: 2,500 volts.
- e. Insulation Resistance (Indirect Method of Electrolytic Corrosion): 5,000 megohms.

2.13 WIRING DEVICES

- A. General. Wiring devices include switches, receptacles and special outlets installed in raceway or conduit boxes, complete with cover plates.
- B. Switches
 - 1. AC tumbler-toggle switches: Meeting minimum requirements of UL 20 and further requirements herein specified and of specification grade, heavy duty, of the type indicated.
 - 2. Provide switches that operate in any position and are fully enclosed with entire body and cover of molded phenolic, carbamide or melamine. Do not use fiber, paper or similar insulating material for body or cover.
 - 3. Equip switches with metal mounting yoke with plaster ears, insulated from the mechanism and fastened to the switch body by bolts, screws, rivets or other substantial means that meet test requirements.
 - 4. Provide a green-colored equipment grounding screw on the yoke.
 - 5. Provide the section of the yoke normally intended to bear on the surface outside the box with a minimum over-all dimension of 3/4 inch, measured at right angles to the longitudinal axis of the yoke.
 - 6. Make switch contacts between silver or silver alloys.
 - 7. Switches shall be back and side wired with terminals of screw or combination screw-clamp type.
 - 8. Terminal Screws: No. 8 or larger, captive or terminal type.
 - 9. Provide access holes for back wiring.
 - 10. Wiring terminals capable of receiving and holding proper wire sizes as shown below:

Switch Rating	Wire Size, AWG No.
20 amperes	12
30 amperes	10

- C. Wall switches: Tumbler type, totally enclosed, heavy duty, in accordance with NEMA 5-WD-1.
- D. Switches for use on incandescent or fluorescent lighting circuits: Fully rated 20 amperes at 120 or 277 volts, as indicated. Actual connected lamp wattage not to exceed the following:

Switch Rating at 120-277Volts		
20 amperes	120 Volts	277 Volts
Maximum Wattage Allowed	1,400 watts	3000 watts

- E. Switches controlling outlets other than lighting, such as motors less than 1/4 horsepower may be specification grade, flush type, AC - DC, T-rated 20 ampere, 125 volts. Switches controlling straight resistance loads may be snap switches as specified herein, of the proper rating up to 30 amperes at 120-277 volts.
- F. Provide ac 120-277 volt snap switches capable of withstanding tests as outlined in NEMA 5-WD-1. If requested by the Engineer, submit satisfactory evidence that the types of switches proposed have satisfactorily withstood these tests.

2.14 RECEPTACLES AND PLUGS

- A. Configuration and requirements for connector and outlet receptacles; UL 498 and NEMA 5-WD-1 for heavy duty general use type.
- B. Receptacles: Fire-resistant nonabsorptive, hotmolded phenolic composition or equal bodies and bases with metal plaster ears integral with supporting member.
- C. Type: Flush type, except where otherwise indicated.
 - 1. Wall receptacles: Single or duplex as shown on the Contract Drawings.
 - 2. Provide receptacles and plugs (caps) with light-colored terminal facilities for neutral connections, amber or brass colored for phase conductor connections, and green-colored hexagonal machine screws for the equipment grounding conductor or connections.
 - 3. All contacts of the receptacles, including the grounding contact: Double grip bronze type with spring steel backup clips so that both sides of each male prong of the plug will be in firm contact.
 - 4. Provide all receptacles with self-grounding clip or mounting strap screws.
 - 5. Ground fault circuit interrupter duplex receptacles shall be 120 volts, 60 Hz, 15 ampere with built-in test, reset buttons, and ground fault tripped indication. They shall interrupt the circuit within 1/30th of a second on a 5 milliampere earth leakage current.
 - 6. They shall be designed for end of run installation or with provisions for feeding through to protect other outlets on the circuit. Maximum circuit capacity for the latter shall be 20 amperes. The receptacles shall be furnished with necessary wire connectors, clips, mounting scores and instruction.
- D. Clock Receptacles
 - 1. Receptacles for clocks are not required for clocks operating on less than fifty volts, and flush- mounted clocks (inserted type).

2. Provide receptacles for clocks conforming to NEMA 5-15R, recessed so that male cap will be flush with the wall to permit the clock to cover the outlet.
3. Provide plates, including finishes, as specified for cover plates, adapted to the recessed receptacles and with substantial hooks to support the clocks.
4. Receptacles for surface-mounted clocks connected to the building 120-volt electrical system: As indicated.
5. Where clock receptacles are shown on the Contract Drawings or specified, furnish the grounded type and provide with a ground jumper.

2.15 COVER PLATES

- A. Provide cover plates for each switch, receptacle, and special purpose outlet.
- B. Use multi-gang plates for multi-gang boxes.
- C. Unless otherwise indicated, use cover plates conforming to Federal Standard WP-455.
- D. Provide and install cover plates of brushed stainless steel in ancillary spaces, mechanical rooms, fan rooms, wire closets, AC switchboard rooms, traction substations, and all unfinished areas.
- E. In public areas provide cover plates fabricated of corrosion-resistant steel, type 304 stainless 18% chromium, 8% nickel with baked porcelain enamel bronze finish.
- F. For special purpose outlets commercially produced using special material, configuration, and size, use plate of brushed stainless steel and of a design for the particular application.
- G. Where plates of material and finish herein specified are not available commercially for these special purpose outlets, plates commercially available and suitable for enameling to match adjacent surface will be acceptable.
- H. Use stainless steel cover plates of 0.032 thickness for flush devices.

2.16 DISCONNECTION DEVICES

- A. Safety Switch Type: Enclosed, conforming to UL Standards and the following:
 1. Motor Circuit Switches (600 Volts AC):
 - a. Furnish motor circuits with a separately mounted disconnect switch where required within sight of the motor.
 - b. Switch: HP rated, UL 508 listed, quick make quick break, full cover interlock and indicator handle, conforming to FS W-S-865 for heavy duty switches.
 - c. Enclosure Type: As indicated.
 - d. Furnished handle mechanism with continuous engagement of the switch handle whether the door is open or closed, and is pad-lockable in the OFF and ON position.

2. Heavy Duty Safety Switches (240 Volts AC):
 - a. Furnish heavy-duty safety switches having electrical characteristics, ratings, and modifications indicated.
 - b. Indoors: Furnish switches with NEMA 1 General Purpose Enclosures, unless otherwise indicated, and with metal nameplates, front cover mounted, containing a permanent record of switch type, catalog number, and HP ratings.
 - c. Outdoors: Furnish switches with NEMA 4X stainless steel enclosures.
 - d. Furnish handle with visible blades; reinforced fuse clips, positive, quick make-quick break mechanism, and which is pad-lockable in the OFF and ON position.
 - e. Furnish switches meeting NEMA KS 1 requirements.
3. Heavy Duty Safety Switches (600 Volts AC):
 - a. Furnish heavy-duty safety switches having electrical characteristics, ratings, and modifications shown on the Contract Drawings.
 - b. Furnish all switches with NEMA 12 General Purpose Enclosures, unless otherwise indicated, meeting NEMA KS 1 requirements.

PART 3 - EXECUTION

3.1 GENERAL

- A. Install all items in their proper locations, rigid and secure, plumb and level, and in true alignment with related and adjoining work. Do not weld electrical materials for attachment or support.
- B. Furnish anchor bolts and anchorage items as required, and field check to ensure proper alignment and location. Provide templates, layout drawings, and supervision at the job site to ensure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.
- C. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts and angles as required to set and connect rigidly the work.
- D. Control erection tolerance requirements to not impair the strength, safety, serviceability, or appearance of the installations, as approved by the Engineer. Determine exact location of conduit. Route all conduit parallel to building lines.
- E. The trade size, type and general routing and location of conduits, raceways, and boxes shall be as required for proper operation and to avoid interferences.
- F. Install exposed conduit so as to avoid conflicts with other work. Install horizontal raceway close to the ceiling or ceiling beams, and above water or other piping whenever possible.

- G. Install individual conductors in conduits, raceways, cable trays, ducts, and trenches and multiple-conductor sheathed cables as shown on the Contract Drawings to complete the wiring systems.
- H. Install switches, receptacles, special purpose outlets, and cover plates complete in a neat manner in accordance with the Massachusetts Electrical Code (MEC).

3.2 CONDUIT AND FITTINGS

A. Metallic Electrical Conduit

1. Install metallic conduit in accordance with the MEC. Prevent concrete and other materials from obstructing the conduit. Pack all outlet, pull and junction boxes with paper prior to pouring concrete ends of embedded conduit. Do not use conduit smaller than 3/4-inch diameter.
2. Make all conduit bends in accordance with the MEC, with not more than 3 90 degree bends per run. Where more than 3 90 degree bends are required in a particular run, install pull boxes as required to facilitate pulling conductors.
3. Unless otherwise indicated, terminate metallic conduit installed for future extension with flush couplings set to finished floor level.
4. Provide metallic numbering tags indicating the conduit number on the end of conduit. Identify train control and communication conduit as indicated.
5. Properly support conduit to be embedded to maintain correct location and spacing during concreting operations. If necessary, provide suitable metal supports for this purpose.
6. Install conduit so that any moisture collecting in the conduit will be drained to the nearest outlet or pull box.
7. Whenever exposed or buried conduit passes through an expansion or contraction joint in the structure, install the conduit at right angles to the joint, and provide an approved conduit expansion joint at the joint. Paint the conduit with an approved bituminous compound for one foot on each side of the expansion couplings.
8. Provide expansion joints in conduit runs where required to compensate for thermal expansion.
9. Rod and swab embedded conduit after installation to remove foreign matter, which may have worked in at the joints. If obstructions are encountered which cannot be removed, or if any conditions exist which may result in damage to wires and cables pulled through the conduit, install new conduit at no additional expense to the Authority.
10. After the conduit has been rodded and swabbed, repack boxes and protect conduit ends to prevent any foreign material from entering the conduit.
11. Where metallic conduit is exposed to different temperatures, seal the conduit to prevent condensation and passage of air from one area to the other.
12. Use only conduits that are electrically and mechanically continuous and connect to the structure ground system. Secure continuous ground by bonding where required.

13. Apply conductive antisieze compound to the threads of threaded rigid conduit joints. Do not use compounds containing lead. Terminate the conduit in appropriate boxes at all motors, switches, outlets, and junction points.
14. When field cutting of conduit is required, thread and ream the conduit to remove any rough edges. Where a conduit enters a box or other fitting, provide a bushing to protect the wire from abrasion. Provide insulation type bushings and double locknuts on ends of rigid conduits terminating at steel boxes, panelboards, cabinets, motor starting equipment, and similar enclosures.
15. Support individual horizontal conduits not larger than 1-1/2 inches diameter by means of one-hole pipe straps with back spacers or individual pipe hangers.
16. Space conduits installed against concrete surfaces away from the surface by clamp backs or other approved means.
17. Support individual horizontal conduits larger than 1-1/2 inches diameter by individual pipe Hanger.
18. In dry locations, spring steel fasteners, clips, or clamps specifically designed for supporting exposed single conduits may be used in lieu of pipe straps or pipe hangers.
19. Hanger rods used with spring steel fasteners, clips, and clamps shall be either 1/4- inch diameter galvanized steel rods or, if concealed above a suspended ceiling, galvanized perforated steel strapping. Do not use wire for support of conduit.
20. Support parallel conduits at the same elevation on multiple conduit hangers or channel inserts.
21. Secure each conduit to the pipe hanger or channel insert member by a U-bolt, one-hole strap, or other specially designed and approved fastener suitable for use with the pipe hangers or channel inserts.
22. Space supports not over 10 feet on centers for vertical conduits spanning open areas. Securely anchor conduit at each end and run so as not to interfere with the installation and operation of equipment at the location.
23. Support conduits and raceways above suspended ceilings from either the floor construction above or from the main ceiling support members, using the applicable method specified herein.
24. Install liquid-tight flexible metal conduit so that liquids tend to run off the surface and not drain toward fittings. Provide sufficient slack to reduce the effects of vibration. Running threads are not acceptable. Where necessary for connecting conduits, use right and left hand couplings.

B. Non-Metallic Electrical Conduit

1. Non-metallic electrical conduit includes polyvinyl chloride (PVC) no asbestos.
2. Cap or plug the ends of embedded conduit to prevent concrete and their materials from obstructing the conduit.

3. Sandpaper joints in PVC conduit to remove all burrs, clean and dry the joints, and brush with a solvent cement acceptable to the manufacturer before installing.
4. Properly support conduits to maintain the correct location and spacing during concreting operations and, if necessary, provide suitable plastic supports and spacers for this purpose.
5. Wherever buried non-metallic conduit passes through an expansion or contraction joint, or where required to compensate for thermal expansion and contraction, provide a conduit expansion joint. Install the conduit to cross the joint at right angles. In areas of floating slabs, install horizontal runs of conduit beneath the floating slab. Conduit shall pass through the floating slab only where required to terminate in a vertical direction as shown on the Contract Drawings.

C. Pull Wires

1. Use nylon pull wires of tensile strength not less than 240 pounds in each conduit and duct, leave pull wires in ducts and conduit after cleaning.
2. No splices in pull wire will be allowed.
3. Leave ample slack length at each end of pull wire.

D. Filling of Openings. Wherever slots, sleeves, or other openings are provided in floors or walls for the passage of raceways, including bus ducts, fill such openings as follows:

1. Use fire-resistive filling material for openings similar to the material of the floor, wall or ceiling being penetrated, and finish to prevent passage of water, smoke, and fumes.
2. Where conduits passing through openings are exposed in finished rooms, use filling material that matches, and is flush with, the adjoining finished floor, ceiling or wall.

3.3 INSERTS

A. Channel Inserts. Install embedded channel inserts with the slotted face flush with the finished concrete surface.

B. Spot Inserts

1. Install with the insert face flush with the finished concrete surface, firmly embedded, with no evidence of movement.
2. Test selected inserts, as required by the Engineer, by suspension of 800 pounds of weight from the insert. If there is evidence of failure, replace the inserts in a manner satisfactory to the Engineer.

3.4 SURFACE METAL RACEWAYS

A. Securely ground surface metal raceways to outlet boxes or to backplates and fixtures by means of bolts, screws or other approved means and as specified in Section 16060 - GROUNDING AND BONDING.

- B. Install surface metal raceways where indicated, in accordance with the NEC. Use fittings and accessories designed for the raceway.

3.5 OUTLET, JUNCTION AND PULL BOXES

A. Outlet Boxes

1. Unless otherwise indicated, flush mount outlet boxes with the front edges of the boxes or plaster covers attached thereto flush with the finished wall or ceiling.
2. Mount boxes so that the long axis of the devices will be vertical, unless otherwise indicated.
3. Locate conduit boxes and conduit box knockouts so as not to interfere with the reinforcing steel.
4. Unless otherwise specified, provide boxes in plastered walls and ceilings with plaster covers. Do not install these covers until the finish plaster line is determined for the particular location.
5. The mounting height indicated for a wall-mounted outlet box shall be construed to mean the height from the finished floor to the horizontal centerline of the cover plate.
6. Mount outlet boxes for switches and receptacles located on columns and pilasters so as not to interfere with installation of partitions.
7. Install boxes located near doors on the lock sides, even where the symbols appear on the hinge sides on the Contract Drawings, unless other locations are approved by the Engineer.

B. Junction and Pull Boxes

1. Install so that covers are readily accessible after completion of the installation.
2. Do not install boxes above suspended ceilings, except where the ceiling is of the removable type or where definite provisions are made for access to each box.

C. Boxes Set in Concrete

1. Adequately support boxes to prevent movement during placement of concrete.
2. Unused nailing holes or other holes in the side or bottom of the boxes will not be permitted.
3. After installation, clean boxes placed in concrete.

3.6 CABLE TRAYS

- A. Install in accordance with MEC Article 392 using approved fittings and adequately supporting the complete system.
- B. Provide anti-sway brackets on all horizontal tray assemblies where necessary.
- C. Connect each isolated cable tray system or the entire tray system to the building equipment grounding system with a green insulated conductor in accordance with the MEC.
- D. Base size determination on the largest power conductor in the rack.

1. Minimum size: No. 6 copper.
2. Maximum size: 4/0 copper

3.7 UNDERFLOOR DUCTS AND FITTINGS

- A. Accurately align and level the ducts with the top of inserts 1/8 inch below the finished concrete floor.
- B. Hold ducts in place during pouring of concrete by use of duct support fitting designed for the duct used, spaced at five-foot intervals. Carefully level all boxes, with the tops flush with the finish floor.
- C. Install appropriate insert markers in the last insert at all dead ends, on each side of partitions, and first insert adjacent to junction box to indicate high and low voltage services.
- D. Seal duct installation watertight with an approved sealing compound.

3.8 WIRING

A. General

1. Furnish wires and cables to the site in unbroken standard coils or reels, to which shall be attached a tag bearing the manufacturer's name, trade name of the wire, and the UL label for 600-volt wire and cable.
2. Provide all wiring complete as indicated. Provide ample slack wire for motor loops, service connections and extensions. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.
3. Do not bend cables during installation, either permanently or temporarily, to radii less than 12 times the outer diameters, except where conditions make the specified radius impracticable, and shorter radii are permitted by the MEC and NEMA Standard WC, 70, Appendix F.
4. Neatly and securely bundle cable conductors located in branch circuit panelboards, cabinets, control boards, switchboards and motor control centers and pull boxes. Use nylon bundling straps.

B. Wire Pulling

1. Install wire and cable in conduit as indicated. Do not pull wiring into any conduit until conduits and outlets have been thoroughly cleaned and swabbed to remove water and debris. Do not use block or tackle or other mechanical means in pulling conductors smaller than No. 2 AWG in raceways.
2. Provide suitable installation equipment to prevent cutting and abrasion of conduits and wire during the pulling of feeders. Use lubricant and installation procedure as recommended by the cable manufacturer, and as approved by the Engineer.
3. Use masking or other means to prevent obliteration of cable identifications when solid color coating or colored tracers are used.
4. Pull together all cables to be installed in a single conduit.

- C. Cable Supports. Install cable supports for vertical feeders in accordance with the MEC
- D. Splices and Terminations
 - 1. Make wire and cable splices only in outlet, junction or pull boxes, or in equipment cabinets. Splices in conduit or raceway will not be permitted. Make splices by means of compression type connectors, and cover with tape to an insulation level equal to that of the cable.
 - 2. Use positive type connector installation tools as recommended by the manufacturer.
 - 3. Mechanical hand tools, with dies for each conductor size, recommended by the manufacturer, may be used on conductor sizes through No. 4/0.
 - 4. For conductor sizes larger than No. 4/0, use hydraulic tools with hexagonal or circumferential installing dies for each conductor size, as recommended by the manufacturer.
 - 5. For inspection purposes, clearly mark die numbers on the installed connectors.
 - 6. Before installation, apply anti-corrosion electrical joint compound to conductors and terminal bolting pads.

3.9 WIRING DEVICES

- A. Locate switches 42 inches above finished floor to center of device, except as otherwise indicated.
- B. Attach receptacles rigidly to outlet box by means of two screws.
- C. Wire duplex receptacles, where so indicated, so that one unit of the duplex may be controlled by a wall switch and the other unit remain continuously energized.
- D. For exterior locations, mount receptacles in watertight cast type outlet boxes with threaded hubs or bosses and equipped with gasketed cover and captive cap of the screw or twist type.
- E. Provide equipment permanently connected to exterior receptacles, or in areas subject to spray or hose cleaning, with watertight male plugs to suit. Such receptacles shall be of the ground fault circuit interrupter type, as specified herein.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16054

OVERCURRENT PROTECTIVE DEVICE SHORT-CIRCUIT STUDY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes a computer-based, fault-current study to determine the minimum interrupting capacity of circuit protective devices.

1.3 DEFINITIONS

- A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.
- B. One-Line Diagram: A diagram which shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.
- C. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion from the system.
- D. SCCR: Short-circuit current rating.
- E. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

1.4 ACTION SUBMITTALS

- A. Product Data: For computer software program to be used for studies.
- B. Submit the following after the approval of system protective devices submittals. Submittals shall be in digital form.
 - 1. Short-circuit study input data, including completed computer program input data sheets.
 - 2. Short-circuit study and equipment evaluation report; signed, dated, and sealed by a qualified professional engineer registered in the Commonwealth of Massachusetts.
 - a. Submit study report for action with the distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from the Owner for preliminary submittal of sufficient study data to ensure that the selection of devices and associated characteristics is satisfactory.
 - b. Revised single-line diagram, reflecting field investigation results and results of short-circuit study.

1.5 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For Short-Circuit Study Software Developer, Short-Circuit Study Specialist and Field Adjusting Agency.
- B. Product Certificates: For short-circuit study software, certifying compliance with IEEE 399.

1.6 QUALITY ASSURANCE

- A. Studies shall use computer programs that are distributed nationally and are in wide use. Software algorithms shall comply with requirements of standards and guides specified in this Section. Manual calculations are unacceptable.
- B. Short-Circuit Study Software Developer Qualifications: An entity that owns and markets computer software used for studies, having performed successful studies of similar magnitude on electrical distribution systems using similar devices.
 - 1. The computer program shall be developed under the charge of a licensed professional Engineer who holds IEEE Computer Society's Certified Software Development Professional certification.
- C. Short-Circuit Study Specialist Qualifications: Professional Engineer in charge of performing the study and documenting recommendations, licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional Owner.
- D. Field Adjusting Agency Qualifications: An independent agency, with the experience and capability to adjust overcurrent devices and to conduct the testing indicated, that is a member company of the International Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 COMPUTER SOFTWARE

- A. Software Developers: Subject to compliance with requirements, provide software by one of the following:
 - 1. SKM Systems Analysis, Inc.
 - 2. CYME International T&D
 - 3. Power Analytics, Corporation.
- B. Comply with IEEE 399 and IEEE 551.
- C. Analytical features of fault-current-study computer software program shall have the capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.
- D. Computer software program shall be capable of plotting and diagramming time-current-characteristic curves as part of its output.

2.2 SHORT-CIRCUIT STUDY REPORT CONTENTS

- A. Executive summary.

- B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of the computer printout.
- C. Calculation of the maximum RMS Amperes at MCC, distribution panelboard, panelboard, etc.) in the electrical system shall be made using a digital computer.
- D. Appropriate motor short-circuit contribution shall be included at the appropriate locations in the system so that the computer calculated values represent the highest short-circuit current the equipment shall be subjected to under fault conditions.
- E. A tabular computer printout shall be included which lists the calculated short-circuit currents, X/R ratios, equipment short-circuit interrupting or withstand current ratings, and notes regarding the adequacy or inadequacy of the equipment.
- F. The study shall include a computer printout of input circuit data including conductor lengths, number of conductors per phase, conductor impedance values, insulation types, transformer impedances and X/R ratios, motor contributions, and other circuit information as related to the short-circuit calculations.
- G. Include a bus-to-bus computer printout identifying the maximum available short-circuit current in RMS symmetrical amperes and the X/R ratio of the fault current for each bus-to-bus calculation.
- H. The system one-line diagram shall be computer generated and shall clearly identify individual equipment buses, bus numbers used in the short-circuit analysis, cable and bus connections between the equipment, calculated maximum short-circuit current at each bus location and other information pertinent to the computer analysis.
- I. A comprehensive discussion section evaluating the adequacy or inadequacy of the equipment must be provided and include recommendations as appropriate for improvements to the system.
- J. Any changes to documents as a result of short circuit analysis shall not result in any additional cost to MBTA.
- K. The Design-Builder shall be responsible for supplying conductor information (lengths, types, number per phase, etc.) in a timely manner to allow the short-circuit analysis to be completed prior to final installation.
- L. Any inadequacies shall be called to the attention of the Owner and recommendations made for improvements as soon as any they are identified.
- M. Any inadequacies shall be called to the attention of the Owner and recommendations made for improvements as soon as any they are identified.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Obtain all data necessary for the conduct of the study.
 - 1. For equipment provided, use characteristics submitted under the provisions of action submittals and information submittals for this Project.

2. For relocated equipment and that which is existing to remain, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and Owner. The qualifications of technicians and Owner shall be qualified as defined by NFPA 70E.
- B. Gather and tabulate the following input data to support the short-circuit study. Comply with recommendations in IEEE 551 as to the amount of detail that is required to be acquired in the field. Field data gathering shall be under the direct supervision and control of the Owner in charge of performing the study, and shall be by the Owner or its representative who holds NETA ETT Level III certification or NICET Electrical Power Testing Level III certification.
1. Product Data for Project's overcurrent protective devices involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
 2. Obtain electrical power utility impedance at the service.
 3. Power sources and ties.
 4. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
 5. For reactors, provide manufacturer and model designation, voltage rating, and impedance.
 6. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip, SCCR, current rating, and breaker settings.
 7. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
 8. Busway manufacturer and model designation, current rating, impedance, lengths, and conductor material.
 9. Motor horsepower and NEMA MG 1 code letter designation.
 10. Cable sizes, lengths, number, conductor material and conduit material (magnetic or nonmagnetic).

3.2 SHORT-CIRCUIT STUDY

- A. Perform study following the general study procedures contained in IEEE 399.
- B. Calculate short-circuit currents according to IEEE 551.
- C. Base study on the device characteristics supplied by device manufacturer.
- D. Begin short-circuit current analysis at the service, extending down to the system overcurrent protective devices as follows:
 1. To normal system low-voltage load buses where fault current is 10 kA or less.
- E. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study all cases of system-switching configurations and alternate operations that could result in maximum fault conditions.
- F. The calculations shall include the ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and shall apply to low- and medium-voltage, three-phase ac systems. The calculations shall also account for the fault-current dc decrement, to address the asymmetrical requirements of the interrupting equipment.
 1. For grounded systems, provide a bolted line-to-ground fault-current study for areas as defined for the three-phase bolted fault short-circuit study.

- G. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault at each of the following:
1. Electric utility's supply termination point.
 2. Incoming switchgear.
 3. Unit substation primary and secondary terminals.
 4. Low-voltage switchgear.
 5. Motor-control centers.
 6. Control panels.
 7. Standby generators and automatic transfer switches.
 8. Branch circuit panelboards.
 9. Disconnect switches.

3.3 ADJUSTING

- A. Make modifications to equipment as required to accomplish compliance with short-circuit study.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16055

OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes computer-based, overcurrent protective device coordination studies to determine overcurrent protective devices and to determine overcurrent protective device settings for selective tripping.
 - 1. Series rated devices shall not be permitted.

1.3 DEFINITIONS

- A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.
- B. One-Line Diagram: A diagram which shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.
- C. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion from the system.
- D. SCCR: Short-circuit current rating.
- E. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

1.4 SUBMITTALS

- A. Product Data: For computer software program to be used for studies.
- B. Submit the following after the approval of system protective devices submittals. Submittals shall be in digital form.
 - 1. Coordination-study input data, including completed computer program input data sheets.
 - 2. Study and equipment evaluation reports.
 - 3. Overcurrent protective device coordination study report; signed, dated, and sealed by a qualified professional engineer registered in the Commonwealth of Massachusetts.
 - a. Submit study report for action with the distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from

the Owner for preliminary submittal of sufficient study data to ensure that the selection of devices and associated characteristics is satisfactory.

1.5 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For Coordination Study Software Developer, Coordination Study Specialist and Field Adjusting Agency.
- B. Product Certificates: For overcurrent, protective device coordination study software, certifying compliance with IEEE 399.

1.6 CLOSEOUT SUBMITTALS

- A. Include emergency, operation, and maintenance manuals.
 - 1. Include the following:
 - a. The following parts from the Protective Device Coordination Study Report:
 - 1) One-line diagram.
 - 2) Protective device coordination study.
 - 3) Time-current coordination curves.
 - b. Power system data.

1.7 QUALITY ASSURANCE

- A. Studies shall use computer programs that are distributed nationally and are in wide use. Software algorithms shall comply with requirements of standards and guides specified in this Section. Manual calculations are unacceptable.
- B. Coordination Study Software Developer Qualifications: An entity that owns and markets computer software used for studies, having performed successful studies of similar magnitude on electrical distribution systems using similar devices.
 - 1. The computer program shall be developed under the charge of a licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.
- C. Coordination Study Specialist Qualifications: Professional engineer in charge of performing the study and documenting recommendations, licensed in the Commonwealth of Massachusetts. All elements of the study shall be performed under the direct supervision and control of this professional Owner.

PART 2 - PRODUCTS

2.1 COMPUTER SOFTWARE DEVELOPERS

- A. Software Developers: Subject to compliance with requirements, provide software by one of the following:
 - 1. SKM Systems Analysis, Inc.
 - 2. CYME International T&D
 - 3. Power Analytics, Corporation.

- B. Comply with IEEE 242 and IEEE 399.
- C. Analytical features of device coordination study computer software program shall have the capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.
- D. Computer software program shall be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program shall report device settings and ratings of all overcurrent protective devices and shall demonstrate selective coordination by computer-generated, time-current coordination plots.

2.2 PROTECTIVE DEVICE COORDINATION STUDY REPORT CONTENTS

- A. Executive summary.
- B. Study descriptions, purpose, basis and scope. Include case descriptions, definition of terms and guide for interpretation of the computer printout.
- C. The time-current coordination analysis shall be performed with the aid of a digital computer and shall include the determination of settings, ratings, or types for the overcurrent protective devices supplied.
- D. Selective coordination shall be performed per MEC Article 700 requirements.
- E. Where necessary, an appropriate compromise shall be made between system protection and service continuity with service continuity considered more important than system protection.
- F. A sufficient number of computer generated log-log plots shall be provided to indicate the degree of system protection and coordination by displaying the time-current characteristics of overcurrent devices and other pertinent system parameters.
- G. Computer printouts shall accompany the log-log plots and shall contain descriptions for each of the devices shown, settings of the adjustable devices, the short-circuit current availability at the device location when known, and device identification numbers to aid in locating the devices on the log-log plots and the system one-line diagram.
- H. The study shall include a separate, tabular computer printout containing the suggested device settings of all adjustable overcurrent protective devices, the equipment where the device is located, the device number corresponding to the device on the system one-line diagram, and the number of the time-current log-log graphs where they are illustrated.
- I. A computer generated system one-line diagram shall be provided which clearly identifies individual equipment buses, bus numbers, device identification numbers and the maximum available short-circuit current at each bus when known.
- J. A discussion section which evaluates the degree of system protection and service continuity with overcurrent devices, along with recommendations as required for increasing system protection or device coordination. Submit curves and study as a shop drawing for approval.
- K. Significant deficiencies in protection and/or coordination shall be called to the attention of Owner and recommendations made for improvements as soon as any they are identified.
- L. Factory set all relays, breaker trips, and select proper HV fuses which coordinate with transformer inrush current and circuit breakers.

- M. Include in study the emergency generator main breaker and associated distribution system.
- N. Preliminary coordination study shall be made by Vendor prior to submission of shop drawings.
- O. Sizes of fuses, breaker interrupting rating, bus bracing shall be minimum as shown on drawing. Exact sizing shall be according to coordination study.
- P. Any changes to engineering documents, as a result of coordination study shall not result in any additional cost to OWNER.
- Q. The Vendor shall contact Owner immediately if any delay occurs due to the lack of required information he needs to complete this study.
- R. If any delay occurs due to time required for manufacturing of the indoor switchgear submit shop drawings on this switchgear prior to coordination study shop drawings.
- S. Present organized time-current analysis of each protective device in series from main circuit breaker in branch circuit panelboard back to Utility Company devices protective service, including on-site service, main and federal circuit protective devices.
- T. Provide two (2) bound copies of the completed protective device time-current coordination analysis to Owner.

2.3 LOAD FLOW VOLTAGE DROP ANALYSIS

- A. The Load Flow and Voltage Drop Analysis shall be made using a digital computer and include calculations of power flow in all three-phase branch and feeder circuits, calculated voltages at each bus and voltage drops of each feeder.
- B. The analysis shall provide the calculated maximum values of kVA, kW, kVAR, power factor, and amperes for each power circuit.
- C. The calculated power losses in each branch and total system losses shall be provided.
- D. A computer printout listing all cables, transformers, loads, and other circuit data shall be included.
- E. Provide tabular bus-to-bus computer printouts listing the calculated values.
- F. The analysis shall include a computer generated system one-line diagram clearly identifying individual equipment buses, bus numbers, cable and bus connections, power flow throughout the system, and other information related to the analysis.
- G. A discussion section evaluating the loading and voltage levels for the system shall be provided and recommendations included as appropriate to improve system operation.
- H. Significant deficiencies in loading or voltage levels shall be called to attention of Owner and recommendations made for improvements as soon as they are identified.
- I. Provide two (2) bound copies of the completed Load Flow and Voltage Drop Analysis to Owner.

2.4 SWITCHING TRANSIENT ANALYSIS STUDY

- A. A Switching Transient Analysis Study shall be made to determine the transient overvoltages for various switching conditions and their effect on the operation of the electrical system.
- B. Various system conditions (consistent with previously gathered data from the Power Factor Correction Study and Harmonic Analysis Study) shall be evaluated so that the proper overvoltage protection specifications may be developed.
- C. Transient simulations shall be performed using a digital computer to determine transient voltage levels at the low voltage buses within the electrical system.
- D. The electrical system parameters shall be varied to determine their effect on the transient voltages.
- E. Various solutions to excessive transient voltage levels shall be considered and additional computer simulations made to determine their validity.
- F. The evaluation must consider solutions to power factor and harmonic concerns with respect to transient overvoltage levels.
- G. Nuisance tripping of electronic power equipment (eg. adjustable speed drives) shall be evaluated and corrective or preventive techniques suggested.
- H. Provide two (2) bound copies of the completed Transient Analysis Study to Owner.

2.5 HARMONIC ANALYSIS STUDY

- A. A Harmonic Analysis Study shall be made to determine the levels of harmonic voltages and currents in the system.
- B. The type and level of compensation needed to achieve the desired power factor and acceptable levels of harmonics shall be considered.
- C. Transient concerns shall be evaluated to determine the optimum equipment size, location in the system, and configuration.
- D. The study shall make appropriate recommendations to provide proper protection and operation of the electrical system.
- E. The study shall be based on load data collected from on-site measurements to characterize the power factor of the system over a period of time and under varying load conditions.
- F. Harmonic measurements shall be performed to provide nonlinear load (eg. dc drive) characteristics, voltage distortion levels, and model verification. The measurements shall be conducted over a 1-5-day period.
- G. Harmonic source models shall be developed for each nonlinear load (drive, etc.) type. The load characteristics shall be determined by measurement and used as harmonic sources for the computer simulations.
- H. Frequency scan cases (impedance vs frequency) shall be completed to determine the system frequency response characteristic for various system conditions.

- I. If required, the application of harmonic filters shall be evaluated to determine the optimum filter size and configurations.
- J. Computer simulations shall be performed to determine the system harmonic voltage and current levels and voltage distortion levels (and compared with measured values to determine the effect of various system conditions).
- K. If required, harmonic filter specifications shall be developed with consideration to cost, filtering options, and effectiveness of harmonic filters.
- L. Provide two (2) bound copies of the completed Harmonic Analysis Study to Owner.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine Project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance. Devices to be coordinated are indicated on Drawings.
 - 1. Proceed with coordination study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to coordination study may not be used in study.

3.2 PROTECTIVE DEVICE COORDINATION STUDY

- A. Comply with IEEE 242 for calculating short-circuit currents and determining coordination time intervals.
- B. Comply with IEEE 399 for general study procedures.
- C. The study shall be based on the device characteristics supplied by device manufacturer.
- D. Begin analysis at the service, extending down to the system overcurrent protective devices as follows:
 - 1. To normal system low-voltage load buses where fault current is 10 kA or less.
- E. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study all cases of system-switching configurations and alternate operations that could result in maximum fault conditions.
- F. Transformer Primary Overcurrent Protective Devices:
 - 1. Device shall not operate in response to the following:
 - a. Inrush current when first energized.
 - b. Self-cooled, full-load current or forced-air-cooled, full-load current, whichever is specified for that transformer.
 - c. Permissible transformer overloads per IEEE C57.96 if required by unusual loading or emergency conditions.
 - 2. Device settings shall protect transformers per IEEE C57.12.00, for fault currents.

- G. Motor Protection:
 - 1. Select protection for low-voltage motors per IEEE 242 and NFPA 70.
 - 2. Select protection for motors served at voltages more than 600 V per IEEE 620.

- H. Conductor Protection: Protect cables against damage from fault currents per ICEA P-32-382, ICEA P-45-482, and protection recommendations in IEEE 242. Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary relay protection or total clearing time of the fuse. To determine temperatures that damage insulation, use curves from cable manufacturers or from listed standards indicating conductor size and short-circuit current.

- I. Generator Protection: Select protection per manufacturer's written recommendations and to IEEE 242.

- J. The calculations shall include the ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and shall apply to low- and medium-voltage, three-phase ac systems. The calculations shall also account for the fault-current dc decrement, to address the asymmetrical requirements of the interrupting equipment.
 - 1. For grounded systems, provide a bolted line-to-ground fault-current study for areas as defined for the three-phase bolted fault short-circuit study.

- K. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault and single line-to-ground fault at each of the following:
 - 1. Electric utility's supply termination point.
 - 2. Switchgear.
 - 3. Unit substation primary and secondary terminals.
 - 4. Low-voltage switchgear.
 - 5. UPS and automatic transfer switches.
 - 6. Branch circuit panelboards.

- L. Protective Device Evaluation:
 - 1. Evaluate equipment and protective devices and compare to short-circuit ratings.
 - 2. Adequacy of switchgear, motor-control centers, and panelboard bus bars to withstand short-circuit stresses.

3.3 LOAD-FLOW AND VOLTAGE-DROP STUDY

- A. Perform a load-flow and voltage-drop study to determine the steady-state loading profile of the system. Analyze power system performance two times as follows:
 - 1. Determine load-flow and voltage drop based on full-load currents obtained in "Power System Data" Article.
 - 2. Determine load-flow and voltage drop based on 80 percent of the design capacity of the load buses.
 - 3. Prepare the load-flow and voltage-drop analysis and report to show power system components that are overloaded, or might become overloaded.

3.4 MOTOR-STARTING STUDY

- A. Perform a motor-starting study to analyze the transient effect of the system's voltage profile during motor starting. Calculate significant motor-starting voltage profiles and analyze the effects of the motor starting on the power system stability.
- B. Prepare the motor-starting study report, noting light flicker for limits proposed by IEEE 141, and voltage sags so as not to affect the operation of other utilization equipment on the system supplying the motor.

3.5 POWER SYSTEM DATA

- A. Obtain all data necessary for the conduct of the overcurrent protective device study.
 - 1. Verify completeness of data supplied in the one-line diagram on Drawings. Call discrepancies to the attention of the Owner.
 - 2. For new equipment, use characteristics submitted under the provisions of action submittals and information submittals for this Project.
 - 3. For existing equipment, whether relocated or not, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and Owners. The technicians shall be qualified as defined by NFPA 70E.
- B. Gather and tabulate the following input data to support coordination study. The list below is a guide. Comply with recommendations in IEEE 241 and IEEE 551 for detail required to be acquired in the field. Field data gathering shall be under the direct supervision and control of the Owner in charge of performing the study, and shall be by the Owner or its representative who holds NETA ETT Level III certification or NICET Electrical Power Testing Level III certification.
 - 1. Product Data for overcurrent protective devices specified in other Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
 - 2. Electrical power utility impedance at the service.
 - 3. Power sources and ties.
 - 4. Short-circuit current at each system bus, three phase and line-to-ground.
 - 5. Full-load current of all loads.
 - 6. Voltage level at each bus.
 - 7. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in percent, and phase shift.
 - 8. For reactors, provide manufacturer and model designation, voltage rating, and impedance.
 - 9. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip and available range of settings, SCCR, current rating, and breaker settings.
 - 10. Generator short-circuit current contribution data, including short-circuit reactance, rated kVA, rated voltage, and X/R ratio.
 - 11. For relays, provide manufacturer and model designation, current transformer ratios, potential transformer ratios, and relay settings.
 - 12. Maximum demands from service meters.
 - 13. Busway manufacturer and model designation, current rating, impedance, lengths, and conductor material.
 - 14. Motor horsepower and NEMA MG 1 code letter designation.
 - 15. Low-voltage cable sizes, lengths, number, conductor material, and conduit material (magnetic or nonmagnetic).

16. Medium-voltage cable sizes, lengths, conductor material, and cable construction and metallic shield performance parameters.
17. Data sheets to supplement electrical distribution system diagram, cross-referenced with tag numbers on diagram, showing the following:
 - a. Special load considerations, including starting inrush currents and frequent starting and stopping.
 - b. Transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.
 - c. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.
 - d. Ratings, types, and settings of utility company's overcurrent protective devices.
 - e. Special overcurrent protective device settings or types stipulated by utility company.
 - f. Time-current-characteristic curves of devices indicated to be coordinated.
 - g. Manufacturer, frame size, interrupting rating in amperes RMS symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers.
 - h. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.
 - i. Panelboards, switchboards ampacity, and SCCR in amperes RMS symmetrical.

3.6 FIELD ADJUSTING

- A. Adjust relay and protective device settings per the recommended settings provided by the coordination study. Field adjustments shall be completed by the Engineering service division of the equipment manufacturer under the Startup and Acceptance Testing contract portion.
- B. Make minor modifications to equipment as required to accomplish compliance with short-circuit and protective device coordination studies.
 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters. Perform NETA tests and inspections for all adjustable overcurrent protective devices.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”

END OF SECTION

SECTION 16056

OVERCURRENT PROTECTIVE DEVICE ARC-FLASH STUDY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes a computer-based, arc-flash study to determine the arc-flash hazard distance and the incident energy to which personnel could be exposed during work on or near electrical equipment.

1.3 DEFINITIONS

- A. Existing to Remain: Existing items of construction that are not to be removed and that are not otherwise indicated to be removed, removed and salvaged, or removed and reinstalled.
- B. One-Line Diagram: A diagram which shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein.
- C. Protective Device: A device that senses when an abnormal current flow exists and then removes the affected portion from the system.
- D. SCCR: Short-circuit current rating.
- E. Service: The conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

1.4 SUBMITTALS

- A. Product Data: For computer software program to be used for studies.
- B. Other Action Submittals: Submit the following submittals after the approval of system protective devices submittals. Submittals shall be in digital form.
 - 1. Arc-flash study input data, including completed computer program input data sheets.
 - 2. Arc-flash study report; signed, dated, and sealed by a qualified professional engineer.
 - a. Submit study report for action prior to receiving final approval of the distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Owner for preliminary submittal of sufficient study data to ensure that the selection of devices and associated characteristics is satisfactory.
- C. For arc-flash hazard analysis software, certifying compliance with IEEE 1584 and NFPA 70E.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance procedures per requirements in NFPA 70E shall be provided in the equipment manuals.
- B. Operation and Maintenance NFPA 70E Procedures provide maintenance procedures for use by Owner's personnel that comply with requirements in NFPA 70E.

1.6 QUALITY ASSURANCE

- A. Studies shall use computer programs that are distributed nationally and are in wide use. Software algorithms shall comply with requirements of standards and guides specified in this Section. Manual calculations are unacceptable.
- B. Arc-Flash Study Software Developer Qualifications: An entity that owns and markets computer software used for studies, having performed successful studies of similar magnitude on electrical distribution systems using similar devices.
 - 1. The computer program shall be developed under the charge of a licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.
- C. Arc-Flash Study Specialist Qualifications: Professional engineer in charge of performing the study, analyzing the arc flash, and documenting recommendations, licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional Owner.
- D. Field Adjusting Agency Qualifications: An independent agency, with the experience and capability to adjust overcurrent devices and to conduct the testing indicated, that is a member company of the International Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 COMPUTER SOFTWARE DEVELOPERS

- A. Software Developers: Subject to compliance with requirements, provide software by one of the following:
 - 1. SKM Systems Analysis, Inc.
 - 2. CYME International T&D
 - 3. Power Analytics, Corporation.
- B. Comply with IEEE 1584 and NFPA 70E.
- C. Analytical features of device coordination study computer software program shall have the capability to calculate "mandatory," "very desirable," and "desirable" features as listed in IEEE 399.

2.2 ARC FLASH STUDY REPORT CONTENT

- A. Executive summary.
- B. Study descriptions, purpose, basis and scope.

- C. Calculation of the maximum available arc flash energy at each significant location (switchgear, substation, MCC, transformer, distribution panelboard, panelboard) to be made using both NFPA 70E and IEEE 1584 calculations for the range of short circuit utility current available per ACE requirements.
- D. A tabular printout shall be included which lists the highest available arc flash energy in cal/cm², the voltage, butted short-circuit current available, flash boundary, working distance, protective device cleaning time and protective equipment category.
- E. Tabulated report shall clearly indicate which calculation method is used and whether calculations are within the valid range parameters set out in IEEE 1584 and NFPA 70E.
- F. A comprehensive single-line diagram indicating the arc flash energy (max) at each point in the system shall be included with the tabular report.
- G. A comprehensive discussion section, evaluating the possibility and ramifications of reducing the arc flash at high arc-flash points (where calculated values exceed the ratings in NFPA 70E).
- H. Provide two (2) bound copies of the completed arc-flash analysis, along with the short-circuit study, to the Owner.
- I. Provide Arc Flash Warning Labels as follows:
 - 1. Provide a 3.5 in. x 5 in. thermal transfer type label of high adhesion polyester for each work location analyzed.
 - 2. The label shall have an orange header with the wording, "WARNING - ARC FLASH HAZARD" and shall include the following information:
 - a. Location designation.
 - b. Nominal voltage.
 - c. Flash protection boundary.
 - d. Hazard/risk category.
 - e. Incident energy.
 - f. Working distance.
 - g. Engineering report number, revision and issue date.
 - 3. Labels shall be machine printed with no field markings.
 - 4. Labels shall be field-installed at the time of start-up and testing by the engineering field service division of the company providing the arc flash analysis.
- J. Training:
 - 1. Train Owner's personnel for a minimum of 4 hours on the potential hazards associated with working on energized equipment. Maintenance procedures in accordance with NFPA 70E shall be provided in the equipment manuals. All training shall be certified for containing education units (CEU's) by IACET.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine Project overcurrent protective device submittals. Proceed with arc-flash study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to arc-flash study may not be used in study.

3.2 ARC-FLASH HAZARD ANALYSIS

- A. Comply with NFPA 70E and its Annex D for hazard analysis study.
- B. Use the short-circuit study output and the field-verified settings of the overcurrent devices.
- C. Calculate maximum and minimum contributions of fault-current size.
 - 1. The minimum calculation shall assume that the utility contribution is at a minimum and shall assume no motor load.
 - 2. The maximum calculation shall assume a maximum contribution from the utility and shall assume motors to be operating under full-load conditions.
- D. Calculate the arc-flash protection boundary and incident energy at locations in the electrical distribution system where personnel could perform work on energized parts.
- E. Include medium- and low-voltage equipment locations, except 240-V ac and 208-V ac systems fed from transformers less than 125 kVA.
- F. Safe working distances shall be specified for calculated fault locations based on the calculated arc-flash boundary, considering incident energy of 1.2 cal/sq.cm.
- G. Incident energy calculations shall consider the accumulation of energy over time when performing arc-flash calculations on buses with multiple sources. Iterative calculations shall take into account the changing current contributions, as the sources are interrupted or decremented with time. Fault contribution from motors and generators shall be decremented as follows:
 - 1. Fault contribution from induction motors should not be considered beyond three to five cycles.
 - 2. Fault contribution from synchronous motors and generators should be decayed to match the actual decrement of each as closely as possible (e.g., contributions from permanent magnet generators will typically decay from 10 per unit to three per unit after 10 cycles).
- H. Arc-flash computation shall include both line and load side of a circuit breaker as follows:
 - 1. When the circuit breaker is in a separate enclosure.
 - 2. When the line terminals of the circuit breaker are separate from the work location.
- I. Base arc-flash calculations on actual overcurrent protective device clearing time. Cap maximum clearing time at two seconds based on IEEE 1584.

3.3 POWER SYSTEM DATA

- A. Obtain all data necessary for the conduct of the arc-flash hazard analysis.

1. For new equipment, use characteristics submitted under the provisions of action submittals and information submittals for this Project.
 2. For existing equipment, whether relocated or not, obtain required electrical distribution system data by field investigation and surveys, conducted by qualified technicians and Owners.
- B. Gather and tabulate the following input data to support coordination study. Comply with recommendations in IEEE 1584 and NFPA 70E as to the amount of detail that is required to be acquired in the field. Field data gathering shall be under the direct supervision and control of the Owner in charge of performing the study, and shall be by the Owner or its representative who holds NETA ETT Level III certification or NICET Electrical Power Testing Level III certification.
1. Product Data for overcurrent protective devices specified in other Sections and involved in overcurrent protective device coordination studies. Use equipment designation tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
 2. Obtain electrical power utility impedance at the service.
 3. Power sources and ties.
 4. For transformers, include kVA, primary and secondary voltages, connection type, impedance, X/R ratio, taps measured in per cent, and phase shift.
 5. For circuit breakers and fuses, provide manufacturer and model designation. List type of breaker, type of trip and available range of settings, SCCR, current rating, and breaker settings.
 6. Motor horsepower and NEMA MG 1 code letter designation.
 7. Low-voltage cable sizes, lengths, number, conductor material and conduit material (magnetic or nonmagnetic).

3.4 LABELING

- A. Apply one arc-flash label for 600-V ac, 480-V ac, and applicable 208-V ac panelboards and disconnects and for each of the following locations:
1. Low-voltage switchboard.
 2. Switchgear.
 3. Medium-voltage switch.
 4. Control panel.

3.5 APPLICATION OF WARNING LABELS

- A. Install the arc-fault warning labels under the direct supervision and control of the Arc-Flash Study Specialist.

3.6 DEMONSTRATION

- A. Engage the Arc-Flash Study Specialist to train Owner's maintenance personnel in the potential arc-flash hazards associated with working on energized equipment and the significance of the arc-flash warning labels.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16060

GROUNDING AND BONDING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 DESCRIPTION OF WORK

- A. Work Included: This Section specifies furnishing and installing complete system neutral grounding, equipment grounding, and building structural grounding.

1.3 SUBMITTALS

- A. As-Built Drawings. Submit prior to final acceptance of the work, drawings showing complete layout of systems installed including physical location of ground rods to which connections were made.
- B. Field Quality Control Test Report. Submit reports complying with requirements of Part 3 "Field Quality Control" Article.

PART 2 - PRODUCTS

2.1 BARE GROUND WIRE

- A. Soft drawn copper, Class A or Class B stranded, meeting the requirements of ASTM B8; size in accordance with the NEC except where sizes specified herein or shown on the Contract Drawings are larger than those required by NEC; UL listed, Label A for lightning protection conductors. Grounding cable shall be continuous without joints or splices through its length.

2.2 INSULATED GROUND WIRE

- A. Copper, Class B Stranded, 600-Volt, 90 degree C, NEC type THWN; meeting requirements of AAR Specifications No. 535.2; sized as indicated; and UL listed.

2.3 PRODUCTS USED FOR COPPER THERMIT WELDED CONNECTIONS

- A. Use products for copper thermit welded connections which are the products of one manufacturer and are produced for the specific application for which they are used.
- B. Use materials and equipment which meet or exceed the applicable acuirements of the AAR Manual, Electrical Section, Section 13, Chapter 3, Part 6.

- C. Coating Materials for Thermit Welded Connections: Use black, rubber based compound coating materials, which are soft, permanently pliable, moldable, and unbacked, not less than 1/8 inch thick, with properties as follows:

Solids	100 percent
Density	12.0 pounds per gallon minimum
Penetration	90-130 ASTM D5
Water Absorption	0.10 percent maximum ASTM D570
Dielectric Strength	500 volts/mil ASTM D149
Volume Resistivity	2,000 megohms-inches ASTM D257 5,000 megohms-cm ASTM D257
Service Temperature	Minus 40 degrees to 160 degrees F.
Chemical Resistance	Melting point, none; flammability, slow burning (ASTM C653); resists alcohol, water, aqueous hydrochloride and sodium hydroxide; dissolved by carbon tetrachloride, naphtha gasoline, mineral spirits, ketones, and benzene.
Highly cohesive and Adhesive	Adheres strongly to metals and concrete and to itself.

2.4 BOLTED GROUNDING CONNECTORS

- A. For solderless type made of high strength electrical bronze with silicon bronze clamping bolts and hardware; designed such that bolts, nuts, lock washers and similar hardware which might nick or otherwise damage the ground wire will not directly contact the ground wire.

2.5 GROUND BUS

- A. 1/4 inch by 2 inch copper bus bar ; drilled and tapped to receive ground cable connections from the ground rod assembly and ground connections for equipment as required.

2.6 GROUND RODS

- A. Medium carbon steel core, copper clad by the molten weld casting process; minimum 3/4" x 10'L; UL approved.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Perform testing as specified in Part 3 “Field Quality Control” Article.

3.2 GENERAL GROUNDING REQUIREMENTS

- A. General. Provide station electrical grounding complying with procedures of NEC and as indicated.
- B. Equipment Ground Conductors
 - 1. Provide each conduit entering switchgear with equipment ground conductor, colored green.
 - 2. Terminate conductor directly on ground bus for switchgear equipment housing and conduit system; do not connect equipment ground conductor to neutral bus. Additionally, do not use these conductors to carry any line-to-ground loads, such as 277 volt lighting.
- C. White Neutral Conductor. Provide each conduit feeding line-to-ground loads, such as 277 volt lighting with both an equipment ground conductor and insulated white neutral conductor.
- D. Provide GFI convenience at all locations required by MEC.

3.3 SYSTEM NEUTRAL GROUNDING

- A. General. Provide three-phase alternating current secondary distribution systems wye connected with neutral grounding at the source.
 - 1. Run throughout as indicated, system neutral and ground bus and equipment ground conductor or both as indicated. Wye-connect generators and ground neutrals. On wye systems where generator neutrals are grounded at unit, to prevent improper operation of ground fault protection equipment, provide four-pole transfer switches, except at 13.8 kilivolt feeder breakers serving primaries of load center unit substations with automatic transfer accessories.
 - 2. Solidly ground neutral deriving equipment.
 - 3. Connection Secondary Wye Neutral Points.
 - a. At Equipment Described in Part 3 Article above. Connect neutral points to primary source equipment ground and where applicable secondary ground bus.
 - b. At Power Transformers and Load Centers. Provide copper conductors, sized, as indicated, but in no case smaller than that required by NEC.
 - c. At Dry-Type Transformers. Use equipment ground conductor for connection of equipment and neutral to ground system.
 - 4. Where source of power is from an electric utility company, at point of service to facility, solidly interconnect utility ground system by way of equipment ground system and where feasible building structural ground system.

3.4 EQUIPMENT GROUNDING

- A. Wiring, Channels, Cable Trays, Metallic Conduit, Rigid Electrical Metallic Tubing, Flexible Conduits, Metallic Boxes, Panelboards, and Transformer Enclosures. Ground with copper ground conductors.

- B. Motors, Lighting Fixtures and Equipment.
 - 1. Accomplish grounding with equipment ground.
 - 2. Provide equipment ground conductor electrically and mechanically continuous from system equipment and neutral ground connection at source of supply to equipment to be grounded.
- C. Building Type Conductors
 - 1. Where conductors are installed in raceways, run equipment ground conductor for alternating current systems within raceways with circuit conductors.
 - 2. Provide copper equipment ground conductor minimum one size smaller than phase conductors, except having minimum size of No. 12 and maximum size No. 4/0 AWG.
 - 3. Identify equipment ground conductors with colored green type THW insulation, except where green insulation is not available on larger sizes, black colored insulation shall be used and suitably identified with green tape at each junction box or device enclosure.
- D. Junction Boxes and Other Enclosures Sized Above Five Square Inches. Securely bond equipment ground conductors to enclosures utilizing equipment ground bus or lug.

3.5 BUILDING STRUCTURAL GROUNDING

- A. Ground Bus. Provide copper ground bus loop, 2/0 AWG copper,, buried to minimum depth of 24".
- B. Ground Electrodes
 - 1. Space electrodes indicated minimum of one rod length apart, and connect each electrode to ground bus loop with copper conductor as indicated.
 - 2. Provide copper-coated, high-strength steel rods ground rod, 3/4" diameter x 10'-0" L, ,Locate top of electrodes minimum depth below grade of 6"
 - 3. Where soil conditions make it impossible to drive ground electrodes to depth indicated, provide three ground rods spaced maximum of 10 feet apart in shape of equilateral triangle and interconnected with copper ground conductor as indicated.
 - 4. Make below-grade connections by brazing or thermite welding.
- C. Steel Columns, Steel Reinforcing Bars and Other Materials.
 - 1. Connect steel columns or steel reinforcing bars in exterior walls to ground bus loop at intervals indicated. For bare copper connections, utilize brazing or thermite welding at ground bus loop and brazing, thermite welding, or bolted pressure fitting at steel columns. Make connections at steel columns 18 inches above finished floor in web of columns.
 - 2. Connect steel columns inside buildings to ground bus loop on each side of each building, with continuous bare copper conductor.
 - 3. In buildings using materials other than steel for columns and where roof structure is steel, ground steel roof beams to ground bus loop similar to the methods described in Part 3 Articles above.
- D. Connect domestic and fire protection metallic water pipes to ground bus loop with bare copper conductor, as indicated, at a minimum of two points.

- E. Connect medium voltage switchgear and load center equipment ground bus to ground bus loop with copper conductor, as indicated, at minimum of two points.
- F. Connect miscellaneous metal objects, including piping, vessels, and structural shapes, within six feet of electrically-grounded metallic objects to ground system with a minimum No. 6 AWG bare copper conductor.
- G. Where a lightning protection system is provided in the form of air terminals of non-conductive materials or in the form of metal protuberances, connect these systems to ground bus loop with copper conductors equivalent to No. 2/0 AWG copper. Provide systems designed in accordance with requirements of NFPA No. 78.

3.6 CONVENIENCE OUTLETS

- A. Ground all convenience outlets in accordance with the Mass Electrical Code (MEC).

3.7 THERMIT WELDING CONNECTIONS

- A. Connect electrical wires together, to reinforcing steel or soldier piles, by thermit welding using the manufacturer's recommended molds and size of charges for application.
- B. Prepare the material to be welded and perform thermit welding in accordance with manufacturer's instructions.
- C. Test completed thermit welds before coating by striking with two pound hammer. If cracks develop, replace welds at no additional expense to the Authority. When required by the Owner, test the electrical continuity of bonds.
- D. Apply coating so that it extends one inch beyond point of attachment to steel member, overlaps wire coating one inch, and provides insulation thickness equivalent to wire insulation, but not less than 1/8 inch in thickness. Do not apply coating material at ambient temperatures below 20 degrees F or above 125 degrees F. Maintain, by an approved method, curing temperature within above temperature range for at least four hours after application of coating. Protect coating by approved means until embedment.

3.8 FIELD QUALITY CONTROL

- A. Testing Existing Grounding Systems
 - 1. General. Prior to installation of grounding systems specified under this Contract, test related grounding systems installed under previous or adjoining contracts to extent as indicated or specified in the Construction Specifications.
 - 2. Test Report. Provide test report completely describing ground resistance test procedures and giving test results.
 - 3. Ground Resistance Testing
 - a. Testing. Verify that resistance between ground and absolute earth for existing grounding systems does not exceed two ohms without benefit of chemical treatment or other artificial means, unless indicated otherwise in the Construction Specifications.

B. Testing Building Structural Grounding

1. **General.** After installation of ground loop bus and ground electrodes, and prior to interconnection of other grounding systems perform ground resistance testing.
2. **Test Report.** Provide report giving results of testing procedures, which shall also include temperature, humidity, and condition of soil at time of tests.
3. **Ground Resistance Testing**
 - a. **Test Equipment and Method.** Perform testing using ground resistance direct-reading single test meter utilizing alternating current fall-of-potential method and two reference electrodes.
 - b. **Test Procedure**
 - 1) Orient ground electrode to be tested and two reference electrodes in straight line space minimum 50 feet apart.
 - 2) Drive two reference electrodes five feet deep.
 - c. **Test Requirement or Limits.** If ground resistance exceeds MEC requirements, install additional ground electrodes until resistance is 5 ohms or less.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16070

ELECTRICAL-MECHANICAL INTERFACE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SCOPE

- A. The Scope of Work under this Section, without limiting the generality thereof, includes the furnishing of all labor, materials, equipment, services, and incidentals necessary to complete all Electrical Work in accordance with the intent of the Specifications. All systems shall be complete, tested and fully operational prior to the acceptance of same by Owner.
- B. The Work under this section shall consist of but not necessarily be limited to the following:
 - 1. Power wiring for plumbing and HVAC Systems equipment.
 - 2. Interlock (line voltage) wiring required for the operation of mechanical equipment furnished and installed under the HVAC and Plumbing Sections of the Specifications. Automatic Temperature Control wiring is not considered a part of interlock wiring and will be provided under Section 15900-HVAC Instrumentation and Controls.
 - 3. Safety Switches.
 - 4. Coordination with all Authorities Having Jurisdiction (AHJ) and other trade Design-Builders.
 - 5. Wiring to Fire Alarm System all duct mounted smoke detectors provided under Division 15.
- C. The work under this section does not include Related Work by others included under other Sections of the Specifications. Electrical Design-Builder shall provide electrical connections as described below.
 - 1. Plumbing System, including equipment requiring electrical connections, devices, starters and contactors will be by the Plumbing Design-Builder. Loose devices, contactors and starters not mounted as an integral part of a unit will be furnished by the plumbing sub Design-Builder but will be received, mounted and wired by the Electrical Design-Builder.
 - 2. HVAC System including' equipment requiring electrical connections, devices, starters and contactors will be by the HVAC Design-Builder. Loose devices, contactors and starters requiring line voltage connections that are not included as an integral part of a unit will be received, mounted and wired by the Electrical Design-Builder.
 - 3. Automatic Temperature Control system will be furnished and installed complete by the HVAC Design-Builder except for 120V power supplies which shall be obtained by the HVAC Design-Builder but will be installed by the Electrical Design-Builder.
 - 4. Fire Protection System, including panel, pump and equipment requiring 120 volt power shall be provided with proper power connections by the Electrical Design Builder.

1.3 CODES AND STANDARDS

- A. The installation and material furnished shall comply with the regulations of the Massachusetts Electrical Code, State and Local Building Department Codes, and all legally constituted authorities having jurisdiction. Where Specification requirements exceed the requirements of the applicable codes the requirements specified in the Contract Documents shall govern.

1.4 HANDLING OF MATERIALS

- A. Receive and accept at the site, properly handle, house and protect from injury as well as the weather until ready for installation, the following materials.
 - 1. Materials, equipment and apparatus furnished under this Section.
 - 2. Electrical control equipment furnished under other Sections of the Specifications and to be installed under this Section.
- B. Equipment damaged in the course of handling, installation or test shall be replaced under this Section or repaired to the satisfaction of Owner without any additional charge.
- C. Electrical materials and equipment, , shall be properly protected against damage.

1.5 PROTECTION

- A. It shall be the responsibility of this Sub-Design-Builder for the maintenance and protection of all materials and equipment provided during all phases of construction from loss damage or deterioration until final acceptance by Owner.

1.6 OPERATING AND MAINTENANCE INSTRUCTIONS

- A. Prior to completion of the Contract, provide operating instructions to the Owner's designated representative with respect to operation functions and maintenance procedures for all equipment and systems installed. Thoroughly instruct the Owner's representatives in the operation of all electrical systems and components to the complete satisfaction of the Owner. Advise Owner's representatives as to the location of all electrical equipment associated with the various systems.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Materials and equipment included under this Part and required for the proper installation and operation of the electrical system shall comply with the applicable requirements of Part 1 of this Section.

2.2 SAFETY SWITCHES

- A. Provide disconnect switches fused as required. Switches shall be NEMA type HD safety switches for heavy duty use with interlocking cover, side operated. Switches exposed to weather shall have rain tight enclosures. Switch enclosure shall be NEMA Listed for location and atmosphere in which they are mounted. Current carrying parts shall be silver plated. Fuse sizes shall be in accordance to manufacturer ratings. HVAC equipment and pumps will be provided with integral motor starters.

- B. Disconnect switches shall be provided and shall be as manufactured by Square D, Siemens, or Eaton.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Wiring and Connections for HVAC, Fire Protection and Plumbing Equipment:
1. Motors, dampers, and/or valves, pumps, fans, thermostats, temperature control devices, motor starters, aqua stats, etc. for the operation and control of HVAC and Plumbing equipment will be furnished under Division 15 of this specification unless noted or indicated otherwise.
 2. Power wiring for HVAC, Fire Protection and Plumbing Equipment furnished under Division 15 shall be furnished and installed under this section of the specification.
 3. Furnish and install disconnect switches not furnished with the HVAC and Plumbing and Fire Protection equipment as required by code or to provide personnel safety. Disconnect switches furnished with the HVAC and Plumbing and Fire Protection equipment shall be handed over by the Division 15 Design-Builders to the Division 16 Design-Builder for installation.
 4. This Division 16 Design-Builder shall make power and line voltage (120V) interlock wiring connections to the HVAC and Plumbing equipment in conformance with wiring diagrams provided by the respective trade Design-Builders. Interlock wiring shown on the electrical drawings or specified herein shall be furnished and installed under this Section; interlock wiring not specifically shown on the electrical drawings will be furnished and installed under the respective Trade Sections by others at no cost to Owner.
 5. Install remotely located selector switches, stop-start stations and pilot lights provided by the HVAC and Plumbing Design-Builders, including line voltage control wiring to same for the operation of the Plumbing and HVAC system equipment.
 6. Automatic temperature control system wiring and the devices required for the operation of same will be furnished and installed complete under Division 15 of this Specification.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16073

HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes the following:
 - 1. Hangers and supports for electrical equipment and systems.
 - 2. Construction requirements for concrete bases.
- B. Related Sections include the following:
 - 1. Section 16050- BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK for additional product and installation requirements and criteria.
 - 2. Section 16074 - SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS for products and installation requirements necessary for compliance with seismic criteria.

1.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Design supports for multiple raceways, including comprehensive engineering analysis by a qualified professional engineer.
- B. Design supports for multiple raceways capable of supporting combined weight of supported systems and its contents.
- C. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
- D. Rated Strength: Adequate in tension, shear, and pullout force to resist maximum loads calculated or imposed for this Project, with a minimum structural safety factor of five times the applied force.

1.4 SUBMITTALS

- A. Product Data: For the following:
 - 1. Steel slotted support systems.
- B. Shop Drawings: Show fabrication and installation details and include calculations for the following:

1. Trapeze hangers. Include Product Data for components.
 2. Steel slotted channel systems. Include Product Data for components.
 3. Equipment supports.
- C. Welding certificates.

1.5 QUALITY ASSURANCE

- A. Welding: Qualify procedures and personnel per AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- B. Comply with. Mass Electrical Code

1.6 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified together with concrete Specifications.

PART 2 - PRODUCTS

2.1 SUPPORT, ANCHORAGE, AND ATTACHMENT COMPONENTS

- A. Steel Slotted Support Systems: Comply with MFMA-4, factory-fabricated components for field assembly.
 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Allied Tube & Conduit.
 - b. Cooper B-Line, Inc.
 - c. ERICO International Corporation.
 - d. GS Metals Corp.
 - e. Thomas & Betts Corporation.
 - f. Unistrut; Atkore International.
 - g. Wesanco, Inc.
 2. Metallic Coatings: Hot-dip galvanized after fabrication and applied according to MFMA-4.
 3. Channel Dimensions: Selected for applicable load criteria.
- B. Raceway and Cable Supports: As described in NECA 1 and NECA 101.
- C. Conduit and Cable Support Devices: Steel hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.
- D. Support for Conductors in Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug or plugs for non-armored electrical conductors or cables in riser conduits.

Plugs shall have number, size, and shape of conductor gripping pieces as required to suit individual conductors or cables supported. Body shall be malleable iron.

- E. Structural Steel for Fabricated Supports and Restraints: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

- F. Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:
 - 1. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened Portland cement concrete, steel, or wood, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.
 - a. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the work include, but are not limited to, the following:
 - b. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Hilti, Inc.
 - 2) ITW Ramset/Red Head; Illinois Tool Works, Inc.
 - 3) MKT Fastening, LLC.
 - 4) Simpson Strong-Tie Co., Inc.
 - 2. Mechanical-Expansion Anchors: Insert-wedge-type, stainless steel, for use in hardened Portland cement concrete with tension, shear, and pullout capacities appropriate for supported loads and building materials in which used.
 - a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1) Cooper B-Line, Inc.
 - 2) Empire Tool and Manufacturing Co., Inc.
 - 3) Hilti, Inc.
 - 4) ITW Ramset/Red Head; Illinois Tool Works, Inc.
 - 5) MKT Fastening, LLC.
 - 3. Concrete Inserts: Steel or malleable-iron, slotted support system units similar to MSS Type 18; complying with MFMA-4 or MSS SP-58.
 - 4. Clamps for Attachment to Steel Structural Elements: MSS SP-58, type suitable for attached structural element.
 - 5. Through Bolts: Structural type, hex head, and high strength. Comply with ASTM A 325.
 - 6. Toggle Bolts: All-steel springhead type.
 - 7. Hanger Rods: Threaded steel.

PART 3 - EXECUTION

3.1 APPLICATION

- A. Comply with NECA 1 and NECA 101 for application of hangers and supports for electrical equipment and systems except if requirements in this Section are stricter.
- B. Maximum Support Spacing and Minimum Hanger Rod Size for Raceway: Space supports for RMC as required by Massachusetts Electrical Code. Minimum rod size shall be 3/8 inch in diameter.
- C. Multiple Raceways or Cables: Install trapeze-type supports fabricated with steel slotted support system, sized so capacity can be increased by at least 25 percent in future without exceeding specified design load limits.
 - 1. Secure raceways and cables to these supports with single-bolt conduit clamps.
- D. Spring-steel clamps designed for supporting single conduits without bolts may be used for 1-1/2-inch and smaller raceways serving branch circuits and communication systems above suspended ceilings and for fastening raceways to trapeze supports.

3.2 SUPPORT INSTALLATION

- A. Comply with NECA 1 and NECA 101 for installation requirements except as specified in this Article.
- B. Raceway Support Methods: In addition to methods described in NECA 1, RMC may be supported by openings through structure members, as permitted in Massachusetts Electrical Code.
- C. Strength of Support Assemblies: Where not indicated, select sizes of components so strength shall be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.
- D. Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:
 - 1. To Wood: Fasten with lag screws or through bolts.
 - 2. To New Concrete: Bolt to concrete inserts.
 - 3. To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
 - 4. To Existing Concrete: Expansion anchor fasteners.

Retain first subparagraph below if powder-actuated devices are allowed. Consider deleting if Project contains both lightweight and standard-weight concrete or more than one thickness of concrete slab.

- 5. Instead of expansion anchors, powder-actuated driven threaded studs provided with lock washers and nuts may be used in existing standard-weight concrete 4 inches thick or greater. Do not use for anchorage to lightweight-aggregate concrete or for slabs less than 4 inches thick.

6. To Steel: Beam clamps (MSS Type 19, 21, 23, 25, or 27) complying with MSS SP-69.
 7. To Light Steel: Sheet metal screws.
 8. Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices on slotted-channel racks attached to substrate by means that meet seismic-restraint strength and anchorage requirements.
- E. Drill holes for expansion anchors in concrete at locations and to depths that avoid reinforcing bars.

3.3 INSTALLATION OF FABRICATED METAL SUPPORTS

- A. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.
- B. Field Welding: Comply with AWS D1.1/D1.1M.

3.4 CONCRETE BASES

- A. Construct concrete bases of dimensions indicated but not less than 4 inches larger in both directions than supported unit, and so anchors shall be a minimum of 10 bolt diameters from edge of the base.
- B. Use 3000-psi, 28-day compressive-strength concrete. Concrete materials, reinforcement, and placement requirements are specified in Section 03300 "CAST-IN-PLACE CONCRETE."
- C. Anchor equipment to concrete base.
 1. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 2. Install anchor bolts to elevations required for proper attachment to supported equipment.
 3. Install anchor bolts per anchor-bolt manufacturer's written instructions.

3.5 PAINTING

- A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
- B. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils.
- C. Touchup: Comply with requirements in Section 09900 "PAINTING" for painting and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
- D. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment shall not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16074

SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Restraint channel bracings.
 - 2. Restraint cables.
 - 3. Seismic-restraint accessories.
 - 4. Mechanical anchor bolts.
 - 5. Adhesive anchor bolts.
- B. Related Requirements:
 - 1. Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK" for commonly used electrical supports and installation requirements.
 - 2. Obtain the services of a qualified registered professional engineer to perform all seismic restraint calculations.

1.3 SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.
 - a. Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by an evaluation service member of ICC-ES.
 - b. Annotate to indicate application of each product submitted and compliance with requirements.
- B. Delegated-Design Submittal: For each seismic-restraint device.
 - 1. Seismic- and Wind-Restraint Details:
 - a. Design Analysis: To support selection and arrangement of seismic and wind restraints. Include calculations of combined tensile and shear loads.
 - b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.

- c. Coordinate seismic-restraint and vibration isolation details with wind-restraint details required for equipment mounted outdoors. Comply with requirements in other Sections for equipment mounted outdoors.
- d. Preapproval and Evaluation Documentation: By an evaluation service member of ICC-ES, showing maximum ratings of restraint items and the basis for approval (tests or calculations).

1.4 SUBMITTALS

- A. Coordination Drawings: Show coordination of seismic bracing for electrical components with other systems and equipment in the vicinity, including other supports and seismic restraints.
- B. Qualification Data: For Qualified professional engineer and testing agency.
- C. Welding certificates.
- D. Field quality-control reports.

1.5 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory as defined by OSHA in 29 CFR 1910.7 and that is acceptable to Authorities Having Jurisdiction (AHJ).
- B. Comply with seismic-restraint requirements in the IBC version in effect with Mass Amendments unless requirements in this Section are more stringent.
- C. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
- D. Seismic-restraint devices shall have horizontal and vertical load testing and analysis. They shall bear anchorage preapproval from OSHPD in addition to preapproval, showing maximum seismic-restraint ratings, by ICC-ES or another agency acceptable to authorities having jurisdiction. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) that support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Wind-Restraint Loading:
 - 1. Basic Wind Speed: Per Mass Building Code.
- B. Seismic-Restraint Loading:
 - 1. Site Class as Defined in the Mass Building Code.

2.2 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Cooper B-Line, Inc.; a Division of Cooper Industries.
 - 2. Hilti, Inc.
 - 3. Mason Industries, Inc.
 - 4. Unistrut; Atkore International.

- B. Description: MFMA-4, shop- or field-fabricated bracing assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end, with other matching components, and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.3 RESTRAINT CABLES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Kinetics Noise Control, Inc.
 - 2. Loos & Co., Inc.
 - 3. Vibration Mountings & Controls, Inc.

- B. Restraint Cables: ASTM A 492 stainless-steel cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; with a minimum of two clamping bolts for cable engagement.

2.4 SEISMIC-RESTRAINT ACCESSORIES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Cooper B-Line, Inc.; a Division of Cooper Industries.
 - 2. Kinetics Noise Control, Inc.
 - 3. Mason Industries, Inc.
 - 4. TOLCO; a brand of NIBCO INC.

- B. Hinged and Swivel Brace Attachments: Multifunctional steel connectors for attaching hangers to rigid channel bracings and restraint cables.

- C. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings and matched to type and size of anchor bolts and studs.

- D. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings and matched to type and size of attachment devices used.

- E. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

2.5 MECHANICAL ANCHOR BOLTS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Cooper B-Line, Inc.; a Division of Cooper Industries.
 - 2. Hilti, Inc.

3. Kinetics Noise Control, Inc.
 4. Mason Industries, Inc.
- B. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and equipment to receive vibration isolation and seismic-control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for reinforcement and cast-in-place anchors to verify actual locations before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

- A. Multiple Raceways or Cables: Secure raceways and cables to trapeze member with clamps approved for application by an evaluation service member of ICC-ES.
- B. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

3.3 SEISMIC-RESTRAINT DEVICE INSTALLATION

- A. Coordinate the location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 03300 "CAST-IN-PLACE CONCRETE."
- B. Equipment and Hanger Restraints:
 1. Install resilient, bolt-isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
 2. Install seismic-restraint devices using methods approved by an evaluation service member of ICC-ES providing required submittals for component.
- C. Install cables so they do not bend across edges of adjacent equipment or building structure.
- D. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.
- E. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

F. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
4. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
5. Set anchors to manufacturer's recommended torque using a torque wrench.
6. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.4 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

- A. Install flexible connections in runs of raceways, cables, wireways, cable trays, and busways where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where connection is terminated to equipment that is anchored to a different structural element from the one supporting them as they approach equipment.

3.5 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
 2. Schedule test with MBTA before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.
 3. Obtain MBTA's approval before transmitting test loads to structure. Provide temporary load-spreading members.
 4. Test at least four of each type and size of installed anchors and fasteners selected by Architect.
 5. Test to 90 % of rated proof load of device.
- C. Seismic controls will be considered defective if they do not pass tests and inspections.
- D. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Adjust restraints to permit free movement of equipment within normal mode of operation.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16091

SLEEVES AND SLEEVE SEALS FOR ELECTRICAL RACEWAYS AND CABLING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Sleeves for raceway and cable penetration of non-fire-rated construction walls and floors.
 - 2. Sleeve-seal systems.
 - 3. Sleeve-seal fittings.
 - 4. Grout.
 - 5. Silicone sealants.
- B. Related Requirements:
 - 1. Section 07840 "FIRESTOPPING" for penetration firestopping installed in fire-resistance-rated walls, horizontal assemblies, and smoke barriers, with and without penetrating items.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 SLEEVES

- A. Wall Sleeves:
 - 1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, plain ends.
 - 2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral water stop unless otherwise indicated.
- B. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies: Galvanized-steel sheet; 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint, with tabs for screw-fastening the sleeve to the board.
- C. Molded-PE or -PP Sleeves: Removable, tapered-cup shaped, and smooth outer surface with nailing flange for attaching to wooden forms.

D. Sleeves for Rectangular Openings:

1. Material: Galvanized sheet steel.
2. Minimum Metal Thickness:
 - a. For sleeve cross-section rectangle perimeter less than 50 inches and with no side larger than 16 inches, thickness shall be 0.052 inch.
 - b. For sleeve cross-section rectangle perimeter 50 inches or more and one or more sides larger than 16 inches, thickness shall be 0.138 inch.

2.2 SLEEVE-SEAL SYSTEMS

A. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and raceway.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Enpro (Pipeline Seal Insulator) - LinkSeal
 - b. Advance Products & Systems, Inc.
 - c. CALPICO, Inc.
 - d. Metraflex Company (The).
 - e. Proco Products, Inc.
2. Sealing Elements: EPDM rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
3. Pressure Plates: Stainless steel.
4. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements.

2.3 GROUT

- A. Description: Non-shrink; recommended for interior and exterior sealing openings in non-fire-rated walls or floors.
- B. Standard: ASTM C 1107/C 1107M, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
- C. Design Mix: 4000-psi, 28-day compressive strength.
- D. Packaging: Premixed and factory packaged.

2.4 SILICONE SEALANTS

- A. Silicone Sealants: Single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below.

1. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces that are not fire rated.
- B. Silicone Foams: Multicomponent, silicone-based liquid elastomers that, when mixed, expand and cure in place to produce a flexible, non-shrinking foam.

PART 3 - EXECUTION

3.1 SLEEVE INSTALLATION FOR NON-FIRE-RATED ELECTRICAL PENETRATIONS

- A. Comply with NECA 1.
- B. Comply with NEMA VE 2 for cable tray and cable penetrations.
- C. Sleeves for Conduits Penetrating Above-Grade Non-Fire-Rated Concrete and Masonry-Unit Floors and Walls:
1. Interior Penetrations of Non-Fire-Rated Walls and Floors:
 - a. Seal annular space between sleeve and raceway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Section 07920 "JOINT SEALANTS."
 - b. Seal space outside of sleeves with mortar or grout. Pack sealing material solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect material while curing.
 2. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
 3. Size pipe sleeves to provide 1/4-inch annular clear space between sleeve and raceway or cable unless sleeve seal is to be installed or unless seismic criteria require different clearance.
 4. Install sleeves for wall penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of walls. Cut sleeves to length for mounting flush with both surfaces of walls. Deburr after cutting.
 5. Install sleeves for floor penetrations. Extend sleeves installed in floors 2 inches above finished floor level. Install sleeves during erection of floors.
- D. Sleeves for Conduits Penetrating Non-Fire-Rated Gypsum Board Assemblies:
1. Use circular metal sleeves unless penetration arrangement requires rectangular sleeved opening.
 2. Seal space outside of sleeves with approved joint compound for gypsum board assemblies.
- E. Roof-Penetration Sleeves: Seal penetration of individual raceways and cables with flexible boot-type flashing units applied in coordination with roofing work.
- F. Aboveground, Exterior-Wall Penetrations: Seal penetrations using steel pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
- G. Underground, Exterior-Wall and Floor Penetrations: Install steel pipe sleeves. Size sleeves to allow for 1-inch annular clear space between raceway or cable and sleeve for installing sleeve-seal system.

3.2 SLEEVE-SEAL-SYSTEM INSTALLATION

- A. Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at raceway entries into building.
- B. Install type and number of sealing elements recommended by manufacturer for raceway or cable material and size. Position raceway or cable in center of sleeve. Assemble mechanical sleeve seals and install in annular space between raceway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

3.3 SLEEVE-SEAL-FITTING INSTALLATION

- A. Install sleeve-seal fittings in new walls and slabs as they are constructed.
- B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position water-stop flange to be centered in concrete slab or wall.
- C. Secure nailing flanges to concrete forms.
- D. Using grout, seal the space around outside of sleeve-seal fittings.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16145

LIGHTING CONTROL DEVICES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:

1. Time switches.
2. Photoelectric switches.
3. Indoor occupancy and vacancy sensors.
4. Switchbox-mounted occupancy sensors.
5. Extreme temperature occupancy sensors.
6. Outdoor motion sensors.
7. Lighting contactors.
8. Emergency shunt relays.

- B. Related Requirements:

1. Section 16272 "Wiring Devices" for wall-box dimmers, non-networkable wall-switch occupancy sensors, and manual light switches.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product.

- B. Shop Drawings:

1. Show installation details for the following:
 - a. Occupancy sensors.
 - b. Vacancy sensors.
2. Interconnection diagrams showing field-installed wiring.
3. Include diagrams for power, signal, and control wiring.

1.4 SUBMITTALS

- A. Submit shop drawings for review and approval for all devices. Submit 4 sets of each.

- B. Shop Drawings: List of legends and description of materials and process used for pre-marking wall plates.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of lighting control device to include in operation and maintenance manuals.
- B. Software and Firmware Operational Documentation:
 - 1. Software operating and upgrade manuals.
 - 2. Program Software Backup: On USB media. Provide names, versions, and website addresses for locations of installed software.
 - 3. Device address list.
 - 4. Printout of software application and graphic screens.

1.6 WARRANTY

- A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace lighting control devices that fail(s) in materials or workmanship within manufacturer's standard warranty period.
 - 1. Failures include, but are not limited to, the following:
 - a. Faulty operation of lighting control software.
 - b. Faulty operation of lighting control devices.

PART 2 - PRODUCTS

2.1 TIME SWITCHES

- A. Electronic Time Switches: Solid state, programmable, with alphanumeric display; complying with UL 917.
 - 1. Contact Configuration: SPST, DPST, DPDT as scheduled.
 - 2. Contact Rating: 30-A inductive or resistive, 240-V ac.
 - 3. Programs: Eight on-off set points on a 24-hour schedule and an annual holiday schedule that overrides the weekly operation on holidays.
 - 4. Circuitry: Allow connection of a photoelectric relay as substitute for on-off function of a program on selected channels.
 - 5. Astronomic Time: All channels.
 - 6. Automatic daylight savings time changeover.
 - 7. Battery Backup: Not less than seven days reserve, to maintain schedules and time clock.

2.2 OUTDOOR PHOTOELECTRIC SWITCHES

- A. Description: Solid state, with DPST dry contacts rated for 1000 W incandescent or 1800 VA inductive as scheduled, to operate connected relay, contactor coils, or microprocessor input; complying with UL 773A, and compatible with ballasts and LED lamps.

1. Light-Level Monitoring Range: 1.5 to 10 fc, with an adjustment for turn-on and turn-off levels within that range, and a directional lens in front of the photocell to prevent fixed light sources from causing turn-off.
2. Time Delay: Fifteen-second minimum, to prevent false operation.
3. Surge Protection: Metal-oxide varistor.
4. Mounting: Twist lock complies with NEMA C136.10, with base-and-stem mounting or stem-and-swivel mounting accessories as required to direct sensor to the north sky exposure.
5. Failure Mode: Luminaire stays ON.

2.3 INDOOR OCCUPANCY AND VACANCY SENSORS

A. General Requirements for Sensors:

1. Wall, Ceiling-mounted, solid-state indoor occupancy and vacancy sensors.
2. Dual technology.
3. Integrated power pack.
4. Hardwired connection to switch; and BAS and lighting control system.
5. Listed and labeled by UL, by a qualified testing agency, and marked for intended location and application.
6. Power: Line voltage.
7. Power Pack: Dry contacts rated for 20-A ballast or LED load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Sensor has 24-V dc, 150-mA, Class 2 power source.
8. Mounting:
 - a. Sensor: Suitable for mounting in any position on a standard outlet box.
 - b. Relay: Externally mounted through a 1/2-inch knockout in a standard electrical enclosure.
 - c. Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
9. Bypass Switch: Override the "on" function in case of sensor failure.
10. Automatic Light-Level Sensor: Adjustable from 2 to 200 fc; turn lights off when selected lighting level is present.

B. Dual-Technology Type: Wall or Ceiling mounted; detect occupants in coverage area using PIR and ultrasonic detection methods. The particular technology or combination of technologies that control on-off functions is selectable in the field by operating controls on unit.

1. Sensitivity Adjustment: Separate for each sensing technology.

2. Detector Sensitivity: Detect occurrences of 6-inch-minimum movement of any portion of a human body that presents a target of not less than 36 sq. in., and detect a person of average size and weight moving not less than 12 inches in either a horizontal or a vertical manner at an approximate speed of 12 inches/s.
3. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. when mounted on a 96-inch-high ceiling.
4. Detection Coverage (Room, Wall Mounted): Detect occupancy anywhere within a 180-degree pattern centered on the sensor over an area of 1000 square feet when mounted 48 inches above finished floor.

2.4 SWITCHBOX-MOUNTED OCCUPANCY SENSORS

- A. General Requirements for: Submit shop drawings for review and approval for all wiring devices. Submit 4 sets of each.
- B. Shop Drawings: List of legends and description of materials and process used for pre-marking wall plates.
- C. Sensors: Automatic-wall-or ceiling mounted switch dual technology occupancy sensor with manual on-off switch, suitable for mounting in a single gang switchbox, with provisions for connection to BAS using hardwired connection.
 1. Listed and labeled by UL, by a qualified testing agency, and marked for intended location and application.

2.5 DIGITAL TIMER LIGHT SWITCH

- A. Description: Combination digital timer and conventional switch lighting control unit. Switchbox-mounted, backlit LCD display, with selectable time interval in 10 minute increments.
 1. Rated 960 W at 120-V ac for tungsten lighting, 10 A at 120-V ac or 10 amps at 277-V ac for ballast or LED, and 1/4 horsepower at 120-V ac.
 2. Integral relay for connection to BAS.
 3. Voltage: Match the circuit voltage including 120 V, 277 V and Dual voltage - 120 and 277 V.
 4. Color: As selected by the Architect and subject to approval by Owner.
 5. Faceplate: Color matched to switch.

2.6 OUTDOOR MOTION SENSORS

- A. General Requirements for Sensors: Solid-state outdoor motion sensors.
 1. Listed and labeled by UL, by a qualified testing agency, and marked for intended location and application.
 2. Switch Rating:
 - a. Luminaire-Mounted Sensor: Sensor rating shall be adequate for fixture(s) controlled.

- b. Separately Mounted Sensor: Dry contacts rated for 20-A ballast or LED load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-VAC. Sensor has 24-V dc, 150-mA, Class 2 power source, as defined by NFPA 70.
- 3. Switch Type: SP. SP, dual circuit. SP, manual "on," automatic "off." SP, field-selectable automatic "on," or manual "on," automatic "off." With bypass switch to override the "on" function in case of sensor failure.
- 4. Voltage: Match the circuit voltage including 120-V, 277-V and Dual voltage, 120- and 277-V types.
- 5. Detector Coverage:
 - a. Standard Range: 210-degree field of view, with a minimum coverage area of 900 sq. ft.
 - b. Long Range: 180-degree field of view and 110-foot detection range.
- 6. Ambient-Light Override: Concealed, field-adjustable, light-level sensor from 10 to 150 fc. The switch prevents the lights from turning on when the light level is higher than the set point of the sensor.
- 7. Concealed, field-adjustable, "off" time-delay selector at up to 30 minutes.
- 8. Concealed, "off" time-delay selector at 30 seconds and 5, 10, and 20 minutes.
- 9. Adaptive Technology: Self-adjusting circuitry detects and memorizes usage patterns of the space and help eliminate false "off" switching.
- 10. Operating Ambient Conditions: Suitable for operation in ambient temperatures ranging from minus 40 to plus 130F, rated as "raintight" per UL 773A.

2.7 LIGHTING CONTACTORS

- A. Description: Electrically operated and mechanically held, combination-type lighting contactors with nonfused disconnect, complying with NEMA ICS 2 and UL 508.
 - 1. Current Rating for Switching: Listing or rating consistent with type of load served, including tungsten filament, inductive, and high-inrush ballast (ballast with 15 percent or less THD of normal load current).
 - 2. Fault Current Withstand Rating: Equal to or exceeding the available fault current at the point of installation.
 - 3. Enclosure, Indoor, NEMA 1, Outdoor, NEMA 4X, stainless steel.
 - 4. Provide with control and pilot devices.
 - 5. Control Interface Coordinate with Owner local control system at each station.

2.8 EMERGENCY SHUNT RELAY

- A. Description: NC, electrically held relay, arranged for wiring in parallel with manual or automatic switching contacts; complying with UL 924.
 - 1. Coil Rating: 277 V.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine lighting control devices before installation. Reject lighting control devices that are wet, moisture damaged, or mold damaged.
- B. Examine walls and ceilings for suitable conditions where lighting control devices will be installed.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SENSOR INSTALLATION

- A. Comply with NECA 1.
- B. Coordinate layout and installation of ceiling-mounted devices with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, smoke detectors, fire-suppression systems, and partition assemblies.
- C. Install and aim sensors in locations to achieve not less than 90-percent coverage of areas indicated. Do not exceed coverage limits specified in manufacturer's written instructions.

3.3 CONTACTOR INSTALLATION

- A. Comply with NECA 1.

3.4 IDENTIFICATION

- A. Identify components and power and control wiring per Section 16195 "Electrical Identification."
 - 1. Identify controlled circuits in lighting contactors.
 - 2. Identify circuits or luminaires controlled by photoelectric and occupancy sensors at each sensor.
- B. Label time switches and contactors with a unique designation.

3.5 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:

1. Operational Test: After installing time switches and sensors, and after electrical circuitry has been energized, start units to confirm proper unit operation.
 2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Lighting control devices will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

3.6 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting lighting control devices to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.
1. For occupancy and motion sensors, verify operation at outer limits of detector range. Set time delay to suit Owner's operations.
 2. For daylighting controls, adjust set points and deadband controls to suit Owner's operations.
 3. Align high-bay occupancy sensors using manufacturer's laser aiming tool.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16195

ELECTRICAL IDENTIFICATION

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 DESCRIPTION OF WORK

- A. Work Included: This Section specifies the furnishing and installing of nameplates and labels, wire and cable markers, and conduit markers, underground warning taps and other electrical identification devices. Engraved nameplates shall be designed, furnished and installed for every major piece of electrical equipment.
- B. Related requirements are included in, but not limited to, the following Sections.
 - 1. Section 09900: PAINTING
 - 2. Section 16050: BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK

1.3 REFERENCES

- A. National Fire Protection Association (NFPA)
 - 1. NFPA No. 70 /Massachusetts Electrical Code

1.4 SUBMITTALS

- A. Product Data/Catalog Cuts
 - 1. Nameplates and labels.
 - 2. Wire and cable markers
 - 3. Conduit markers.
 - 4. Underground warning tape.
- B. Certificates of Compliance
 - 1. Nameplates and labels.
 - 2. Wire and cable markers.
 - 3. Conduit markers.
 - 4. Underground warning tape
- C. Manufacturer's Instructions
 - 1. Delivery, handling, transportation, storage and protection.
 - 2. Surface preparation, and application/installation of products.
 - 3. Application conditions and limitations of use.
- D. Engraved nameplate schedule shall be submitted for review and approval by Owner.

- E. Submittals required for painting work shall be as specified in Section 09900 - PAINTING.

1.5 DELIVERY, HANDLING, TRANSPORTATION, STORAGE AND PROTECTION

- A. Delivery, handling, transportation, storage and protection shall be in accordance with the manufacturer's instructions, unless otherwise required by Division 1.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Conform to requirements of Massachusetts Electrical Code.
- B. Provide products listed and classified by Underwriters Laboratories, or a testing firm acceptable to authorities having jurisdiction as suitable for purpose specified and indicated.
 - 1. The Design-Builder shall submit certificates of compliance for products provided.
 - 2. The Design-Builder shall provide the manufacturer's instructions indicating application conditions and limitations of use stipulated by the product testing agency.

2.2 NAMEPLATES AND LABELS FOR EQUIPMENT

- A. Nameplates and Labels
 - 1. Engraved three-layer laminated plastic, black letters on white background. Nomenclature shall be according to a schedule approved by Owner.
- B. Locations
 - 1. All parts of equipment, such as switchboards, panel boards, safety switches, motor starters, circuit breakers, time clocks, contactors and similar items shall be identified by name, function or control.
 - 2. The outside of the covers of all junction or pull boxes located above hung ceilings and the inside of the covers of all junction or pull boxes exposed shall be labeled with an indelible marker indicating the operating voltage and the system contained therein.
 - 3. All device plates of receptacles connected to a standby or emergency power distribution system shall be labeled with plastic nameplate, engraved with the panel board and circuit number to which the receptacle is connected. Nameplate character engraved shall be not less than 6 mm in height.
 - 4. Unless otherwise shown on the Drawings, all panel boards, switchboards, switchgear, circuit breakers, switches and transformers connected to a standby or emergency power distribution system shall be labeled "Standby" or "Emergency".
- C. Letter Sizes
 - 1. Use 1/4-inch letters for identifying individual equipment and loads.
 - 2. Use 1/4-inch letters for identifying grouped equipment and loads.
 - 3. Use 1/8-inch letters for identifying voltage, phase, and neutral.

2.3 WIRE MARKERS

- A. Wire markers shall be manufactured by Panduit, Ideal, 3M, or approved equal.
 - 1. Description: Cloth tape or tubing type wire markers.
 - 2. Locations: Each conductor at panelboard, gutters, pull boxes, outlet and junction boxes and each load connection.
- B. Legend
 - 1. Power and lighting circuits: Branch circuit or feeder number indicated on the Drawings.
 - a. Control circuits: Control wire number indicated on schematic and interconnection diagrams on the Drawings.
 - 2. Power supervisory control and data acquisition (SCADA) system circuits:
 - a. Circuits shown on the riser diagrams or schematic diagrams. The riser diagrams and schematic diagrams are shown on the Drawings.

2.4 CONDUIT MARKERS

- A. Conduit markers shall be manufactured by Banded Labeling System, Brady USA, Inc., Panduit, Seton, or approved equal.
- B. Location: Furnish markers for each conduit longer than 6 feet.
- C. Spacing
 - 1. Spacing shall be 20 feet on center, unless otherwise specified.
 - a. Fire alarm conduits shall be marked every 10 feet.
 - b. 13.8 kV system shall be marked for its entire length.
- D. Color

<u>System Name</u>	<u>Color</u>
1. 480-volt system	Orange
2. 208 volt system	Blue
3. Fire alarm system	Red
4. Telephone system	Gray
5. 13.8 kV system	Yellow
6. Management information system	Purple
7. Passenger assistance system	Green
8. Public address system	White
9. Closed circuit television system	Black
10. Power SCADA	Pink

- E. Legend

<u>System Name</u>	<u>Legend</u>
1. 480 volt system	480 V
2. 208 volt system	208 V
3. Fire alarm system	FAS

4. Telephone system	TS
5. 13.8 kV system	13.8 kV
6. Management information system	MIS -
7. Passenger assistance system	PNRA
8. Public address system	PAS
9. Closed circuit television system	CCTV
10. Power SCADA	PSCADA

2.5 PAINTED CONDUIT IDENTIFICATION

- A. Conduit shall be painted for identification purposes. Paint system Identification Number shall be as specified Section 09900 - PAINTING
- B. Paint colored band on each conduit longer than 6 feet.
- C. Paint bands, 3 inches wide, 20 feet on center, unless otherwise specified.
 - 1. Fire alarm conduits shall be painted every 10 feet.
 - 2. 13.8 kV system shall be painted for its entire length
- D. Color

<u>System Name</u>	<u>Color</u>
1. 480-volt system	Orange
2. 208 volt system	Blue
3. Fire alarm system	Red
4. Telephone system	Gray
5. 13.8 kV system	Yellow
6. Management information system	Purple
7. Passenger assistance system	Green
8. Public address system	White
9. Closed circuit television system	Black
10. Power SCADA	Pink

2.6 UNDERGROUND WARNING TAPE

- A. Underground warning tape shall be manufactured by Panduit, Ideal, or approved equal.
- B. Description: Detectable underground warning tape shall be 6 inch wide plastic tape, colored yellow with suitable warning legend describing: CAUTION - BURIED ELECTRICAL LINES BELOW.

PART 3 - EXECUTION

3.1 PREPARATION

- A. Degrease and clean surfaces to receive nameplates, labels and markers, in accordance with the manufacturer's instructions.

3.2 APPLICATION INSTALLATION

- A. Application/installation of products shall be in accordance with the manufacturer's instructions.

- B. Nameplates and Labels
 - 1. Install nameplates and labels parallel to equipment lines.
 - 2. Secure nameplate to equipment front using screws.
 - 3. Secure nameplate to inside surface of door on panelboard that is recessed in finished locations.
- C. Conduit Identification by Markers
 - 1. Identify conduit using conduit markers.
 - a. Apply conduit markers parallel to conduit runs.
- D. Conduit Identification by Painting
 - 1. Identify conduit, using paint. Paint shall be field applied.
 - a. Painting, including surface preparation, shall be in accordance with Section 09900 - PAINTING
- E. Identify underground conduits using underground warning tape. Install one tape per trench at 12 inches below finished grade.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16260

VARIABLE FREQUENCY MOTOR CONTROLLERS FOR STORMWATER PUMP STATIONS

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. Provide complete simplex type Variable Frequency Drive (VFD) units and appurtenances including drive reactors, DC chokes, harmonic filters, enclosures, and certain auxiliary items, as indicated and as specified, to provide a complete operating system.
- B. Construction of the Red Bridge and Washington Street Pump Stations (RPS and WSP, respectively) was initiated under IGMP-03, a previous GLX construction contract. That work was advanced to near completion of the basic structure. The pumps, variable frequency motor controllers, communication programmable logic controllers, and pump station controls were not (or may not have been) completed, however certain items of that equipment were procured by the Owner and will be provided to the Design-Builder. The Design-Builder shall complete the construction of these two pump stations in full compliance with the specifications. The Design-Builders shall complete all work within this Section and all related work, to provide complete operable pump station facilities.
- C. The specifications relative to the WPS and RPS pump stations, including all operating parameters, control logic and other parameters, shall not be modified in any way.
- D. The Design-Builder may elect to adapt these specifications, if appropriate, to any pump station it may propose at Gilman Square.
- E. Certain work under this Section was, or may have been, completed by the previous GLX contractor. The Design-Builder shall be responsible for making its own assessments and evaluations as to the exact scope and limits of the completed and the uncompleted work. The Design-Builder shall complete any and all work associated with this Section and all Related Sections, including any and all uncompleted and/or partially completed work. The Design-Builder shall coordinate all related work, to provide complete and operable stormwater pumping facilities.
- F. The terms and meaning of “Manufacturer’s Services Engineer”, “Startup/Testing Engineer”, “Factory Trained Service Engineer” and “Service Engineer” (collectively, “Startup, Testing and Service Engineers”) as used in this Section shall all remain unchanged and any remaining work required of these Startup, Testing and Service Engineers shall be the responsibility of the Design-Builder.
- G. The use of the word “Contractor” has been retained in this Section; however, it shall be interpreted to mean the Design-Builder for any and all work remaining to be completed. Likewise, the word “Engineer” has been retained; however, it shall be interpreted to mean the Owner for any and all work remaining to be completed.
- H. Variable frequency motor controllers can be supplied by the Contractor or the pump manufacturer at the Contractor’s option. The pumping system must be a complete and integrated package to insure proper coordination, compatibility and operation of the system.
 - 1. The Contractor shall coordinate the variable frequency motor controllers with the

pump and motor manufacturer and submit as part of the shop drawings a written statement signed by the Contractor, pump manufacturer, motor manufacturer and variable frequency motor controller manufacturer that the variable frequency motor controller manufacturer has received the required information from the pump and motor manufacturers and that all parties have reviewed the system and coordinated the equipment selection. Also include all motor data and information that has been used for the coordination.

- I. Installation of the units shall be the responsibility of the General Contractor.
- J. VFD units shall be manufacturer's standard technology and in production for a minimum of 2 years.
- K. Provide control system operation, input and control signals, status signals and devices in accordance with Section 02401 – STORMWATER PUMP STATIONS CONTROLS.
- L. Provide VFD output filter or reactor, when cable length between VFD and motor is greater than 100 feet (30 m), to insure motor terminals do not experience overvoltage condition as defined by NEMA Standard MG-1.
- M. Each VFD unit shall exhibit less than 5 percent voltage total harmonic distortion and less than 3 percent voltage distortion on each harmonic at their immediate upstream distribution bus as verified by calculation and testing. Harmonic current distortion to be in accordance with Table 16260-1. This bus shall be referred to as the point of common coupling (PCC).

1.2 REFERENCES

- A. American Society for Testing and Materials International (ASTM):
 - 1. D178: Standard Specification for Rubber Insulating Matting
- B. National Electrical Manufacturers Association (NEMA):
 - 1. ICS 2: Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 Volts.
 - 2. AB 1: Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures.
 - 3. KS 1: Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum).
 - 4. MG 1: Motors and Generators.
- C. National Fire Protection Association (NFPA):
 - 1. 70: National Electrical Code (NEC).
- D. Underwriter's Laboratories Inc. (UL):
 - 1. 489: Molded-Case Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
 - 2. 508: Electrical Industrial Control Equipment.
 - 3. 1066: Low Voltage AC and DC Power Circuit Breakers Used in Enclosures.

1.3 SEISMIC DESIGN REQUIREMENTS

Conform to the requirements indicated on the structural drawings and as specified.

1.4 SUBMITTALS

- A. Submit the following shop drawings in accordance with Section 01300 - SUBMITTALS.
- B. Submit shop drawings and manufacturers' product data in accordance with the Contract requirements.
- C. Complete list of equipment and materials, including manufacturer's descriptive and technical literature, catalog cuts, and installation instructions for all major components.
- D. Complete wiring and schematic diagrams for the equipment furnished. Each wiring diagram shall be legible and not reduced from the original design drafted format. Provide a list of equipment on each wiring diagram for which it is applicable.
- E. Panel layout and front view drawings.
- F. Time versus current curves for protection devices.
- G. Data sheets for all devices provided as part of the assembly.
- H. All other details required to demonstrate that system has been coordinated and will properly function as a unit.
- I. Provide data to verify that drives can be used for motor lead lengths up to 100 feet (30 meters) without output filters. Include information from the VFD manufacturer or output filter or reactor manufacturer (if required) stating that the motor terminal voltage limitations as defined by NEMA Standard MG 1, Part 31 are met. For VFDs located more than a cable length of 100 feet (30 meters) from the motor load, provide drawings which include information demonstrating that an output filter or reactor is included within the VFD.
- J. Provide enclosure drawings and details showing all dimensions and construction details.
- K. Harmonic Analysis Report: Provide harmonic analysis report. Report to be accepted by Owner prior to release of drives for fabrication.
 - 1. Submit voltage THD frequency scan of each type of VFD supplied for use in field testing.
- L. Submit information relative to location and expertise of local service office and personnel.
- M. For informational purposes only, submit manufacturer's printed installation instructions.
- N. Spare Parts Data: Submit a list of spare parts for the equipment specified.
- O. Operating and Maintenance Instruction Manuals:
 - 1. Furnish:
 - a. Operating instruction manuals outlining step-by-step procedures required for system startup and operation.
 - b. Manufacturer's name, model number, service manual parts list.
 - c. Brief description of equipment and basic operating features.
 - d. Maintenance instruction manuals outlining maintenance procedures.
 - e. Troubleshooting guide listing possible breakdown and repairs.

- f. Point-to-point connection wiring diagram for the system.
- g. Performance Test Reports: Upon completion of installed system, submit in booklet form all shop and field tests performed to prove compliance with specified performance criteria.

P. Submit Pump, Motor, and VFD Statement of Compliance Coordinate Certificate.

1.5 QUALITY ASSURANCE

- A. Provide in accordance with Section 01400 – QUALITY ASSURANCE and as specified.
- B. Provide variable frequency drives in accordance with UL 508A, supplement SB, and Article 409 of the National Electrical Code (NEC). All VFD units shall be provided with a UL label.
- C. Ensure that conduit size and wire quantity, size, and type are suitable for the equipment supplied. Coordinate all design information with the Electrical Contractor. Review the proper installation of each type of VFD unit with the equipment supplier prior to installation.
 - 1. Services of Service Engineer, specifically trained on type of equipment specified. Person-day requirements listed exclusive of travel time.
 - a. Assist in location of devices, methods of mounting, field erection, etc.
1 person-day.
 - b. Functional Completion
Testing 2 person-days.
 - c. Startup.
2 person-days.
 - d. Commissioning.
2 person-days.
 - e. At the end of start-up service provide for a maximum of six members of the owners staff at the facility site to receive training from the startup/testing service Engineer.
1 person-day.
 - f. Service-inspections during first year of operation, for use at Owner's request, and exclusive of repair, malfunction or other trouble-shooting service calls:
1 person-day.
 - g. Person-day is defined as one 8-hour day, excluding travel time.

1.6 DELIVERY, STORAGE AND HANDLING

- A. Provide in accordance with Section 01600 – MATERIALS AND EQUIPMENT and as specified.
- B. Shipping:
 - 1. Ship equipment and materials, except where partial disassembly is required by transportation regulations or for protection, complete with identification and quantity of items.

2. Pack spare parts in containers bearing labels clearly designating contents and pieces of equipment for which intended.
3. Deliver spare parts after installation but as specified before start-up of drives. Deliver to Owner after completion of work.

C. Storage:

1. Inspect and inventory items upon delivery to site.
2. Store and safeguard equipment, material and spare parts.
 - a. If the equipment cannot be placed into service after its receipt, store in a closed building or structure, in a clean, dry and ventilated area free from temperature, dirt and moisture extremes. Acceptable storage temperatures are from 32 degrees F (0 degrees C) to 104 degrees F (40 degrees C) with temporary heaters provided within enclosures to prevent condensation. Provide heavy plastic envelope directly over motor control center to protect against dust, dirt, and moisture. Provide lifting angles outside of envelope.

1.7 WARRANTY AND SERVICE

- A. Provide in accordance with Section 01400 – QUALITY ASSURANCE and as specified.
- B. Guarantee components, parts, and assemblies supplied by manufacturer against defects in materials and workmanship for a period of 24 months after turning the equipment over to the Owner, and in this time period include onsite, parts and labor warranty. All labor to be performed by local factory trained service engineers.
- C. Ensure that equipment manufacturer has local branch office staff with trained, full-time employees who are capable of performing testing, inspecting, repair, and maintenance services.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturer shall have at least five years commercial experience in the manufacture, operation and servicing of equipment of type, size, quality, performance, and reliability equal to that specified.
- B. Variable Frequency Drive Units:
 1. Allen Bradley
 2. Danfoss
 3. Eaton Corporation, Electric Drives Division.
 4. Siemens Inc.
 5. Toshiba Industrial.
- C. VFD Input Filters and Output Filters/Reactors:
 1. Trans-Coil, Inc.
 2. MTE Corporation.

3. Power Quality International.

2.2 HARMONIC ANALYSIS

- A. Each VFD unit shall be designed such that there is less than 5 percent voltage total harmonic distortion at the PCC. Current distortion at the PCC will be in accordance with Table 16260-1. For the purpose of the analysis, it will be assumed that the facility transformer feeding the electrical system is at a lightly (50 percent) loaded condition.

Table 16260-1 Maximum Harmonic Current Distortion In Percent IL						
Odd Harmonic						
Ratio	5 to 9	11 to 15	17 to 21	23 to 33	35 +	TDD
Less than 20	4.0	2.0	1.5	0.6	0.3	5.0
20 to 50	7.0	3.5	2.5	1.0	0.5	8.0
50 to 100	10.0	4.5	4.0	1.5	0.7	12.0
100 to 1000	12.0	5.5	5.0	2.0	1.0	15.0
1000 +	15.0	7.0	6.0	2.5	1.4	20.0

Notes:

1. Even harmonics are limited to 25 percent of odd harmonics.
2. DC offset distortions not allowed.
3. Ratio = I_{sc}/I_L where:
 I_{sc} = Maximum short circuit current at PCC.
 I_L = Maximum demand load current at PCC (fundamental frequency component)

- B. For each VFD unit, provide a harmonic analysis study at the point of connection to the immediate upstream distribution bus (PCC), based on pre-submittal data.

Each VFD unit shall be designed such that there is less than 5 percent voltage total harmonic distortion and less than 3 percent voltage distortion on each harmonic at the PCC. Current distortion to be within the limits of Table 16260-1. For the purpose of the analysis, it will be assumed that the electrical system is at a lightly loaded condition, 50 percent load. If the VFD loads exceed 50 percent system loading, assume system is loaded at VFD full load ratings.

1. At each PCC, where more than one type or size VFD unit is to be connected, provide the following:
 - a. Contractor shall have the supplier of the largest drive (in Hp) provide a harmonic study for each point of common coupling based on pre-submittal information
2. The Contractor shall supply the following pre-submittal information to the largest VFD supplier to complete the harmonics study.
 - a. Full load fundamental current for each variable frequency drive (VFD) unit.
 - b. Harmonic currents on per unit basis of full load fundamental for each VFD unit.
 - c. Available fault current information from the electric utility and upstream transformer data.
 - d. Distribution transformer sizes and impedances, if any.
 - e. VFD input line reactor and/or isolation transformer sizes and impedances from the

- utility source to the VFD units.
 - f. Conductor information between transformer secondary or generator terminals to the distribution buses and VFDs.
 - g. Generator kW, impedance, subtransient reactance generator constants for the condition when the electrical system is powered from the generator.
3. The results of the harmonics study shall verify that the levels of total harmonic voltage at each point of common coupling are less than 5 percent and that the voltage distortion on each harmonic is less than 3 percent. In addition, harmonic currents at the PCC will be within the limits of Table 16260-1. The study shall separately consider each VFD distribution bus as points of common connection (PCCs). The study shall specify additional equipment required (e.g., filters) at each harmonic where harmonic reduction is required to insure compliance.
- C. The study shall consider the following conditions:
- 1. The electrical system shall be powered by the electric utility, case 1, or solely by local generation, case 2.
 - 2. The study shall include an explanation of all assumptions, sources of data, methodologies and formulas used in the study and a summary of the study results.
 - 3. The Contractor shall supply all equipment required as a result of the final accepted harmonics study to comply with the requirements of Paragraph 1.1 F.

2.3 PROVISIONS

- A. Service Conditions:
- 1. Ambient Temperature Range: 0 degrees C to 40 degrees C.
 - 2. Operational Humidity: Up to 90 percent non-condensing.
 - 3. Environment: As indicated on enclosure schedule.
 - 4. Altitude: Below 3,300 feet above sea level.
 - 5. Maximum acceptable speed: 60 Hz
 - 6. Input Power:
 - a. Nominal Voltage: 480 volts (plus 10 percent or minus 10 percent), 3-phase, 3 wire
 - b. Nominal Frequency: 60 Hertz (plus or minus 2 Hertz.)
 - c. Service provided from feeder breaker on distribution bus.
- B. Drive System: 0-500 HP Units
- 1. General:
 - a. Furnish solid state variable frequency, microprocessor type with Pulse Width Modulated (PWM) output wave form converter. The VFD shall employ a full wave rectifier to prevent input line notching, a DC bus choke, DC bus capacitors and Insulated Gate Bipolar Transistors (IGBT) as the output switching device to convert nominal 480 volts, 3 phase, 60 Hertz, 3 wire input power into adjustable-frequency 3 wire system at 0 to 480 volts, 3 phase, 0 to 60 Hertz output power. Provide output speed control of required motor under variable torque load or constant torque as required by the driven equipment.
 - b. Motor control circuits shall be wired in accordance with the requirements specified herein or indicated on the Drawings. Where not indicated, the control circuits shall be

standard two-wire “start-stop” and the Contractor shall furnish wiring accordingly. Controls shall be designed to allow for automatic re-start when power is returned after a system outage, unless otherwise directed.

- c. Variable frequency drive manufacturer shall be responsible for the successful application and operation of the entire drive and control system serving the motor and driven equipment. This includes the responsibility for obtaining all loads, torque, speed and performance requirements from the respective sources and integrating these into a variable frequency drive system that fulfills the requirements of this Specification.
 - d. The Contractor and variable frequency drive system manufacturer are cautioned regarding the review and compliance with the total Contract Documents. Typical examples are circuit breakers, motor circuit protectors, magnetic starters, relays, timers, control and instrumentation products, pilot devices including pushbuttons, selector switches and pilot lights, enclosures, conduit, disconnect switches, terminal boxes, and other equipment.
2. For units rated 50 Hp or less, provide 6 pulse drive with 5 percent impedance input line reactor.
 - a. Provide trap filters for the drive unit meeting the requirements of the harmonic study under Paragraph 2.02. Filters shall be provided with contactors and controlled by the VFD to remove them from the line when the drive is not operating. Contactors shall be provided with spare contacts for remote alarm and to energize status lamp at VFD enclosure.
 3. For units rated greater than 50 Hp, provide VFD with the following type three phase PWM rectifier section: 18-pulse, or higher full wave diode bridge. Provide multiple secondary integral transformer within enclosure at input bridge to provide appropriate phase shift.
 - a. As a minimum, the transformer shall provide for the cancellation of the 5th, 7th, 17th, 19th, positive and negative sequence harmonic currents at the primary connection.
 - b. The transformer shall reduce voltage and current distortion on the primary side and voltage distortion on the secondary side.
 - c. The design shall be optimized for harmonic rich and high neutral current environment.
 - d. Harmonic cancellation shall be by electromagnetic means only, capacitors or electronics are not acceptable.
 - e. Provide a primary to secondary phase shift by use of multiple secondaries.
 4. As an alternate to the VFDs specified in Paragraph 3 above, provide active converter low harmonic drives for VFDs rated 125 Horsepower or larger.
 - a. High order harmonics to be controlled with line filtering.
 - b. Direct torque control (DTC) AC to AC converter with IGBT technology.
 - c. Operational modes of scalar or V/Hz operation.
 - d. AC line reactor and DC choke shall be provided to reduce input harmonic content, and provide protection from power line transients.
 5. All components of the drive shall be designed and sized for the abnormal condition of continuous operation of the driven equipment specified herein at loads up to 15 percent above rated full load.

6. RMS harmonic output of the drive not to provide more than 5 percent increase in motor heating over similar operation of the motor with zero harmonics in the current.
7. The unit shall withstand drive output terminal line-to-line and line-to-ground short circuits without component failure during start-up and during operation. Drive to safely shutdown until short is cleared.
8. NEMA type cabinet for each drive unit, as indicated on drawings and enclosure schedule.

NEMA 4 and NEMA 4X enclosures to be provided with stainless steel hand operated quick disconnect devices and interior cooling systems. Provide hinged acrylic door with gasketing on front of door for each access to keypad controls.

9. For inverter rated squirrel cage motors, per NEMA Standard MG-1, Part 31.40.4.2, the following limit values at the motor terminals are to be observed:
 - a. For motors with base rating voltage less than or equal to 600 volts, the peak instantaneous voltage must be limited to 1600 volts or less, with a voltage rise time greater than or equal to 0.1 micro-seconds.
10. The VFD manufacturer shall guarantee that the required voltage limits will be met with the motor installed up to 100 cable feet (30 m) from the VFD drive unit and as required for each motor installation. It should be noted that one or more of the motors may require a cable length greater than 100 feet (30 m). If the VFD manufacturer is not able to guarantee that the above voltage limits will be met for each motor installation, provide a drive output filter or reactor, appropriately rated, located within the VFD enclosure and near the VFD output terminals, which shall ensure that the limitations listed above are maintained. A device located at the motor terminals is not acceptable.
11. When controlling for non-inverter rated squirrel cage motors, provide output filters to limit peak voltage at the motor terminal to less than 1000 V, increase voltage rise time and reduce common mode current.
12. VFD shall be capable of full rated output when powered by incoming voltage with Total Harmonic Distortion (THD) in excess of 10 percent.
13. Furnish series choke and capacitors on dc bus to reduce ripple in rectifier output and to reduce harmonic distortion reflected into incoming power feeders.
14. Properly size enclosure to dissipate heat generated by VFD within limits of specified service conditions.
 - a. Provide NEMA enclosure type and size as indicated on drawings. If a larger enclosure is required by the equipment necessary to meet these requirements, all related modifications, including modifications to the Control Building, must be completed at no additional cost to the Owner.
 - b. Provide integral fans or cooling systems as required by the application.
 - c. NEMA 4 and 4X type enclosures to use hand-operated locking devices for door closing hardware.

- d. Circuit breaker interlock to be able to be bypassed via lever on front door surface.
- e. NEMA 1 and 12 type enclosures to have keypad controls located on exterior of enclosure.
- f. Provide visual alarm indicator on cabinet door.
- g. Fans shall be located to allow quick removal and replacement without disassembly of drive components.

2.4 PERFORMANCE CHARACTERISTICS

- A. Output amps: 110 percent of rated, continuous.
- B. Current limit: Range 0 to 130 percent for constant torque applications, 0 to 110 percent for variable torque applications, for 1 minute minimum.
- C. Acceleration time to top speed, 1-300 seconds, minimum, adjustable.
- D. Deceleration time from top speed, 1-300 seconds, minimum, adjustable.
- E. Frequency stability: +/- 0.5 percent (at 25 degrees C, +10 degrees C) after reaching operating temperature.
- F. Output voltage: Proportional to frequency with low speed boost.
- G. Combined drive/and filtering efficiency, defined as motor shaft KW divided by VFD input KW, shall meet the following minimum requirements at the specified operating points:
 - 1. 97 percent at 60 Hertz VFD output and 100 percent load.
 - 2. 92 percent at 50 Hertz VFD output and 60 percent load.
- H. VFD fundamental power factor shall be 0.98 or higher at all speeds and loads.
- I. The VFD shall be capable of sustaining continued operation with a 30 percent dip in nominal line voltage. Output speed may decline only if current limit rating of the VFD is exceeded.
- J. Losses to be utilized in drive system efficiency calculation shall include the input line reactor, phase shifting transformer and, harmonic trap filter with capacitors. Auxiliary controls such as internal VFD control boards and cooling fans shall be included in all loss calculations.

2.5 DRIVE PROTECTION

- A. General:
 - 1. Fault detection and trip circuits shall protect VFD and connected motor against line voltage transients, single-phase, power line overvoltage and undervoltage, output overvoltage and overcurrent, and VFD overtemperature.
 - a. The VFD shall employ three current limit circuits to provide trip free operation.
 - b. The slow current regulation limit circuit shall be adjustable to a minimum 125 percent

- of the VFD's variable torque current rating.
 - c. The rapid current regulation limit shall be adjustable to a minimum 170 percent of the VFD's variable torque current rating.
 - d. The current switch off limit shall be fixed at a minimum 225 percent of the VFD's variable torque current rating.
2. Internal Protection: Minimum circuitry as follows:
- a. Current limiting, fast acting, semiconductor input fuses for protection of internal power semiconductors.
 - b. Instantaneous output overcurrent trip maximum: 200 percent.
 - c. DC bus and control circuit transformer fusing.
 - d. Grounded control chassis.
 - e. Under and over voltage trip, 3 phases.
 - f. Motor overload protection, with solid state relays.
 - g. Circuit breaker, with door interlocked handle. Provide means to allow entry into panel where required by authorized personnel. Circuit breaker to be rated 25,000 AIC, minimum.
 - h. Fault reset push button.
 - i. Line to ground faults.
 - j. Input metal oxide varistor and input line reactor for transient protection.
 - k. VFD overtemperature.
3. Troubleshooting: Diagnostic aids to indicate cause of fault; used to assist in troubleshooting circuit problems. Isolated Form C contacts for remote indication of alarms to include the following:
- a. Over/under voltage indication.
 - b. Overcurrent trip indication.
 - c. DC bus charged indication.
 - d. Fault detection indication.
 - e. Recycle start indication (to indicate that the unit tried to pick up load for three previous tries and failed).
4. Provide power loss ride through capability which will allow the logic to maintain control due to load inertia without faulting.
5. Provide a programmable automatic restart function which will provide a minimum with time delays between restarts of 3 restarts following a fault condition other than a ground fault, short circuit, internal fault, or user programmable fault condition. Restart type to be programmable for time delay or coasting motor restart.

2.6 CONTROL INTERFACE

- A. Provide variable frequency drive unit with appropriate power circuitry and auxiliary contacts for energizing and controlling the following devices associated with the motor, if required:
- 1. Space heaters
 - 2. Remote indication of motor start and stop (isolated contacts)
- B. Minimum Control Features:
- 1. LOCAL/REMOTE selection of Start/Stop control.
 - 2. LOCAL/REMOTE selection of Speed Control.

3. Accept a grounded, isolated, 4-20 mA input remote speed control signal from an external device.
4. Provide a 4-20 mA output signal proportion to VFD output frequency for remote speed indication.

C. Control Devices:

1. Provide operating, monitoring or alarm indicating devices, door mounted, with minimum as follows:
 - a. Drive System Disconnect Operator.
 - b. System control selector switch (RUN/OFF/REMOTE) (When in RUN position drive will run). Control switch shall be oil-tight, 30 mm units.
 - c. System speed control selector switch (LOCAL/REMOTE) (When in LOCAL position, speed controlled by manual speed potentiometer). Control switch shall be oil tight, 30 mm units.
 - d. Manual keypad controls to set speed in manual mode.
 - e. Speed indicating meter in percent speed to indicate speed of the converter powered motor.
 - f. Run time meter, mechanical type, round, UL Certified, non-reset type, with register to indicate hours and tenths of hours up to 99,999.9 hours.
 - g. Alarm and status lights. Provide LED cluster type, heavy duty, 30 mm oil tight units.
2. Control circuits shall be isolated from power circuits.
 - a. Unit to accept a 4-20 mA DC speed control signal from an isolated, ungrounded transmitter with unit in remote mode and from local door-mounted micro-processor type keypad with unit in local mode.
 - b. The input 4-20 mA signal to be optically isolated from the drive run control circuit.
 - c. Furnish door-mounted switch on the enclosure for local/remote mode.
 - d. Keypad controls to have adjustable minimum speed setting of 10 to 80 percent of full speed and maximum speed setting of 50 to 100 percent of full speed. The total speed setting to follow a linear time ramp, adjustable from 1-300 seconds for acceleration and deceleration control.

D. Provide a Modbus network card and interface modules to allow serial communications on a Modbus network.

1. Interface connection cable shall utilize a RJ-45 connector.
2. Network to allow a selection of standard and custom register values to communicate drive parameters, including:
 - a. Drive fault
 - b. Overload
 - c. Trip
 - d. Loss of control power
 - e. Speed
 - f. Power (kW)
 - g. Amps (Phase A, B and C)
 - h. Voltage (Phase A-B, B-C, C-A)
3. Provide all components and drive programming to allow network interface with control system.

2.7 REDUCED VOLTAGE SOLID STATE STARTER VFD BYPASS

- A. The reduced voltage solid state starter shall be full wave, 6-SCR power bridge type, rated for 480 VAC, +10 percent/-10 percent, 3 phase, 60 Hertz., +3 Hz. SCRs shall be PRV rated for at least 2.5 times rated line voltage.
- B. The following control adjustments shall be provided:
 - 1. Current Limit: 50 percent - 500 percent of FLA.
 - 2. Voltage Ramp During Start: Adjustable up to 60 seconds.
 - 3. Voltage Ramp During Soft Stop: Adjustable up to 15 seconds.
- C. Transient voltage suppression shall be supplied to protect against high potential transient voltage spikes.
- D. Overload capacity shall be as follows:
 - 1. Continuous: 115 percent of FLA.
 - 2. 1 Minute: 450 percent of FLA.
 - 3. 30 Seconds: 500 percent of FLA.
 - 4. 5 Seconds: 600 percent of FLA.
- E. One reduced voltage solid state soft start starter bypass shall be provided for each motor, where indicated in the drawings, to allow the motor to run across-the-line in the event of VFD shutdown. The transfer from the VFD to the line shall be accomplished manually by means of a selector switch. The bypass circuitry shall be mounted and wired in a free-standing, force ventilated, filtered, gasketed cabinet.
- F. The reduced voltage solid state starter cabinets shall each include a door-interlocked input circuit breaker, starting contactor and running contactor (all contactors electrically interlocked), a thermal overload relay to provide motor protection and a control power transformer. Mounted on the cabinet door shall be the bypass selector switch, motor fault light, power "ON" light, motor "ON VFD" light and motor "ON LINE" light.

2.8 SHOP TESTING

- A. Provide a factory performance test for each variable frequency drive unit. The test to consist of simulating the expected load to be driven. The drive to operate the actual motor load through the expected speed ranges. Test length to be a minimum of two hours.
- B. Provide a factory burn-in test for 24 hours minimum and a control and alarm test on each drive unit by simulating each control signal and each alarm function to verify proper and correct drive unit action.
- C. Provide typical prototype factory test data for short circuit testing of each type of drive supplied. Data to verify that each drive can be started into a line-to-line fault and line-to-ground fault on the drive terminals. Each drive can be operating at full load and be subjected to a line-to-line fault and line-to-ground fault on the drive terminals. All phases (A, B & C) to be included in test data.
- D. Provide certified documentation of all tests performed.
- E. Provide above stated tests in addition to routine factory tests.

- F. Engineer will witness all factory tests for drives 100 Hp and larger. Notify CMCG and Engineer 30 days before all tests.

2.9 SPARE PARTS

- A. Provide in accordance with Section 01600 – MATERIALS AND EQUIPMENT and as specified.
- B. Provide one spare board or card, three diodes, for each horsepower size drive. Spares will be color- coded or otherwise keyed to their original counterpart such that improper installation of spare cards is impossible. In addition to the cards, the manufacturer shall provide three spares for all expendable items such as pilot lamps, power fuses, and control fuses. Provide one spare keypad for every three VFD of the same model.

PART 3 - EXECUTION

3.1 INSPECTION

- A. Examine VFD location for satisfactory preparation. Check conduits and raceway location for connection to units.
- B. Visually inspect delivered unit(s) and accessories for conformance with specification and drawings.
- C. Verify availability of appropriate pacing signal.
- D. Maintain variable frequency drive in upright position at all times.
- E. Protect variable frequency drive against damage. Store drive in clean, dry environment with temperature and humidity within range as specified by drive manufacturer. Energize space heaters during storage as recommended by manufacturer.

3.2 INSTALLATION

- A. Erect, install, and start-up equipment.
- B. The VFDs shall be installed as shown on the drawings, in accordance with the manufacturer's installation instructions, and accepted shop drawings.
- C. Install VFDs to allow complete door swing required for component removal. This is specifically required where a VFD is set in the corner of a room.
- D. Factory-trained service personnel, other than sales representatives, shall supervise field installation, inspect, make final adjustments and operational checks, make functional checks of spare parts, and prepare a final report for record purposes. Adjust control and instrument equipment until this equipment has been field tested.

3.3 RUBBER MATS

Three foot wide rubber mats shall be furnished and installed on the floor and in front of each VFD assembly. The mats shall be long enough to cover the full length of each VFD system. The mats shall be 1/2-inch (12 mm) thick with beveled edges, canvas back, solid type with

corrugations running the long way, and shall be guaranteed extra quality, free from cracks, blow holes or other defects detrimental to their mechanical or electrical strength. The mats shall meet the requirements of ASTM D178 for Type II, Class 4 insulating matting.

3.4 FIELD TESTING

- A. Perform testing checkout, and start-up for variable frequency drive equipment under technical direction of manufacturer's service engineer. Under no circumstances energize any portion of the drive system without authorization from manufacturer's technical representative.

- B. Field Tests:
 - 1. Test each drive over the total speed range that it will be required to operate through for the load being driven for a minimum of two hours. Determine for each drive, motor, and load combination the following at minimum speed, maximum speed, and at 1/3 and 2/3 points between the minimum and maximum speeds:
 - a. Input power (kW), voltage, current and RMS power factor on the line side of the drive isolation device.
 - b. Output to the driven load in kilowatts.
 - c. For each drive, measure the harmonic voltage distortion and harmonic current distortion for each harmonic at the main distribution bus for maximum and minimum load conditions.
 - d. Measure the total harmonic voltage distortion and total harmonic current distortion at each PCC for maximum and minimum load conditions.
 - 2. Test each drive by using the actual control signal for remote and local operation.
 - 3. Test each drive's alarm functions.
 - 4. Perform all tests in the presence of the Owner's representative.
 - 5. Perform the above test in addition to the manufacturer's normal field tests.
 - 6. Submit final test report with summary comparing field test data with harmonic analysis design calculated values for each drive.
 - 7. Testing determined not in compliance with Contract documents shall be repeated by the Contractor at no additional cost to the Owner.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- ~~A.~~ Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".~~Section 01015—SCHEDULE OF PRICES.~~
- ~~B.A.~~

END OF SECTION

SECTION 16265

UNINTERRUPTIBLE POWER SUPPLY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. On-line, double-conversion, static-type, UPS units with the following features:
 - a. Surge suppression.
 - b. Rectifier-charger.
 - c. Inverter.
 - d. Controls and indications.
 - e. Static bypass transfer switch.
 - f. External maintenance bypass/isolation switch.
 - g. Output distribution section.
 - h. Output isolation transformers.
 - i. Remote status and alarm panels.
 - j. Remote monitoring provisions.
 - k. Battery and battery disconnect device.
 - l. Battery monitoring.

1.3 DEFINITIONS

- A. EMI: Electromagnetic interference.
- B. GTO: Gate turn-off thyristor.
- C. IGBT: Isolated gate bipolar transistor.
- D. LCD: Liquid-crystal display.
- E. LED: Light-emitting diode.
- F. NiCd: Nickel cadmium.
- G. PC: Personal computer.
- H. SPD: Surge protection device.
- I. THD: Total harmonic distortion.

- J. UPS: Uninterruptible power supply.

1.4 SUBMITTALS

- A. Product Data: For each type of UPS.
 - 1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for UPS.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
- B. Shop Drawings: For UPS.
 - 1. Include plans, elevations, sections, and mounting attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.
 - 4. Include diagrams for power, signal, and control wiring.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For UPS units to include in emergency, operation, and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Fuses: One for every 10 of each type and rating, but no fewer than one set of each.
 - 2. Cabinet Ventilation Filters: Four (4) complete sets.

1.7 QUALITY ASSURANCE

- A. Power Quality Specialist Qualifications: A registered professional electrical engineer or qualified technician, currently certified by the National Institute for Certification in engineering Technologies, NICET Level 4, minimum, experienced in performance testing UPS installations and in performing power quality surveys like that required in "Performance Testing" Article.
- B. Testing Agency Qualifications: Certified by NETA.
 - 1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

1.8 WARRANTY

A. Special Battery Warranties: Manufacturer and Installer agree to repair or replace UPS system storage batteries that fail in materials or workmanship within specified warranty period.

1. Warranted Cycle Life for Valve-Regulated, Lead-Calcium Batteries: Equal to or greater than that represented in manufacturer's published table, but not less than the following, based on annual average battery temperature of 77 deg F:

Discharge Rate	Discharge Duration	Voltage at End of Discharge	Warranted Life
8 hours	8 hours	1.67	6 cycles
30 minutes	30 minutes	1.67	20 cycles
15 minutes	45 seconds	1.67	120 cycles

2. Warranted Cycle Life for Premium Valve-Regulated, Lead-Calcium Batteries: Equal to or greater than that represented in manufacturer's published table, but not less than the following, based on annual average battery temperature of 77 deg F:

Discharge Rate	Discharge Duration	Discharge End Voltage	Cycle Life
8 hours	8 hours	1.67	40 cycles
30 minutes	30 minutes	1.67	125 cycles
15 minutes	1.5 minutes	1.67	750 cycles

3. Warranted Cycle Life for Flooded Batteries: Equal to or greater than that represented in manufacturer's published table, but not less than the following, based on annual average battery temperature of 77 deg F:

Discharge Rate	Discharge Duration	Discharge End Voltage	Cycle Life
8 hours	8 hours	1.75	40 cycles
1 hour	1 hour	1.75	80 cycles
15 minutes	45 seconds	1.67	2700 cycles

B. Special UPS Warranties: Specified form in which manufacturer and Installer agree to repair or replace components that fail in materials or workmanship within special warranty period.

1. Special Warranty Period: 1 year from date of acceptance by Owner

PART 2 - PRODUCTS

2.1 OPERATIONAL REQUIREMENTS

A. Automatic operation includes the following:

1. Double Conversion, Standard Efficiency:

- a. Normal Conditions: Load is supplied with power flowing from the normal power input terminals, through the rectifier-charger and inverter, with the battery connected in parallel with the rectifier-charger output.
 - b. Abnormal Supply Conditions: If normal supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, the battery supplies energy to maintain constant, regulated inverter power output to the load without switching or disturbance.
 - c. Power Failure: If normal power fails, energy supplied by the battery through the inverter continues supply-regulated power to the load without switching or disturbance.
2. Double Conversion, Line Interactive:
- a. Normal Conditions: Load is supplied with power flowing from the normal power input terminals, with the rectifier-charger and inverter turned off and the battery disconnected.
 - b. Abnormal Supply Conditions: If normal supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, the rectifier-charger and inverter turn on and the battery supplies energy to provide constant, regulated inverter power output to the load with minimum of 98 %UPS system efficiency.
 - c. Power Failure: If normal power fails, there is a maximum 4-microsecond delay while the rectifier-charger and inverter turn on and the battery supplies energy to re-establish constant, regulated power output to the load.
- B. Manual operation includes the following:
1. Turning the inverter off causes the static bypass transfer switch to transfer the load directly to the normal ac supply circuit without disturbance or interruption.
 2. Turning the inverter on causes the static bypass transfer switch to transfer the load to the inverter.
- C. Maintenance Bypass/Isolation Switch Operation: Switch is interlocked so it cannot be operated unless the static bypass transfer switch is in the bypass mode. Device provides manual selection among the three conditions described below without interrupting supply to the load during switching:
1. Full Isolation: Load is supplied, bypassing the UPS. Normal UPS ac input circuit, static bypass transfer switch, and UPS load terminals are completely disconnected from external circuits.
 2. Maintenance Bypass: Load is supplied, bypassing the UPS. UPS ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.
 3. Normal: Normal UPS ac supply terminals are energized and the load is supplied through the static bypass transfer switch and the UPS rectifier-charger and inverter, or the battery and the inverter.
- D. Environmental Conditions: The UPS shall be capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability, except battery performance:
1. Ambient Temperature for Electronic Components: 32 to 104 deg F.
 2. Ambient Temperature for Battery: 41 to 95 deg F.
 3. Relative Humidity: Zero to 95 percent, noncondensing.
 4. Altitude: Sea level to 4000 feet.

2.2 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: UPS shall withstand the effects of earthquake motions determined per ASCE/SEI 7.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified for Seismic region and the unit will be fully operational after the seismic event."
- B. UL Compliance: Listed and labeled by an NRTL to comply with UL 1778.
- C. The UPS shall perform as specified in this article while supplying rated full-load current, composed of any combination of linear and nonlinear load, up to 100 % nonlinear load with a maximum load crest factor of 3.0, under the following conditions or combinations of the following conditions:
1. Inverter is switched to battery source.
 2. Steady-state ac input voltage deviates up to plus or minus 10 % from nominal voltage.
 3. Steady-state input frequency deviates up to plus or minus 5 % from nominal frequency.
 4. THD of input voltage is 15 % or more with a minimum crest factor of 3.0, and the largest single harmonic component is a minimum of 5 % of the fundamental value.
 5. Load is 100 % unbalanced continuously.
- D. Minimum Duration of Supply: If battery is sole energy source supplying rated full-load UPS current at 80 % power factor, duration of shall be a minimum of 1 hour.-30 minutes.
- E. Input Voltage Tolerance: System steady-state and transient output performance remains within specified tolerances when steady-state ac input voltage varies plus 10 % and minus 15 % from nominal voltage.
- F. Overall UPS Efficiency: Equal to or greater than 95 % at 100 % load, 95 % at 75 % load, and 94 % at 25 % load.
- G. Insert noise values in "Maximum Acoustical Noise" Paragraph below that are consistent with rated capacity of UPS units specified in this Section. See the Evaluations for table of typical values.
- H. AC Output-Voltage Regulation for Loads 100 % Unbalanced: Maximum of plus or minus 2 % over the full range of battery voltage.
- I. AC Output-Voltage Regulation for Loads 100 % Balanced: Maximum of plus or minus 1 % over the full range of battery voltage.
- J. Output Frequency: 60 Hz, plus or minus 0.1 % over the full range of input voltage, load, and battery voltage.
- K. Limitation of harmonic distortion of input current to the UPS shall be as follows:
1. Description: Rectifier-charger circuits shall limit THD to 5 percent, maximum, at rated full-load UPS current, for power sources with X/R ratio between 2 and 30. Provide tuned harmonic filter if required to meet harmonic distortion limit.
 2. Description: THD is limited to a maximum of 32 percent, at rated full-load UPS current, for power sources with X/R ratio between 2 and 30.

- L. Maximum Harmonic Content of Output-Voltage Waveform: 5 %RMS total and 3 %RMS for any single harmonic, for 100 %rated nonlinear load current with a load crest factor of 3.0.
- M. Maximum Harmonic Content of Output-Voltage Waveform: 5 %RMS total and 3 %RMS for any single harmonic, for rated full load with THD up to 50 percent, with a load crest factor of 3.0.
- N. Minimum Overload Capacity of UPS at Rated Voltage: 125 %of rated full load for 10 minutes, 200 %for 60 seconds in normal operation, and 150 %for 30 seconds in battery operating mode.
- O. Maximum Output-Voltage Transient Excursions from Rated Value: For the following instantaneous load changes, stated as percentages of rated full UPS load, voltage shall remain within stated percentages of rated value and recover to, and remain within, plus or minus 2 %of that value within 50 ms:
 - 1. 50 Percent: Plus or minus 3 percent.
 - 2. 100 Percent: Plus or minus 5 percent.
 - 3. Loss of AC Input Power: Plus or minus 1 percent.
 - 4. Restoration of AC Input Power: Plus or minus 1 percent.
- P. Input Power Factor: A minimum of 0.95 lagging when supply voltage and current are at nominal rated values and the UPS is supplying rated full-load current without additional filters.
- Q. Output Power Factor Rating: Loads with power factor of 0.9 leading to 0.8 lagging shall not require derating of the UPS. For loads with power factors outside this range, derate the UPS output as follows:
 - 1. Derate the UPS a maximum of 5 %for 0.7 PF lagging.
 - 2. Derate the UPS a maximum of 10 %for 0.6 PF lagging.
 - 3. Derate the UPS a maximum of 15 %for 0.5 PF lagging.
 - 4. Derate the UPS a maximum of 20 %for a range of 0.4 to 0.1 PF lagging.
- R. EMI Emissions: Comply with FCC rules and regulations and with 47 CFR 15 for Class A equipment.

2.3 UPS SYSTEMS

- A. Description: Self-contained, battery backup device and accessories that provides three-phase electrical power in the event of failure or sag in the normal power system.
- B. Electronic Equipment: Solid-state devices using hermetically sealed, semiconductor elements. Devices include rectifier-charger, inverter, static bypass transfer switch, and system controls.
- C. Enclosures: Comply with NEMA 250, Type 1, unless otherwise indicated.
- D. Configuration: Single-cabinet Control Assemblies: Mount on modular plug-ins, readily accessible for maintenance.
- E. Maintainability Features: Mount rectifier-charger and inverter sections and the static bypass transfer switch on modular plug-ins, readily accessible for maintenance.
- F. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

- G. Capacity Upgrade Capability: Arrange wiring, controls, and modular component plug-in provisions to permit future 15 > %increase in UPS capacity.
- H. Seismic-Restraint Design: UPS assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces for the listed area.
- I. UPS Cabinet Ventilation: Redundant fans or blowers draw in ambient air near the bottom of cabinet and discharge it near the top rear.
- J. Output Circuit Neutral Bus, Conductor, and Terminal Ampacity: Rated phase current times a multiple of 1.73, minimum.

2.4 SURGE SUPPRESSION

- A. Protect internal UPS components from surges that enter at each ac power input connection including main disconnect switch, static bypass transfer switch, and maintenance bypass/isolation switch. Protect rectifier-charger, inverter, controls, and output components.
 - 1. Use factory-installed surge suppressors tested per IEEE C62.41.1 and IEEE C62.41.2, Category B.

2.5 RECTIFIER-CHARGER

- A. Description: Voltage source converter, **12**-pulse rectifier.
- B. Capacity: Adequate to supply the inverter during rated full output load conditions and simultaneously recharge the battery from fully discharged condition to 95 % of full charge within 10 times the rated discharge time for duration of supply under battery power at full load.
- C. Output Ripple: Limited by output filtration to less than 0.5 % of rated current, peak to peak.
- D. Control Circuits: Immune to frequency variations within rated frequency ranges of normal and emergency power sources.
 - 1. Response Time: Field adjustable for maximum compatibility with local generator-set power source.
- E. Battery Float-Charging Conditions: Comply with battery manufacturer's written instructions for battery terminal voltage and charging current required for maximum battery life. The battery charger shall be matched to the battery type supplied.

2.6 INVERTER

- A. Description: Pulse-width modulated,] with sinusoidal output.

2.7 CONTROLS AND INDICATIONS

- A. Description: Group displays, indications, and basic system controls on a common control panel on front of UPS enclosure.
- B. Minimum displays, indicating devices, and controls include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. AlaRMS include audible signals and visual displays.
- C. Indications : Plain-language messages on a digital LCD.
 - 1. Quantitative indications shall include the following:
 - a. Input voltage, each phase, line to line.
 - b. Input current, each phase, line to line.
 - c. Bypass input voltage, each phase, line to line.
 - d. Bypass input frequency.
 - e. System output voltage, each phase, line to line.
 - f. System output current, each phase.
 - g. System output frequency.
 - h. DC bus voltage.
 - i. Battery current and direction (charge/discharge).
 - j. Elapsed time discharging battery.
 - 2. Basic status condition indications shall include the following:
 - a. Normal operation.
 - b. Load-on bypass.
 - c. Load-on battery.
 - d. Inverter off.
 - e. Alarm condition.
 - 3. Alarm indications shall include the following:
 - a. Bypass ac input overvoltage or under-voltage.
 - b. Bypass ac input over-frequency or under-frequency.
 - c. Bypass ac input and inverter out of synchronization.
 - d. Bypass ac input wrong-phase rotation.
 - e. Bypass ac input single-phase condition.
 - f. Bypass ac input filter fuse blown.
 - g. Internal frequency standard in use.
 - h. Battery system alarm.
 - i. Control power failure.
 - j. Fan failure.
 - k. UPS overload.
 - l. Battery-charging control faulty.
 - m. Input overvoltage or under-voltage.
 - n. Input transformer over-temperature.
 - o. Input circuit breaker tripped.
 - p. Input wrong-phase rotation.
 - q. Input single-phase condition.
 - r. Approaching end of battery operation.
 - s. Battery under-voltage shutdown.

- t. Maximum battery voltage.
- u. Inverter fuse blown.
- v. Inverter transformer over temperature.
- w. Inverter over temperature.
- x. Static bypass transfer switch over temperature.
- y. Inverter power supply fault.
- z. Inverter transistors out of saturation.
- aa. Identification of faulty inverter section/leg.
- bb. Inverter output overvoltage or under voltage.
- cc. UPS overload shutdown.
- dd. Inverter current sensor fault.
- ee. Inverter output contactor open.
- ff. Inverter current limit.

4. Controls shall include the following:

- a. Inverter on-off.
- b. UPS start.
- c. Battery test.
- d. Alarm silence/reset.
- e. Output-voltage adjustment.

D. Dry-form "C" contacts shall be available for remote indication of the following conditions:

- 1. UPS on battery.
- 2. UPS on-line.
- 3. UPS load-on bypass.
- 4. UPS in alarm condition.
- 5. UPS off (maintenance bypass closed).

E. Emergency Power off Switch: Capable of local operation and operation by means of activation by external dry contacts.

2.8 STATIC BYPASS TRANSFER SWITCH

- A. Description: Solid-state switching device providing uninterrupted transfer with a contactor or electrically operated circuit breaker to automatically provide electrical isolation for the switch.
- B. Switch Rating: Continuous duty at the rated full-load UPS current, minimum.
- C. Input SPD: 80 kA.

2.9 MAINTENANCE BYPASS/ISOLATION SWITCH

- A. Description: Manually operated switch or arrangement of switching devices with mechanically actuated contact mechanism arranged to route the flow of power to the load around the rectifier-charger, inverter, and static bypass transfer switch.
 - 1. Switch shall be electrically and mechanically interlocked to prevent interrupting power to the load when switching to bypass mode.

2. Switch shall electrically isolate other UPS components to permit safe servicing.
 3. Switch shall electrically isolate the rectifier-charger, inverter, and static bypass transfer switch from the load, but shall allow primary power to the UPS for testing.
- B. Switch Rating: Continuous duty at rated full-load UPS current.
- C. Mounting Provisions: Separate wall- or floor-mounted unit.
- D. Key interlock with key that is released only when the rectifier-charger and inverter are bypassed by the static bypass transfer switch. Key shall be required to unlock maintenance bypass/isolation switch before switching from open (normal) position to closed position. Lock shall be designed specifically for mechanical and electrical component interlocking.

2.10 OUTPUT DISTRIBUTION SECTION

- A. Panelboards: Comply with Section 16471 "Distribution and Branch Circuit Panelboards," except provide assembly integral to UPS cabinet.

2.11 OUTPUT ISOLATION TRANSFORMER

- A. Description: Shielded unit with low forward transfer impedance up to 3 kHz, minimum. Include the following features:
1. Comply with applicable portions of UL 1561, including requirements for nonlinear load current-handling capability for a K-factor of approximately 4.
 2. Output Impedance at Fundamental Frequency: Between 3 and 4 percent.
 3. Regulation: 5 percent, maximum, at rated nonlinear load current.
 4. Full-Load Efficiency at Rated Nonlinear Load Current: 96 percent, minimum.
 5. Electrostatic Shielding of Windings: Independent for each winding.
 6. Coil Leads: Physically arranged for minimum interlead capacitance.
 7. Shield Grounding Terminal: Separately mounted; labeled "Shield Ground."
 8. Capacitive Coupling between Primary and Secondary: 33 pF, maximum, over a frequency range of 20 Hz to 1 MHz.

2.12 BATTERY

- A. Description: Sealed, lead-calcium, heavy-duty industrial units in styrene acrylonitrile containers. Acid-resistant, painted steel racks. Assembly includes battery disconnect switch, intercell connectors, hydrometer syringe, and thermometer with specific gravity-correction scales.
1. Factory assembled in an isolated compartment of UPS cabinet.
 2. Mount on acid-resistant, painted steel racks.
 3. Arrange for drawout removal of battery assembly from cabinet for testing and inspecting.
- B. Seismic-Restraint Design: Battery racks, cabinets, assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces.

2.13 BASIC BATTERY MONITORING

- A. Description: Continuous, real-time capture of battery performance data.
- B. Battery Ground-Fault Detector: Initiates alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.
- C. Annunciation of Alarms: At UPS control panel and remotely.

2.14 BATTERY-CYCLE WARRANTY MONITORING

- A. Description: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring of charge-discharge cycle history of batteries covered by cycle-life warranties.
- B. Performance: Automatically measure and record each discharge event, classify it per duration category and total discharges per warranty criteria, and display remaining warranted battery life on front panel display.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for conditions affecting performance of the UPS.
- B. Proceed with installation only after unsatisfactory conditions have been corrected.
- C. Verify installation conditions are representative of the conditions used in the coordination studies for the electrical system. Provide fuse protection per Section 262813 "Fuses" if required for coordination with UPS overcurrent protective device requirements.

3.2 INSTALLATION

- A. Comply with NECA 1.
- B. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.
- C. Equipment Mounting: Install UPS on concrete base, minimum 6" above floor or grade.
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base 6 inches from the outer edge of the base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- D. Maintain minimum clearances and workspace at equipment per manufacturer's written instructions and Massachusetts Electrical Code.
- E. Connections: Interconnect system components. Make connections to supply and load circuits per manufacturer's wiring diagrams unless otherwise indicated. Apply oxide inhibitor on battery terminals.

3.3 GROUNDING

- A. Comply with MEC requirements for connecting to grounding electrodes and for bonding to metallic piping near isolation transformer. Comply with requirements in Section 16060 "Grounding and Bonding."

3.4 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "Electrical Identification."
1. Identify each battery cell individually.

3.5 BATTERY EQUALIZATION

- A. Equalize charging of battery cells per manufacturer's written instructions. Record individual-cell voltages.

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Tests and Inspections:
1. Inspect interiors of enclosures, including the following:
 - a. Inspect anchorage, alignment, grounding, and required clearances.
 - b. Component type and labeling verification.
 - c. Ratings of installed components.
 2. Test electrical and mechanical interlock systems for correct operation and sequencing.
 3. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 - a. Use of low-resistance ohmmeter per Section 7.22.2.2 of NETA ATS.

- b. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method per manufacturer's published data or Table 100.12 of NETA ATS.
 - c. Perform thermographic survey per Section 9 of NETA ATS.
4. Test static transfer from inverter to bypass and back. Use normal load, if possible.
 5. Test dc under-voltage trip level on inverter input breaker. Set per manufacturer's published data.
 6. Verify synchronizing indicators for static switch and bypass switches.
 7. Test insulated-case and molded-case breakers.
 - a. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage according to manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 of NETA ATS.
 - b. Perform insulation-resistance tests on all control wiring for ground. Applied potential shall be 500-V dc for 300-V rated cable and 1000-V dc for 600-V rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
 - c. Use primary current injection to determine long time and short time, ground fault, and instantaneous pickup, use secondary current injection to test trip functions.
 - d. Perform minimum pickup voltage tests on shunt trip and close coils according to manufacturer's published data.
 - e. Verify operation of charging mechanism.
 - f. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, anti-pump function, and trip unit battery condition. Reset all trip logs and indicators.
 8. Test automatic transfer switches.
 - a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, per Section 7.22.3.1 of NETA ATS.
 - b. Perform insulation-resistance tests on all control wiring for ground. Applied potential shall be 500-V dc for 300-V rated cable and 1000-V dc for 600-V rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
 - c. Perform a contact/pole-resistance test.
 - d. Verify settings and operation of control devices.
 - e. Calibrate and set all relays and timers per Section 7.9 of NETA ATS.
 - f. Verify phase rotation, phasing, and synchronized operation as required by the application.
 - g. Perform automatic transfer tests.
 - 1) Simulate loss of normal power.
 - 2) Return to normal power.
 - 3) Simulate loss of emergency power.
 - 4) Simulate all forms of single-phase conditions.
 - h. Verify correct operation and timing of the following functions:
 - 1) Normal source voltage-sensing and frequency-sensing relays.

- 2) Time delay on transfer.
- 3) Alternative source voltage-sensing and frequency-sensing relays.
- 4) Automatic transfer operation.
- 5) Interlocks and limit switch function.
- 6) Time delay and retransfer on normal power restoration.

9. Test direct current system's batteries.

- a. Verify adequacy of battery support racks, mounting, anchorage, alignment, grounding, and clearances.
- b. Verify electrolyte level. Measure electrolyte level, specific gravity, and temperature.
- c. Inspect spill containment installation. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
- d. Verify all charger functions and alarms.
- e. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.
- f. Perform a load test per manufacturer's published data or IEEE 450.
- g. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended settings.
- h. Test values.
 - 1) Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 % of the lowest value.
 - 2) Charger float and equalize voltage levels shall be per battery manufacturer's published data.
 - 3) The results of charger functions and alarms shall be per manufacturer's published data.
 - 4) Cell voltages shall be within 0.05 V of each other or per manufacturer's published data.
 - 5) Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 % of the lowest value.
 - 6) Cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 % between identical cells that are in a fully charged state.
 - 7) Results of load tests shall be per manufacturer's published data or IEEE 450.
- i. Simulate malfunctions to verify protective device operation.
- j. Test duration of supply on emergency, low-battery voltage shutdown, and transfers and restoration due to normal source failure.
- k. Test harmonic content of input and output current at 25, 50, and 100 % of rated loads.
- l. Test output voltage under specified transient-load conditions.
- m. Test efficiency at 50, 75, and 100 % of rated loads.

D. The UPS system will be considered defective if it does not pass tests and inspections.

E. Record of Tests and Inspections: Maintain and submit documentation of tests and inspections, including references to manufacturers' written instructions and other test and inspection criteria. Include results of tests, inspections, and retests.

F. Prepare test and inspection reports.

3.7 PERFORMANCE TESTING

- A. Engage the services of a qualified power quality specialist to perform tests and activities for each UPS system.
- B. Revise "Monitoring and Testing Schedule" Paragraph below to specify extent and basic schedule for

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment"

END OF SECTION

SECTION 16269

VARIABLE-FREQUENCY MOTOR CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes separately enclosed, preassembled, combination VFCs, rated 600 V and less, for speed control of, squirrel-cage induction motors.

1.3 DEFINITIONS

- A. BAS: Building automation system.
- B. CE: Conformance Europeene (European Compliance).
- C. CPT: Control power transformer.
- D. EMI: Electromagnetic interference.
- E. LED: Light-emitting diode.
- F. NC: Normally closed.
- G. NO: Normally open.
- H. OCPD: Overcurrent protective device.
- I. PID: Control action, proportional plus integral plus derivative.
- J. RFI: Radio-frequency interference.
- K. VFC: Variable-frequency motor controller.

1.4 SUBMITTALS

- A. Product Data: For each type and rating of VFC indicated.
 - 1. Include dimensions and finishes for VFCs.
 - 2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

- B. Shop Drawings: For each VFC indicated.
 - 1. Include mounting and attachment details.
 - 2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 3. Include diagrams for power, signal, and control wiring.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals.
 - 1. Include the following:
 - a. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and motor-circuit protector trip settings.
 - b. Manufacturer's written instructions for setting field-adjustable overload relays.
 - c. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
 - d. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
 - e. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.
 - f. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and install temporary electric heating, with at least 250 W per controller.
- B. Properly store at site to avoid damage by weather elements and field conditions.

1.7 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cerus Industrial, Inc.
2. Danfoss Inc; Danfoss Drives Div.
3. Eaton Electrical Sector; Eaton Corporation; Cutler-Hammer Business Unit.
4. Rockwell Automation, Inc; Allen-Bradley Brand.
5. Schneider Electric USA, Inc.
6. Siemens Energy & Automation, Inc.

2.2 SYSTEM DESCRIPTION

- A. General Requirements for VFCs:
 1. VFCs and Accessories: Listed and labeled as defined by a qualified testing agency, and marked for intended location and application.
 2. Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C.
- B. Application: Constant torque and variable torque.
- C. VFC Description: Variable-frequency motor controller, consisting of power converter that employs pulse-width-modulated inverter, factory built and tested in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.
 1. Units suitable for operation of NEMA MG 1, Design A and Design B motors, as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."
 2. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
 3. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.
- D. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.
- E. Output Rating: Three phase or Single Phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range; maximum voltage equals input voltage.
- F. Unit Operating Requirements:
 1. Input AC Voltage Tolerance: Plus 10 and minus 10 % of VFC input voltage rating.
 2. Input AC Voltage Unbalance: Not exceeding 3 %.
 3. Input Frequency Tolerance: Plus or minus 3 % of VFC frequency rating.
 4. Minimum Efficiency: 96 % at 60 Hz, full load.
 5. Minimum Displacement Primary-Side Power Factor: 96 % under any load or speed condition.
 6. Minimum Short-Circuit Current (Withstand) Rating: 65 kA.
 7. Ambient Temperature Rating: Not less than 32 deg F and not exceeding 104F.
 8. Humidity Rating: Less than 95 % (noncondensing).
 9. Altitude Rating: Not exceeding 3300 feet.
 10. Vibration Withstand: Comply with NEMA ICS 61800-2.
 11. Overload Capability: 1.5 times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.

12. Starting Torque: Minimum 100 % of rated torque from 3 to 60 Hz.
 13. Speed Regulation: plus or minus 5 %.
 14. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.
 15. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.
- G. Inverter Logic: Microprocessor based, 32 bit, isolated from all power circuits.
- H. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.
1. Signal: Electrical.
- I. Internal Adjustability Capabilities:
1. Minimum Speed: 5 to 25 % of maximum rpm.
 2. Maximum Speed: 80 to 100 % of maximum rpm.
 3. Acceleration: 0.1 to 999.9 seconds.
 4. Deceleration: 0.1 to 999.9 seconds.
 5. Current Limit: 30 to minimum of 150 % of maximum rating.
- J. Self-Protection and Reliability Features:
1. Surge Suppression: Factory installed as an integral part of the VFC, complying with UL 1449 SPD, Type 1 or Type 2.
 2. Surge Suppression: Field-mounted surge suppressors complying with Section 16289 "Surge Protection for Low-Voltage Electrical Power Circuits," UL 1449 SPD, Type 2.
 3. Loss of Input Signal Protection: Selectable response strategy, including speed default to a % of the most recent speed, a preset speed, or stop; with alarm.
 4. Under- and overvoltage trips.
 5. Inverter overcurrent trips.
 6. VFC and Motor-Overload/Over-temperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC over-temperature and motor-overload alarm and trip; settings selectable via the keypad.
 7. Critical frequency rejection, with three selectable, adjustable deadbands.
 8. Instantaneous line-to-line and line-to-ground overcurrent trips.
 9. Loss-of-phase protection.
 10. Reverse-phase protection.
 11. Short-circuit protection.
 12. Motor-over-temperature fault.
- K. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
- L. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
- M. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
- N. Integral Input Disconnecting Means and OCPD: UL 489, thermal-magnetic circuit breaker with pad-lockable, door-mounted handle mechanism.

1. Disconnect Rating: Not less than 115 % of VFC input current rating.
2. Disconnect Rating: Not less than 115 % of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.
3. Auxiliary Contacts: NO or NC, arranged to activate before switch blades open.
4. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
5. **NO**] alarm contact that operates only when circuit breaker has tripped.

2.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: VFCs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7. The designated VFCs shall be tested and certified by an NRTL as meeting the ICC-ES AC 156 test procedure requirements.
1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2.4 CONTROLS AND INDICATION

- A. Status Lights: Door-mounted LED indicators displaying the following conditions:
1. Power on.
 2. Run.
 3. Overvoltage.
 4. Line fault.
 5. Overcurrent.
 6. External fault.
- B. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and Plain-English-language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.
1. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
 2. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.
 - a. Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.
- C. Historical Logging Information and Displays:
1. Real-time clock with current time and date.
 2. Running log of total power versus time.
 3. Total run time.
 4. Fault log, maintaining last four faults with time and date stamp for each.
- D. Indicating Devices: Digital display mounted flush in VFC door and connected to display VFC parameters including, but not limited to:

1. Output frequency (Hz).
2. Motor speed (rpm).
3. Motor status (running, stop, fault).
4. Motor current (amperes).
5. Motor torque (%).
6. Fault or alarming status (code).
7. PID feedback signal (%).
8. DC-link voltage (V dc).
9. Set point frequency (Hz).
10. Motor output voltage (V ac).

E. Control Signal Interfaces:

1. Electric Input Signal Interface:
 - a. A minimum of two programmable analog inputs: 0- to 10-V dc.
 - b. A minimum of six multifunction programmable digital inputs.
2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:
 - a. 0- to 10-V dc.
 - b. 4- to 20-mA dc.
 - c. Potentiometer using up/down digital inputs.
 - d. Fixed frequencies using digital inputs.
3. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc), which can be configured for any of the following:
 - a. Output frequency (Hz).
 - b. Output current (load).
 - c. DC-link voltage (V dc).
 - d. Motor torque (%).
 - e. Motor speed (rpm).
 - f. Set point frequency (Hz).
4. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
 - a. Motor running.
 - b. Set point speed reached.
 - c. Fault and warning indication (over-temperature or overcurrent).
 - d. PID high- or low-speed limits reached.

F. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.

1. Number of Loops: Two.

G. BAS Interface: Factory-installed hardware and software shall interface with BAS to monitor, control, display, and record data for use in processing reports. VFC settings shall be retained within VFC's nonvolatile memory.

1. Hardwired Points:
 - a. Monitoring: On-off status.
 - b. Control: On-off operation.
2. Communication Interface: Comply with ASHRAE 135. Communication shall interface with BAS to remotely control and monitor lighting from a BAS operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through the BAS.

2.5 LINE CONDITIONING AND FILTERING

- A. Input Line Conditioning: Based on the manufacturer's harmonic analysis study and report, provide input filtering, as required, to limit total demand (harmonic current) distortion and total harmonic voltage demand at the defined point of common coupling to meet IEEE 519 recommendations.
- B. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.

2.6 OPTIONAL FEATURES

- A. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
- B. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
- C. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

2.7 ENCLOSURES

- A. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.
 1. Dry and Clean Indoor Locations: Type 1.
 2. Outdoor Locations: Type 4X-Stainless Steel.
 3. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

2.8 ACCESSORIES

- A. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFC enclosure cover unless otherwise indicated.
 1. Push Buttons: Lockable Shielded.
 2. Pilot Lights: Push to test.
 3. Selector Switches: Rotary type.
 4. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied has arranged so padlock can be used to lock push button in depressed position with control circuit open.
- B. Reversible NC/NO bypass contactor auxiliary contact(s).

- C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.
- D. Phase-Failure, Phase-Reversal, and Under-voltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable under-voltage, overvoltage, and time-delay settings.
 - 1. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.
- E. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, Type 4X Type 12 enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- F. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, Type 4X enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
- G. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
- H. Spare control-wiring terminal blocks; unwired.

2.9 SOURCE QUALITY CONTROL

- A. Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2.
 - 1. Test each VFC while connected to its specified motor.
 - 2. Verification of Performance: Rate VFCs per operation of functions and features specified.
- B. VFCs will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance of the Work.
- B. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.
- C. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Wall-Mounting Controllers: Install with tops at uniform height and with disconnect operating handles not higher than 79 inches above finished floor, unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with Section 16073 "Hangers and Supports for Electrical Systems."
- B. Floor-Mounting Controllers: Install VFCs on 4-inch nominal thickness concrete base. Comply with requirements for concrete base specified in Section 03300 "Cast-in-Place Concrete."
 - 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
 - 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
 - 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- C. Seismic Bracing: Comply with requirements specified in Section 16074 "Seismic Controls for Electrical Systems."
- D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
- E. Install fuses in each fusible-switch VFC.
- F. Install fuses in control circuits if not factory installed. Comply with requirements in Section 16491 "Fuses."
- G. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors are installed.
- H. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
- I. Comply with NECA 1.

3.3 CONTROL WIRING INSTALLATION

- A. Install wiring between VFCs and remote devices and facility's central-control system. Comply with requirements in Section 16123 "Control-Voltage Electrical Power Cables."
- B. Bundle, train, and support wiring in enclosures.
- C. Connect selector switches and other automatic-control devices where applicable.
 - 1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switches are in manual-control position.
 - 2. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor-overload protectors.

3.4 IDENTIFICATION

- A. Identify VFCs, components, and control wiring. Comply with requirements for identification specified in Section 16075 "Electrical Identification."
 - 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 - 2. Label each VFC with engraved nameplate.
 - 3. Label each enclosure-mounted control and pilot device.
- B. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. Perform tests and inspections with the assistance of a factory-authorized service representative.
- C. Acceptance Testing Preparation:
 - 1. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
 - 2. Test continuity of each circuit.
- D. Tests and Inspections:
 - 1. Inspect VFC, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
 - 2. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.
 - 3. Test continuity of each circuit.
 - 4. Verify that voltages at VFC locations are within 5 % of motor nameplate rated voltages. If outside this range for any motor, notify MBTA before starting the motor(s).
 - 5. Test each motor for proper phase rotation.
 - 6. Perform tests per the Inspection and Test Procedures for Adjustable Speed Drives stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
 - 8. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.
- E. VFCs will be considered defective if they do not pass tests and inspections.
- F. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

3.6 STARTUP SERVICE

- A. Engage a factory-authorized service representative to perform startup service.
 - 1. Complete installation and startup checks according to manufacturer's written instructions.

3.7 ADJUSTING

- A. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Substantial Completion.
- B. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
- C. Adjust the trip settings of instantaneous-only circuit breakers and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to 6 times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed 8 times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify MBTA before increasing settings.
- D. Set the taps on reduced-voltage autotransformer controllers.
- E. Set field-adjustable circuit-breaker trip ranges as specified in Section 16055 "Overcurrent Protective Device Coordination Study."
- F. Set field-adjustable pressure switches.

3.8 PROTECTION

- A. Temporary Heating: Apply temporary heat to maintain temperature per manufacturer's written instructions until controllers are ready to be energized and placed into service.
- B. Replace VFCs whose interiors have been exposed to water or other liquids prior to Substantial Completion.
- C. Properly protect VFCs to avoid damage before final acceptance by MBTA.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”

END OF SECTION

SECTION 16271

MEDIUM-VOLTAGE TRANSFORMERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes the following types of transformers with medium-voltage primaries:

- 1. Pad-mounted, cast coil transformers.

1.3 DEFINITIONS

- A. NETA ATS: Acceptance Testing Specification.

1.4 SUBMITTALS

- A. Product Data: Include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features, location of each field connection, and performance for each type and size of transformer indicated.

- 1. Submit the following data with submittals:
 - a. Core Losses at 85 deg C or 20 deg C
 - b. Winding Losses
 - c. Exciting Current at 100% and 110% rated voltage
 - d. % Impedance
 - e. Efficiencies at 100%, 75%, 50%, and 25% loading levels.
 - f. % regulation must be provided at 0.8 PF

- B. Shop Drawings: Construction Drawings, Record Drawings.

- C. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:

- 1. Underground primary secondary primary and secondary conduit stub-up location.
- 2. Dimensioned concrete base, outline of transformer, and required clearances.
- 3. Ground rod and grounding cable locations.

- D. **Manufacturer Seismic Qualification Certification:** Submit certification that transformer assembly and components will withstand seismic forces defined in Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS."

Coordinate first paragraph below with qualification requirements in Section 01400 "Quality Requirements" and as supplemented in "Quality Assurance" Article.

- E. **Operation and Maintenance Data:** For transformer and accessories to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

- A. Comply with IEEE C2.
- B. Comply with ANSI C57.12.10, ANSI C57.12.28, IEEE C57.12.70, and IEEE C57.12.80.
- C. Comply with Massachusetts Electrical Code.

1.6 DELIVERY, STORAGE, AND HANDLING

- A. Store transformers protected from weather and so condensation will not form on or in units. Provide temporary heating according to manufacturer's written instructions.

1.7 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.
- B. Coordinate installation of louvers, doors, spill retention areas, and sumps. Coordinate installation so no piping or conduits are installed in space allocated for medium-voltage transformers except those directly associated with transformers.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. **Manufacturers:** Subject to compliance with requirements, provide products by one of the following:
 1. Eaton (Cooper)
 2. Siemens Energy & Automation, Inc.
 3. Square D; Schneider Electric.

2.2 DRY-TYPE DISTRIBUTION AND POWER TRANSFORMERS

- A. **Description:** NEMA ST 20, IEEE C57.12.01, ANSI C57.12.50, UL 1562 listed and labeled, dry-type, 2-winding transformers. KVA, impedance, primary voltage, and secondary voltage ratings as indicated on Contract Drawings.

1. Outdoor, ventilated, cast coil/encapsulated coil, with primary and secondary windings individually cast in epoxy; with insulation system rated at 185 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.
- B. Primary Connection: Air terminal compartment with hinged door. Tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.
- C. Secondary Connection: Air terminal compartment with hinged door. Tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.
- D. Insulation Materials: IEEE C57.12.01, rated at 220 deg C.
- E. Insulation Temperature Rise: 150 deg C, maximum rise above 40 deg C.

See Editing Instruction No. 5 in the Evaluations for discussion of basic impulse levels.

- F. Basic Impulse Level: 95 kV.
- G. Full-Capacity Voltage Taps: Four nominal 2.5 % taps, 2 above and 2 below rated primary voltage.
- H. Cooling System: Class AA, self-cooled, complying with IEEE C57.12.01.
- I. High-Temperature Alarm: Sensor at transformer with local audible and visual alarm and contacts for remote alarm.

2.3 IDENTIFICATION DEVICES

- A. Nameplates: Engraved, laminated-plastic or metal nameplate for each transformer, mounted with corrosion-resistant screws. Nameplates and label products are specified in Section 16195 "ELECTRICAL IDENTIFICATION."

2.4 SOURCE QUALITY CONTROL

- A. Factory Tests: Perform design and routine tests according to standards specified for components. Conduct transformer tests according to ANSI C57.12.50 IEEE C57.12.90 IEEE C57.12.91.
- B. Factory Tests: Perform the following factory-certified tests on each transformer:
 1. Resistance measurements of all windings on rated-voltage connection and on tap extreme connections.
 2. Ratios on rated-voltage connection and on tap extreme connections.
 3. Polarity and phase relation on rated-voltage connection.
 4. No-load loss at rated voltage on rated-voltage connection.
 5. Excitation current at rated voltage on rated-voltage connection.
 6. Impedance and load loss at rated current on rated-voltage connection and on tap extreme connections.
 7. Applied potential.
 8. Induced potential.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for medium-voltage transformers.
- B. Examine roughing-in of conduits and grounding systems to verify the following:
 - 1. Wiring entries comply with layout requirements.
 - 2. Entries are within conduit-entry tolerances specified by manufacturer and no feeders will have to cross section barriers to reach load or line lugs.
- C. Examine walls, floors, roofs, and concrete bases for suitable mounting conditions where transformers will be installed.
- D. Verify that ground connections are in place and that requirements in Section 16060 "GROUNDING AND BONDING" have been met. Maximum ground resistance shall be 5 ohms at location of transformer.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install transformers on concrete bases.
 - 1. Anchor transformers to concrete bases according to manufacturer's written instructions, seismic codes at Project, and requirements in Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
 - 2. Construct concrete bases of not less than 4 inches larger in both directions than supported unit and 4 inches high.
 - 3. Use 3000-psi, 28-day compressive-strength concrete and reinforcement as specified in Section 03300 "CAST-IN-PLACE CONCRETE."
 - 4. Install dowel rods to connect concrete bases to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around full perimeter of base.
 - 5. Install epoxy-coated anchor bolts, for supported equipment, that extend through concrete base and anchor into structural concrete floor.
 - 6. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 - 7. Tack-weld or bolt transformers to channel-iron sills embedded in concrete bases. Install sills level and grout flush with floor or base.
- B. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

3.3 IDENTIFICATION

- A. Identify field-installed wiring and components and provide warning signs as specified in Section 16195 "ELECTRICAL IDENTIFICATION."

3.4 CONNECTIONS

- A. Ground equipment according to Section 16060 "GROUNDING AND BONDING."
- B. Connect wiring according to Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

3.5 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.
- B. Testing Agency: Engage a qualified testing and inspecting agency to perform the following field tests and inspections and prepare test reports:
- C. Perform the following field tests and inspections and prepare test reports:
 - 1. After installing transformers but before primary is energized, verify that grounding system at substation is tested at specified value or less.
 - 2. After installing transformers and after electrical circuitry has been energized, test for compliance with requirements.
 - 3. Perform visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
 - 4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
- D. Remove and replace malfunctioning units and retest as specified above.
- E. Test Reports: Prepare written reports to record the following:
 - 1. Test procedures used.
 - 2. Test results that comply with requirements.
 - 3. Test results that do not comply with requirements and corrective actions taken to achieve compliance with requirements.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment"

END OF SECTION

SECTION 16272
WIRING DEVICES
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions
- B. Identification for Electrical Systems-Section 16055

1.2 DESCRIPTION OF WORK

- A. Section Includes:
 - 1. Straight-blade convenience, , isolated-ground, and tamper-resistant receptacles.
 - 2. GFCI receptacles.
 - 3. Hazardous (classified) location receptacles.
 - 4. Twist-locking receptacles.
 - 5. Toggle switches.
 - 6. Decorator-style convenience.
 - 7. Wall switch sensor light switches with dual technology sensors.
 - 8. Digital timer light switches.
 - 9. Wall-box dimmers.
 - 10. Wall plates.
 - 11. Floor service outlets.
 - 12. Poke-through assemblies.
 - 13. Prefabricated multi-outlet assemblies.

1.3 DEFINITIONS

- A. Approved Manufacturers' Names:
 - 1. Cooper: Cooper Wiring Devices; Division of Cooper Industries, Inc.
 - 2. Hubbell: Hubbell Incorporated: Wiring Devices-Kellems.
 - 3. Leviton: Leviton Mfg. Company, Inc.
 - 4. Pass & Seymour: Pass& Seymour/Legrand.
- B. BAS: Building automation system.
- C. EMI: Electromagnetic interference.
- D. GFI: Ground-fault circuit interrupter.
- E. Pigtail: Short lead used to connect a device to a branch-circuit conductor.
- F. RFI: Radio-frequency interference.

- G. SPD: Surge protective device.
- H. UTP: Unshielded twisted pair.

1.4 SUBMITTALS

- A. Submit shop drawings for review and approval for all wiring devices. Submit 4 sets of each.
- B. Shop Drawings: List of legends and description of materials and process used for pre-marking wall plates

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For wiring devices to include in all manufacturers' packing-label warnings and instruction manuals that include labeling conditions.

PART 2 - PRODUCTS

2.1 GENERAL WIRING-DEVICE REQUIREMENTS

- A. Wiring Devices, Components, and Accessories: Listed and labeled as defined in Massachusetts Electrical Code (MEC) and UL listed, or by a qualified testing agency, and marked for intended location and application.
- B. Devices that are manufactured for use with modular plug-in connectors may be substituted under the following conditions:
 - 1. Connectors shall comply with UL 2459 and shall be made with stranding building wire.
 - 2. Devices shall comply with the requirements in this Section.
- C. Furnished Equipment:
 - 1. Receptacles: Match plug configurations.
 - 2. Cord and Plug Sets: Match equipment requirements.
- D. Source Limitations: Obtain each type of wiring device and associated wall plate from single source from single manufacturer.
- E. Surface mounted LBs, outlet and gang boxes shall be malleable iron as approved by MBTA.

2.2 STRAIGHT-BLADE RECEPTACLES

- A. Duplex Convenience Receptacles: 125 V, 20 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, and FS W-C-596.
- B. Tamper-Resistant Convenience Receptacles: 125 V, 20 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, and FS W-C-596.

2.3 GFI RECEPTACLES

A. General Description:

1. 125 V, 20 A, straight blade, feed-through type.
2. Comply with NEMA WD 1, NEMA WD 6 Configuration 5-20R, UL 498, UL 943 Class A, and FS W-C-596.
3. Include indicator light that shows when the GFI has malfunctioned and no longer provides proper GFI protection.

2.4 TWIST-LOCKING RECEPTACLES

A. Twist-Lock, Single Convenience Receptacles: 125 V, 20 A; comply with NEMA WD 1, NEMA WD 6 Configuration L5-20R, and UL 498.

B. Twist-Lock, Isolated-Ground, Single Convenience Receptacles: 125 V, 20 A; comply with NEMA WD 1, NEMA WD 6 Configuration L5-20R, and UL 498.

1. Grounding: Equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.

2.5 TOGGLE SWITCHES

A. Comply with NEMA WD 1, UL 20, and FS W-S-896.

B. Switches, 120/277 V, 20 A:

1. Single Pole, Two Pole, Three Way, Four Way.

C. Pilot-Light Switches: 120/277 V, 20 A.

1. Description: Single pole, with LED-lighted handle, illuminated when switch is off.

D. Key-Operated Switches: 120/277 V, 20 A.

1. Description: Single pole, with factory-supplied key in lieu of switch handle.

E. Key-Operated, Single-Pole, Double-Throw, Momentary-Contact, Center-off Switches: 120/277 V, 20 A; for use with mechanically held lighting contactors, with factory-supplied key in lieu of switch handle.

2.6 DECORATOR-STYLE DEVICES

A. Convenience Receptacles: Square face, 125 V, 15 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-15R, and UL 498.

B. Tamper-Resistant Convenience Receptacles: Square face, 125 V, 15 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-15R, and UL 498.

1. Description: Labeled to comply with MEC, "Receptacles, Cord Connectors, and Attachment Plugs (Caps)" Article, "Tamper-Resistant Receptacles in Dwelling Units" Section.
- C. Weather-Resistant Convenience Receptacles: Square face, 125 V, 15 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-15R, and UL 498.
1. Description: NEMA 4, stainless steel.
- D. GFI, Feed-Through Type, Convenience Receptacles: Square face, 125 V, 15 A; comply with NEMA WD 1, NEMA WD 6 Configuration 5-15R, UL 498, and UL 943 Class A.
- E. Lighted Toggle Switches: Square Face, 120 V, 15 A; comply with NEMA WD 1 and UL 20.
1. Description: With LED-lighted handle, illuminated when switch is off.

2.7 WALL SWITCH SENSOR LIGHT SWITCH, DUAL TECHNOLOGY

- A. Description: Switchbox-mounted, combination lighting-control sensor and conventional switch lighting-control unit using dual technology.
1. Connections: Provisions for connection to BAS.
 2. Connections: Hard wired.
 3. Connections: Wireless.
 4. Rated 960 W at 120-V ac for tungsten lighting, 10 A at 120-V ac or 10 A at 277-V ac for fluorescent or LED lighting, and 1/4 hp at 120-V ac.
 5. Integral relay for connection to BAS.
 6. Adjustable time delay of **[five] [10] [15] [20]** minutes.
 7. Able to be locked to **[Automatic-On] [Manual-On]** mode.
 8. Automatic Light-Level Sensor: Adjustable from 2 to 200 fc.
 9. Comply with NEMA WD 1, UL 20, and FS W-S-896.

2.8 WALL-BOX DIMMERS

- A. Dimmer Switches: Modular, full-wave, solid-state units with integral, quiet on-off switches, with audible frequency and EMI/RFI suppression filters.
- B. Control: Continuously adjustable [slider] [toggle switch] [rotary knob]; with single-pole or three-way switching. Comply with UL 1472.
- C. Incandescent Lamp Dimmers: 120 V; control shall follow square-law dimming curve. On-off switch positions shall bypass dimmer module.
1. 600 W; dimmers shall require no derating when ganged with other devices. **[Illuminated when "off."]**
- D. LED Lamp Dimmer Switches: Modular; compatible with LED lamps; trim potentiometer to adjust low-end dimming; capable of consistent dimming with low end not greater than 20 percent of full brightness.

2.9 WALL PLATES

- A. Single and combination types shall match corresponding wiring devices.
 - 1. Plate-Securing Screws: Metal with head color to match plate finish.
 - 2. Material for Finished Spaces: As approved by Owner.
 - 3. Material for Unfinished Spaces: As approved by owner.
 - 4. Material for Damp Locations: Listed and labeled for use in wet and damp locations.
- B. Wet-Location, Weatherproof Cover Plates: NEMA 250, complying with Type 3R, weather-resistant [**die-cast aluminum**] with lockable cover.

2.10 FLOOR SERVICE FITTINGS

- A. Type: Modular, [**flush-type**], dual-service units suitable for wiring method used.
- B. Compartments: Barrier separates power from voice and data communication cabling.
- C. Service Plate: [**Rectangular**] [**Round**], [**die-cast aluminum**] [**solid brass**] with satin finish.
- D. Power Receptacle: NEMA WD 6 Configuration 5-20R, gray finish, unless otherwise indicated.
- E. Data Communication Outlet: [**Blank cover with bushed cable opening.**] [**Two modular, keyed, color-coded, RJ-45 jacks for twisted pair cable complying with requirements in Section 271513 "Communications Copper Horizontal Cabling."**]

2.11 PREFABRICATED MULTIOUTLET ASSEMBLIES

- A. Description:
 - 1. Two-piece surface metal raceway, with factory-wired multioutlet harness.
 - 2. Components shall be products from single manufacturer designed for use as a complete, matching assembly of raceways and receptacles.
- B. Raceway Material: [**Metal, with manufacturer's standard finish**].
- C. Multioutlet Harness:
 - 1. Receptacles: 15-A, 125-V, NEMA WD 6 Configuration 5-15R receptacles complying with NEMA WD 1, UL 498, and FS W-C-596.
 - 2. Receptacle Spacing: [**18 inches**].
 - 3. Wiring: No. 12 AWG, Type XHHW-2 copper, [**single circuit**].

2.12 FINISHES

- A. Device Color:
 - 1. Wiring Devices Connected to Normal Power System: [**As selected by Architect**] unless otherwise indicated or required by MEC or device listing.
 - 2. Wiring Devices Connected to Emergency Power System: [**Red**].

3. SPD Devices: Blue.
 4. Isolated-Ground Receptacles: [**Orange, with orange triangle on face**].
- B. Wall Plate Color: For plastic covers, match device color.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Comply with Mass Architectural Board (ABB), mounting heights. Coordination with Other Trades:
1. Protect installed devices and their boxes. Do not place wall finish materials over device boxes and do not cut holes for boxes with routers that are guided by riding against outside of boxes.
 2. Keep outlet boxes free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
 3. Install device boxes in brick or block walls so that the cover plate does not cross a joint unless the joint is troweled flush with the face of the wall.
 4. Install wiring devices after all wall preparation, including painting, is complete.
- B. Conductors:
1. Do not strip insulation from conductors until right before they are spliced or terminated on devices.
 2. Strip insulation evenly around the conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.
 3. The length of free conductors at outlets for devices shall meet provisions of MEC, Article 300, without pigtails.
 4. Existing Conductors:
 - a. Cut back and pigtail, or replace all damaged conductors.
 - b. Straighten conductors that remain and remove corrosion and foreign matter.
 - c. Pigtailing existing conductors is permitted, provided the outlet box is large enough.
- C. Device Installation:
1. Replace devices that have been in temporary use during construction and that were installed before building finishing operations were complete.
 2. Keep each wiring device in its package or otherwise protected until it is time to connect conductors.
 3. Do not remove surface protection, such as plastic film and smudge covers, until the last possible moment.
 4. Connect devices to branch circuits using pigtails that are not less than 6 inches in length.
 5. When there is a choice, use side wiring with binding-head screw terminals. Wrap solid conductor tightly clockwise, two-thirds to three-fourths of the way around terminal screw.
 6. Use a torque screwdriver when a torque is recommended or required by manufacturer.
 7. When conductors larger than No. 12 AWG are installed on 15- or 20-A circuits, splice No. 12 AWG pigtails for device connections.
 8. Tighten unused terminal screws on the device.
 9. When mounting into metal boxes, remove the fiber or plastic washers used to hold device-mounting screws in yokes, allowing metal-to-metal contact.

- D. Receptacle Orientation:
 - 1. Install ground pin of vertically mounted receptacles down, and on horizontally mounted receptacles to the left. Once an orientation has been selected, maintain throughout the entire project.
- E. Device Plates: Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening.
- F. Dimmers:
 - 1. Install dimmers within terms of their listing.
 - 2. Verify that dimmers used for fan-speed control are listed for that application.
 - 3. Install unshared neutral conductors on line and load side of dimmers according to manufacturers' device listing conditions in the written instructions.
- G. Arrangement of Devices: Unless otherwise indicated, mount flush, with long dimension vertical and with grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.
- H. Adjust locations of floor service outlets and service poles to suit arrangement of partitions and furnishings.

3.2 IDENTIFICATION

- A. Comply with Section 16195 "Electrical Identification."
- B. Identify each receptacle with panelboard identification and circuit number. Use hot, stamped, or engraved machine printing with white-filled lettering on face of plate, and durable wire markers or tags inside outlet boxes.

3.3 FIELD QUALITY CONTROL

- A. Test Instruments: Use instruments that comply with UL 1436.
- B. Test Instrument for Convenience Receptacles: Digital wiring analyzer with digital readout or illuminated digital-display indicators of measurement.
- C. Perform the following tests and inspections:
 - 1. Test Instruments: Use instruments that comply with UL 1436.
 - 2. Test Instrument for Convenience Receptacles: Digital wiring analyzer with digital readout or illuminated digital-display indicators of measurement.
- D. Tests for Convenience Receptacles:
 - 1. Line Voltage: Acceptable range is 105 to 132 V.
 - 2. Percent Voltage Drop under 15-A Load: A value of 6 percent or higher is unacceptable.
 - 3. Ground Impedance: Values of up to 2 ohms are acceptable.
 - 4. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.
 - 5. Using the test plug, verify that the device and its outlet box are securely mounted.

6. Tests shall be diagnostic, indicating damaged conductors, high resistance at the circuit breaker, poor connections, inadequate fault current path, defective devices, or similar problems. Correct circuit conditions, remove malfunctioning units and replace with new ones, and retest as specified above.
- E. Wiring device will be considered defective if it does not pass tests and inspections.
- F. Prepare test and inspection reports.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- G. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”

END OF SECTION

SECTION 16289

SURGE PROTECTION FOR LOW-VOLTAGE ELECTRICAL POWER CIRCUITS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes field-mounted Surge Protection Devices for low-voltage (120 to 600 V) power distribution and control equipment.
- B. Related Requirements:
 - 1. Section 16426 - "METAL-ENCLOSED DRAWOUT SWITCHGEAR" for factory-installed SPDs.

1.3 DEFINITIONS

- A. I Nominal: Nominal discharge current.
- B. MCOV: Maximum continuous operating voltage.
- C. Mode(s), also Modes of Protection: The pair of electrical connections where the VPR applies.
- D. MOV: Metal-oxide varistor; an electronic component with a significant non-ohmic current-voltage characteristic.
- E. OCPD: Overcurrent protective device.
- F. SCCR: Short-circuit current rating.
- G. SPD: Surge protective device.
- H. VPR: Voltage protection rating.

1.4 SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

2. Copy of UL Category Code VZCA certification, as a minimum, listing the tested values for VPRs, I Nominal ratings, MCOVs, type designations, OCPD requirements, model numbers, system voltages, and modes of protection.

1.5 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For SPDs to include in maintenance manuals.

1.6 WARRANTY

- A. Manufacturer's Warranty: Manufacturer agrees to replace or replace SPDs that fail in materials or workmanship within manufacturer's standard warranty period.

PART 2 - PRODUCTS

2.1 GENERAL SPD REQUIREMENTS

- A. SPD with Accessories: Listed and labeled as by UL, by a qualified testing agency, and marked for intended location and application.
- B. Comply with MEC.
- C. Comply with UL 1449.
- D. MCOV of the SPD shall be the nominal system voltage.

2.2 SERVICE ENTRANCE SUPPRESSOR

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. Eaton Corporation.
 2. Surge Suppression Inc.
 3. Schneider Electric Industries.
 4. Siemens Industry, Inc.
- B. SPDs: Comply with UL 1449 3rd Edition, Type 1.
- C. SPDs: Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 1449 3rd Edition, Type 1.
 1. SPDs with the following features and accessories:
 - a. Integral disconnect switch.
 - b. Internal thermal protection that disconnects the SPD before damaging internal suppressor components.
 - c. Indicator light display for protection status.
 - d. Form-C contacts rated at 2 A and 24-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge

diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.

- e. Surge counter.
- D. Comply with UL 1283.
- E. Peak Surge Current Rating: The minimum single-pulse surge current withstand rating per phase shall not be less than 240 kA. The peak surge current rating shall be the arithmetic sum of the ratings of the individual MOVs in a given mode.
- F. Protection modes and UL 1449 VPR for grounded wye circuits with 480Y/277 V, three-phase, four-wire circuits shall not exceed the following:
 - 1. Line to Neutral: 1200 V for 480Y/277 V.
 - 2. Line to Ground: 1200 V for 480Y/277 V.
 - 3. Line to Line: 2000 V for 480Y/277 V.
- G. SCCR: Equal or exceed 100 kA.
- H. I Nominal Rating: 20 kA.

2.3 ENCLOSURES

- A. Indoor Enclosures: NEMA 1.
- B. Outdoor Enclosures: NEMA Type 4X stainless steel.

2.4 CONDUCTORS AND CABLES

- A. Power Wiring: Same size as SPD leads, complying with Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
- B. Class 2 Control Cables: Multiconductor cable with copper conductors not smaller than No. 18 AWG, complying with Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
- C. Class 1 Control Cables: Multiconductor cable with copper conductors not smaller than No. 14 AWG, complying with Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Comply with NECA 1.
- B. Install an OCPD or disconnect as required to comply with the UL listing of the SPD.

- C. Install SPDs with conductors between suppressor and points of attachment as short and straight as possible, and adjust circuit-breaker positions to achieve shortest and straightest leads. Do not splice and extend SPD leads unless specifically permitted by manufacturer. Do not exceed manufacturer's recommended lead length. Do not bond neutral and ground.
- D. Use crimped connectors and splices only. Wire nuts are unacceptable.
- E. Wiring:
 - 1. Power Wiring: Comply with wiring methods in Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL INSULATIONS."
 - 2. Controls: Comply with wiring methods in Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL INSULATIONS."

3.2 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections with the assistance of a factory-authorized service representative.
 - 1. Compare equipment nameplate data for compliance with Drawings and Specifications.
 - 2. Inspect anchorage, alignment, grounding, and clearances.
 - 3. Verify that electrical wiring installation complies with manufacturer's written installation requirements.
- B. An SPD will be considered defective if it does not pass tests and inspections.
- C. Prepare test and inspection reports.

3.3 STARTUP SERVICE

- A. Complete startup checks according to manufacturer's written instructions.
- B. Do not perform insulation-resistance tests of the distribution wiring equipment with SPDs installed. Disconnect SPDs before conducting insulation-resistance tests, and reconnect them immediately after the testing is over.
- C. Energize SPDs after power system has been energized, stabilized, and tested.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to operate and maintain SPDs.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”.

END OF SECTION

SECTION 16342

MEDIUM-VOLTAGE LOAD INTERRUPTER SWITCHGEAR

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. This Section includes metal-enclosed interrupter switchgear with the following optional components, features, and accessories:
 - 1. Copper, tin-plated main bus.
 - 2. Communication modules.
 - 3. Analog instruments.
 - 4. Relays.
 - 5. Surge arresters.
 - 6. Provisions for future devices.
 - 7. Fungus proofing.
 - 8. Control battery system.
 - 9. Mimic bus.

1.3 DEFINITIONS

- A. ATS: Acceptance Testing Specifications.
- B. GFCI: Ground-Fault Circuit Interrupter.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of switchgear and related equipment, include the following:
 - 1. Rated capacities, operating characteristics, furnished specialties, and accessories for individual interrupter switches.
 - 2. Time-current characteristic curves for overcurrent protective devices, including fusible devices.
- B. Shop Drawings: For each type of switchgear and related equipment, include the following:
 - 1. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show method of field assembly and location and size of each field connection. Include the following:
 - a. Tabulation of installed devices with features and ratings.
 - b. Outline and general arrangement drawing showing dimensions, shipping sections, and weights of each assembled section.
 - c. Drawing of cable termination compartments showing preferred locations for conduits and indicating space available for cable terminations.
 - d. Floor plan drawing showing locations for anchor bolts.
 - e. Current ratings of buses.

- f. Short-time and short-circuit ratings of switchgear assembly.
 - g. Nameplate legends.
 - h. Mimic-bus diagram.
 - i. Utility company's metering provisions with indication of approval by utility company.
- 2. Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting seismic restraints.
 - 3. Wiring Diagrams: For each type of switchgear and related equipment, include the following:
 - a. Power, signal, and control wiring.
 - b. Three-line diagrams of current and future secondary circuits showing device terminal numbers and internal diagrams.
 - c. Schematic control diagrams.
 - d. Diagrams showing connections of component devices and equipment.
 - e. Schematic diagrams showing connections to remote devices including SCADA remote terminal unit.
- C. Samples: Representative portion of mimic bus with specified finish. Manufacturer's color charts showing colors available for mimic bus.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around switchgear where piping and ducts are prohibited. Show switchgear layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Identify field measurements.
- B. Manufacturer Seismic Qualification Certification: Submit certification that switchgear, accessories, and components will withstand seismic forces defined in Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Qualification Data: For testing agency.
- D. Source quality-control test reports.
- E. Field quality-control test reports.
- F. Operation and Maintenance Data: For switchgear and switchgear components to include in emergency, operation, and maintenance manuals. Include the following:

1. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
2. Time-current curves, including selectable ranges for each type of overcurrent protective device.

1.6 QUALITY ASSURANCE

- A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the International Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
 1. Testing Agency's Field Supervisor: Person currently certified by the International Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.
- B. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7.
- C. Source Limitations: Obtain each type of switchgear and associated components through one source from a single manufacturer.
- D. Product Options: Drawings indicate size, profiles, and dimensional requirements of switchgear and are based on the specific system indicated.
- E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
- F. Comply with IEEE C2.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Deliver in sections of lengths that can be moved past obstructions in delivery path as indicated.
- B. Store switchgear indoors in clean dry space with uniform temperature to prevent condensation. Protect switchgear from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- C. If stored in areas subjected to weather, cover switchgear to provide protection from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside switchgear; install electric heating (250 W per section) to prevent condensation.

1.8 PROJECT CONDITIONS

- A. Environmental Limitations: Rate equipment for continuous operation at indicated ampere ratings for the following conditions:

1. Ambient temperature not exceeding 122 deg F.
 2. Altitude of above sea level.
- B. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.
- C. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear and adjacent surfaces and other items. Comply with indicated maximum dimensions.
- D. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by MBTA or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
1. Notify MBTA no fewer than ten days in advance of proposed interruption of electrical service.
 2. Do not proceed with interruption of electrical service without MBTA's written permission.

1.9 COORDINATION

- A. Coordinate layout and installation of switchgear and components with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required clearances for workspace and equipment access doors and panels.
- B. Coordinate size and location of concrete bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

1.10 EXTRA MATERIALS

- A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fuses: Six of each type and rating used. Include spares for future transformers, control power circuits, and fusible devices.
 2. Indicating Lights: Six of each type installed.
- B. Maintenance Tools: Furnish tools and miscellaneous items required for interrupter switchgear test, inspection, maintenance, and operation. Include the following:
1. Fuse-handling tool.
 2. Extension rails, lifting device, transport or dockable dolly or mobile lift, and all other items necessary to remove circuit breaker from housing and transport to remote location.
 3. Racking handle to move circuit breaker manually between connected and disconnected positions, and a secondary test coupler to permit testing of circuit breaker without removal from switchgear.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.
 - a. S&C
 - b. Eaton Corporation; Electrical Sector
 - c. Siemens Energy, Inc.
 - d. Square D; a brand of Schneider Electric.

2.2 MANUFACTURED UNITS

- A. Description: Factory assembled and tested, and complying with IEEE C37.20.1.
- B. Ratings: Suitable for application in 3-phase, 60-Hz, solidly grounded-neutral system.
- C. System Voltage: 13.8 kV nominal; 15 kV maximum.

2.3 METAL-ENCLOSED INTERRUPTER SWITCHGEAR

- A. Comply with IEEE C37.20.3.
- B. Design Level of Available-Source Fault Current: Integrated short-circuit rating consistent with value of fault current indicated.
- C. Ratings: Comply with standard ratings designated in IEEE C37.20.3 for maximum-rated voltage specified.
 1. Main-Bus Rating: 1200 A, continuous.
- D. Interrupter Switches: Stationary, gang operated, and suitable for application at maximum short-circuit rating of integrated switchgear assembly.
 1. Rating: 1200-A continuous duty and load break.
 2. Duty-Cycle, Fault Closing: 40,000 asymmetrical A.
 3. Switch Action: No external arc and no significant quantities of ionized gas released into the enclosure.
 4. Switch Construction: Supported entirely by interior framework of structure, with copper switchblades and stored-energy operating mechanism.
 5. Phase Barriers: Full length of switchblades and fuses for each pole; designed for easy removal; allow visual inspection of switch components if barrier is in place.
 6. Protective Shields: Cover live components and terminals.
 7. Fuses: De-energized if switch is open.
- E. Mechanical Interlock: Prevent opening switch compartment door unless switchblades are open, and prevent closing switch if door is open.
- F. Window: Permit viewing switchblade positions if door is closed.
- G. Power Fuses: Comply with the following and with applicable requirements in NEMA SG 2:

1. Indicator: Integral with each fuse to indicate when it has blown.
2. Mounting: Positively held in position with provision for easy removal and replacement from front without special tools.
3. Current-Limiting Fuses: Full-range, fast-replaceable, current-limiting type that will operate without explosive noise or expulsion of gas, vapor, or foreign matter from tube.

2.4 FABRICATION

- A. Outdoor Enclosure: Galvanized steel, weatherproof construction; integral structural-steel base frame with factory-applied asphaltic undercoating.
 1. Each compartment shall have the following features:
 - a. Structural design and anchorage adequate to resist loads imposed by 125-mph wind.
 - b. Space heater operating at one-half or less of rated voltage, sized to prevent condensation.
 - c. Louvers equipped with insect and rodent screen and filter, and arranged to permit air circulation while excluding rodents and exterior dust.
 - d. Hinged front door with locking provisions.
 - e. Power for heaters, lights, and receptacles to be provided by control power transformer.
 2. Weatherproof internal aisle construction shall have the following features:
 - a. Common internal aisle of sufficient width to permit protective-device withdrawal, disassembly, and servicing in aisle.
 - b. Aisle access doors at each end with exterior locking provisions and interior panic latches.
 - c. Aisle space heaters operating at one-half or less of rated voltage, thermostatically controlled.
 - d. Aisle ventilation louvers equipped with insect and rodent screen and filter, and arranged to permit air circulation while excluding rodents and exterior dust.
- B. Finish: Manufacturer's standard gray finish over rust-inhibiting primer on phosphatizing-treated metal surfaces.
- C. Bus Transition Unit: Arranged to suit bus and adjacent units.
- D. Incoming-Line Unit: Arranged to suit incoming line.
- E. Outgoing Feeder Units: Arranged to suit distribution feeders.
- F. Auxiliary Compartments: Arranged to suit house meters, relays, controls, and auxiliary equipment; isolated from medium-voltage components.
- G. Key Interlocks: Arranged to effect interlocking schemes indicated.
- H. Provisions for Future Key Interlocks: Mountings and hardware required for future installation of locks, where indicated.

2.5 COMPONENTS

- A. Main Bus: Copper, tin plated; full length of switchgear.

- B. Ground Bus: Copper, silver plated or copper, tin plated; minimum size 1/4 by 2 inches; full length of switchgear.
- C. Bus Insulation: Covered with flame-retardant insulation.
- D. Instrument Transformers: Comply with IEEE C57.13.
 - 1. Potential Transformers: Secondary voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.
 - 2. Current Transformers: Burden and accuracy class suitable for connected relays, meters, and instruments.
- E. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems, listed and labeled by an NRTL, and with the following features:
 - 1. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 - 2. Switch-selectable digital display with the following features:
 - a. Phase Currents, Each Phase: Plus or minus 1 %.
 - b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 %.
 - c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 %.
 - d. Three-Phase Real Power: Plus or minus 2 %.
 - e. Three-Phase Reactive Power: Plus or minus 2 %.
 - f. Power Factor: Plus or minus 2 %.
 - g. Frequency: Plus or minus 0.5 %.
 - h. Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 %.
 - i. Accumulated energy, in megawatt hours, plus or minus 2 %; stored values unaffected by power outages for up to 72 hours.
 - 3. Mounting: Display and control unit that is flush or semiflush mounted in instrument compartment door.
- F. Surge Arresters: Distribution class, metal-oxide-varistor type. Comply with NEMA LA 1.
 - 1. Install in cable termination compartments in each phase of circuit.
 - 2. Coordinate rating with circuit voltage.
- G. Fungus Proofing: Permanent fungicidal treatment for switchgear interior, including instruments and instrument transformers.
- H. Control Power Supply: DC battery system.
- I. Control Power Supply: Control power transformer supplies 120-V control circuits through secondary disconnect devices. Include the following features:
 - 1. Dry-type transformers, in separate compartments for units larger than 3 kVA, including primary and secondary fuses.
 - 2. Control Power Fuses: Primary and secondary fuses provide current-limiting and overload protection.

- J. Control Wiring: Factory installed, complete with bundling, lacing, and protection; and complying with the following:
 - 1. Conductors sized according to NFPA 70 for duty required.

2.6 IDENTIFICATION

- A. Materials: Refer to Section 16195 "ELECTRICAL IDENTIFICATION." Identify units, devices, controls, and wiring.
- B. Mimic Bus: Continuous mimic bus applied to front of switchgear, arranged in single-line diagram format, using symbols and lettered designations consistent with approved final mimic-bus diagram.
 - 1. Mimic-bus segments coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
 - 2. Medium: Painted graphics, as approved.
 - 3. Color: Contrasting with factory-finish background; selected by Architect.

2.7 SOURCE QUALITY CONTROL

- A. Before shipment of equipment, perform the following tests and prepare test reports:
 - 1. Production tests on completed switchgear assembly according to IEEE C37.20.2.
- B. Assemble switchgear and equipment in manufacturer's plant and perform the following:
 - 1. Functional tests of all relays, instruments, meters, and control devices by application of secondary three-phase voltage to voltage circuits and injection of current in current transformer secondary circuits.
- C. Prepare equipment for shipment.
 - 1. Provide suitable crating, blocking, and supports so equipment will withstand expected domestic shipping and handling shocks and vibration.
 - 2. Weatherproof equipment for shipment. Close connection openings to prevent entrance of foreign material during shipment and storage.

2.8 FACTORY FINISHES

- A. Finish: Manufacturer's standard color finish applied to equipment before shipping.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine elements and surfaces to receive switchgear for compliance with requirements for installation tolerances, required clearances, and other conditions affecting performance.

1. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Anchor switchgear assembly to 4-inch, channel-iron sill embedded in concrete base and attach by bolting.
 1. Sills: Select to suit switchgear; level and grout flush into concrete base.
 2. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS" for seismic-restraint requirements.
 3. Concrete Bases: 4 inches high or as indicated on the Contract Drawings, reinforced, with chamfered edges. Extend base no less than 3 inches in all directions beyond the maximum dimensions of switchgear, unless otherwise indicated or unless required for seismic anchor support.
- B. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from switchgear units and components.

3.3 IDENTIFICATION

- A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Section 16195 "ELECTRICAL IDENTIFICATION."
- B. Diagram and Instructions:
 1. Frame under clear acrylic plastic on front of switchgear.
 - a. Operating Instructions: Printed basic instructions for switchgear, including control and key-interlock sequences and emergency procedures.
 - b. System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads.
 2. Storage for Maintenance: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

3.4 CONNECTIONS

- A. Cable terminations at switchgear are specified in Section 16120 "MEDIUM VOLTAGE POWER CABLE FOR THE TRACTION POWER SYSTEM."
- B. Tighten bus joints, electrical connectors, and terminals according to manufacturer's published torque-tightening values.
- C. Ground equipment according to Section 16060 "GROUNDING AND BONDING."
- D. Connect wiring according to Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK" and 16120 "MEDIUM VOLTAGE POWER CABLE FOR THE TRACTION POWER SYSTEM."

3.5 FIELD QUALITY CONTROL

- A. Prepare for acceptance tests as follows:
 - 1. Test insulation resistance for each switchgear bus, component, connecting supply, feeder, and control circuit.
 - 2. Test continuity of each circuit.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to perform the following:
 - 1. Assist in field testing of equipment.
 - 2. Report results in writing.
- C. Testing Agency: Engage a qualified independent testing and inspecting agency to perform field tests and inspections and prepare test reports.
- D. Perform the following field tests and inspections and prepare test reports:
 - 1. Perform each electrical test and visual and mechanical inspection stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for each of the following NETA categories:
 - a. Switchgear.
 - b. Circuit breakers.
 - c. Protective relays.
 - d. Instrument transformers.
 - e. Metering and instrumentation.
 - f. Ground-fault systems.
 - g. Battery systems.
 - h. Surge arresters.
 - i. Capacitors.
- E. Remove and replace malfunctioning units and retest as specified above.
- F. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform infrared scan of each switchgear. Remove front and rear panels so joints and connections are accessible to portable scanner.
 - 1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchgear 11 months after date of Substantial Completion.
 - 2. Instrument: Use an infrared-scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
 - 3. Record of Infrared Scanning: Prepare a certified report that identifies switchgear checked and that describes infrared-scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.6 ADJUSTING

- A. Set field-adjustable, protective-relay trip characteristics according to results in Section 16055 "OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY."

3.7 CLEANING

- A. On completion of installation, inspect interior and exterior of switchgear. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair damaged finishes.

3.8 PROTECTION

- A. Temporary Heating: Apply temporary heat to switchgear, according to manufacturer's written instructions, throughout periods when switchgear environment is not controlled for temperature and humidity within manufacturer's stipulated service conditions.

3.9 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain switchgear.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16362

SECONDARY UNIT SUBSTATIONS WITH SWITCHGEAR

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes secondary unit substations, each consisting of medium-voltage primary incoming section, transformer section, and low-voltage secondary switchgear section, with the following features:
 - 1. Outdoor enclosure.
 - 2. Medium-voltage, metal-clad switchgear section.
 - 3. Liquid-filled or Dry-type transformer.
- B. Related Requirements:
 - 1. Section 16120 "MEDIUM-VOLTAGE CABLES FOR THE TRACTION POWER SYSTEM" for requirements for terminating cables in incoming section of substation.

1.3 DEFINITIONS

- A. BIL: Basic insulation level.
- B. MCC: Motor-control center.
- C. MVA: Megavolt ampere.
- D. NETA ATS: Acceptance testing specification.
- E. NiCd: Nickel cadmium.
- F. PCB: Polychlorinated biphenyl.
- G. RTD: Resistance temperature device.
- H. SCR: Silicon-controlled rectifier.
- I. SPD: Surge protective device.
- J. VRLA: Valve-regulated lead acid.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include rated capacities, operating characteristics, and furnished specialties and accessories.
- B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 - 1. Wiring Diagrams: Power, signal, and control wiring.
 - 2. Dimensioned plans and elevations showing major components and features.
 - a. Include a plan view and cross section of equipment base, showing clearances, manufacturer's recommended workspace that accounts for breaker service and removal, and locations of penetrations for grounding and conduits.
 - 3. One-line diagram.
 - 4. List of materials.
 - 5. Nameplate legends.
 - 6. The material, size and number of bus bars, and current rating for each bus, including mains and branches of phase, neutral, and ground buses.
 - 7. Short-time and short-circuit current ratings of secondary unit substations and components.
 - 8. Ratings of individual protective devices.
 - 9. Mimic-bus diagram.
- C. Time-Current Characteristic Curves: For overcurrent protective devices.
- D. Primary Fuses: Submit recommendations and size calculations.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings for Outdoor Installations:
 - 1. Utilities site plan, drawn to scale, showing heavy equipment or truck access paths for maintenance and replacement.
- B. Qualification Data: For testing agency.
- C. Seismic Qualification Certificates: For transformer assembly, accessories, and components, from manufacturer.
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity, and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- D. Product Certificates: For secondary unit substations, signed by product manufacturer.
- E. Factory test reports.

- F. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For secondary unit substations and accessories to include in emergency, operation, and maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Spare Fuses: Six of each type and rating of fuse and fusible device used, except for medium-voltage fuses. Include spares for the following:
 - a. Primary disconnect fuses.
 - b. Potential transformer fuses.
 - c. Control power fuses.
 - d. Fuses and fusible devices for fused circuit breakers.
 - e. Fuses for secondary fusible devices.
 - 2. Spare Indicating Lights: Six of each type installed.
 - 3. Touchup Paint: Three half-pint containers of paint matching enclosure's exterior finish.
 - 4. Primary Switch Contact Lubricant: One container(s).
 - 5. One set(s) of spare mounting gaskets for bushings, handholes, and the gasket between relief cover and flange of pressure-relief device.

1.8 QUALITY ASSURANCE

- A. Testing Agency Qualifications: Member company of NETA or an NRTL.
 - 1. Testing Agency's Field Supervisor: Certified by NETA or the National Institute for Certification in Engineering Technologies to supervise on-site testing.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver in shipping splits in sizes that can be moved past obstructions in delivery path.
- B. Coordinate delivery of secondary unit substations to allow movement into designated space.
- C. Store secondary unit substation components protected from weather and so condensation does not form on or in units. Provide temporary heating per manufacturer's written instructions.
- D. Handle secondary unit substation components per manufacturer's written instructions. Use factory-installed lifting provisions.

1.10 FIELD CONDITIONS

- A. Service Conditions: The unit substation shall be suitable for operation under service conditions specified as usual service conditions in IEEE C37.121, except for the following:
1. Exposure to significant solar radiation.
 2. Altitudes above 3300 ft.
 3. Exposure to fumes, vapors, or dust.
 4. Exposure to explosive environments.
 5. Exposure to hot and humid climate or to excessive moisture, including steam, salt spray, and dripping water.
 6. Exposure to seismic shock or to abnormal vibration, shock, or tilting.
 7. Exposure to excessively high or low temperatures.
 8. Unusual transportation or storage conditions.
 9. Unusual grounding resistance conditions.
 10. Unusual space limitations.

1.11 WARRANTY

- A. Manufacturer's Special Warranty: Manufacturer agrees to repair or replace components of the dc system battery equipment that fail(s) in materials or workmanship within specified warranty period. Special warranty, applying to batteries only, applies to materials only, on a prorated basis, for period specified.
1. Warranty Period: Include the following warranty periods, from date of Substantial Completion:
 - a. DC System Equipment (excluding Batteries): Two year(s).
 - b. Standard VRLA Batteries:
 1. Full Warranty: One year(s).
 2. Pro Rata: Nine years.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Eaton Corporation; Electrical Sector.
 2. Siemens Energy, Inc.
 3. Square D; a brand of Schneider Electric.

2.2 SYSTEM DESCRIPTION

- A. Description: Medium-voltage, primary incoming section; transformer section; and low-voltage secondary switchgear section; and including coordinated circuit breakers, fusible switches, and metering components.
 - 1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
 - 2. Comply with IEEE C2.
 - 3. Comply with IEEE C37.121.
 - 4. Comply with NFPA 70.

2.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: The secondary unit substations shall withstand the effects of earthquake motions determined per ASCE/SEI 7.
 - 1. The term "withstand" means "the secondary unit substation will remain in place without separation of any parts when subjected to the seismic forces specified."
 - 2. Component Importance Factor Component Amplification Factor and Component Response Modification Factor: Refer to Structural Drawings.

2.4 MANUFACTURED UNITS

- A. Outdoor Unit Arrangement: Single assembly.
 - 1. Weatherproof, listed for installation outdoors, complying with IEEE C37.20.1.
 - 2. Aisle-less Construction: Full-height doors in front of basic weatherproof equipment.
- B. Connections between the primary device and transformer shall be bus, and between the transformer and secondary shall be flexible bus braid unless noted otherwise.
- C. Outdoor Enclosure: Weatherproof, aisle-less construction for outdoor service. Galvanized-steel, weatherproof construction; integral structural-steel base frame with factory-applied asphaltic undercoating.
 - 1. Enclosure: Downward, rearward sloping roof; rear hinged doors for each section, with provisions for padlocking.
 - 2. Each compartment shall have the following features:
 - a. Structural design and anchorage adequate to resist loads imposed by 125-mph wind.
 - b. Space heater operating at one-half or less of rated voltage, sized to prevent condensation, controlled by thermostats to maintain temperature of each section above expected dew point.
 - c. Louvers equipped with insect and rodent screens and filters, and arranged to permit air circulation while excluding rodents and exterior dust.
 - d. Weatherproof ground-fault circuit interrupter (GFCI) duplex receptacle.
 - e. Power for heaters, lights, and receptacles shall be provided by control power transformer.

- D. Skid Mounted: Mount each shipping group on an integral base frame as a complete weatherproof unit.
- E. Unit Substation Enclosures Finish: Factory-applied finish in manufacturer's standard color, including under surfaces treated with corrosion-resistant undercoating.

2.5 MEDIUM-VOLTAGE TERMINAL COMPARTMENT SECTION

- A. Primary Incoming Section: Terminal assembly with adequate space for incoming-cable terminations and surge arresters, complying with NEMA SG 4 and meeting thermal, mechanical, and dielectric requirements specified for the transformer section.
- B. Ratings: Suitable for application in three-phase, 60-Hz, solidly grounded-neutral system.
- C. System Voltage: 13.8 kV nominal; 15 kV maximum.
- D. Surge Arresters: Comply with IEEE C62.11, Distribution Class; metal-oxide-varistor type, connected in each phase of incoming circuit and ahead of any disconnecting device.

2.6 MEDIUM-VOLTAGE METAL-CLAD SWITCHGEAR SECTION

- A. Metal-clad, circuit-breaker switchgear, complying with IEEE C37.20.3.
 - 1. Switchgear shall be arc resistant: complying with IEEE C37.20.7, Type 2.
- B. Ratings shall comply with IEEE C37.04, suitable for application in three-phase, 60-Hz, solidly grounded-neutral system.
 - 1. System Voltage: 13.8 kV nominal; 15 kV maximum.
 - 2. Design Level of Available-Source Fault Current: Integrated short-circuit rating consistent with value of fault current indicated.
 - 3. Main-Bus Rating: 600 A, continuous.
- C. Interrupter Switches: Stationary, gang operated, and suitable for application at maximum short-circuit rating of integrated switchgear assembly.
 - 1. Rating: 600-A continuous duty and load break.
 - 2. Two-Time Duty-Cycle Fault Closing: 40,000 asymmetrical amperes.
 - 3. Switch Action: No external arc and no significant quantities of ionized gas released into the enclosure.
 - 4. Switch Construction: Supported entirely by interior framework of structure, with copper switchblades and stored-energy operating mechanism.
 - 5. Phase Barriers: Full length of switchblades and fuses for each pole; designed for easy removal; allow visual inspection of switch components if barrier is in place.
 - 6. Protective Shields: Cover live components and terminals.

- a. Fuse Mounts: Single-frame mounted and de-energized when switch is open.
- 7. Mechanical Interlock: Prevent opening of switch compartment door unless switchblades are open, and prevent closing switch if door is open. Interlock air-interrupter switch with transformer secondary main circuit breaker, preventing switch from being opened or closed unless secondary main circuit breaker is open.
- 8. Window: Permits viewing switchblade positions when door is closed.
- 9. Accessory Set: Tools and miscellaneous items required for interrupter switchgear test, inspection, maintenance, and operation. Include fuse-handling tool as recommended by switchgear manufacturer.
- D. Fuses: Sizes recommended by secondary unit substation manufacturer, considering fan cooling, temperature-rise specification, and cycle loading.
 - 1. Current-Limiting Fuses: Full-range, fast-replaceable, current-limiting type that will operate without explosive noise or expulsion of gas, vapor, or foreign matter from tube.
 - 2. Indicator integral with each fuse to show when it has blown.
 - 3. Spares: Include three fuses in use and three spare fuses in storage clips in each switch.
- E. Surge Arresters: Comply with IEEE C62.11, Distribution Class; metal-oxide-varistor type, with ratings as indicated, connected in each phase of incoming circuit and ahead of any disconnecting device.

2.7 MEDIUM-VOLTAGE INSTRUMENTS SECTION

- A. Instrument Transformers: Comply with IEEE C57.13.
 - 1. Potential Transformers: Secondary voltage rating of 120 V and NEMA C 12.11 Accuracy Class of 0.3 with burdens of W, X, and Y.
 - 2. Current Transformers: Burden and Accuracy Class suitable for connected relays, meters, and instruments.
- B. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems.
 - 1. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 - 2. Switch-selectable digital display with the following features:
 - a. Phase Currents, Each Phase: Plus or minus 1 %.
 - b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 %.
 - c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 %.
 - d. Three-Phase Real Power: Plus or minus 2 %.
 - e. Three-Phase Reactive Power: Plus or minus 2 %.
 - f. Power Factor: Plus or minus 2 %.
 - g. Frequency: Plus or minus 0.5 %.

- h. Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 %.
 - 3. Mounting: Display and control unit that is flush or semiflush mounted in instrument compartment door.
- C. Control Power Supply: Control power transformer supplies 120-V control circuits through secondary disconnect devices.
 - 1. Dry-type transformers, in separate compartments for units larger than 3 kVA, including primary and secondary fuses.
 - a. Secondary windings connected through an internal automatic transfer switch to switchgear control power bus.
 - 2. Control Power Fuses: Primary and secondary fuses provide current-limiting and overload protection.

2.8 LIQUID-FILLED TRANSFORMER SECTION

- A. Description: IEEE C57.12.00 and UL 1062, liquid-filled, two-winding, secondary unit substation transformer.
- B. Insulating Liquid: Less flammable, edible-seed-oil based, and listed and labeled by an NRTL as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested per ASTM D 92. Liquid shall be biodegradable and nontoxic.
- C. Insulation Temperature Rise: 55 deg C, based on an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C. Insulation system shall be rated to continuously allow an additional 12 % kVA output, at 65 deg C temperature rise, without decreasing rated transformer life.
- D. BIL: 60 kV.
- E. Full-Capacity Voltage Taps: Four nominal 2.5 % taps, two above and two below rated primary voltage; with externally operable tap changer for de-energized use and with position indicator and padlock hasp.
- F. Cooling System: Class ONAN, liquid cooled. Cooling systems shall include auxiliary cooling equipment, automatic controls, and status indicating lights.
- G. Impedance: 5.75%.
- H. Accessories: Grounding pads, lifting lugs, and provisions for jacking under base. Transformers shall have a steel base and frame allowing use of pipe rollers in any direction, and an insulated, low-voltage, neutral bushing with removable ground strap. Include the following additional accessories:
 - 1. Liquid-level gage.
 - 2. Pressure-vacuum gage.
 - 3. Liquid temperature indicator.
 - 4. Drain and filter valves.

5. Pressure-relief device.

2.9 DRY-TYPE TRANSFORMER SECTION

- A. Description: IEEE C57.12.01, IEEE C57.12.50, and dry-type, two-winding, secondary unit substation transformer.
- B. Style: Outdoor, ventilated, vacuum-pressure, impregnated type, and with insulation system rated at 220 deg C with an 80deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.
- C. Cooling System: Class AA, air cooled, complying with IEEE C57.12.01.
- D. Insulation Materials: IEEE C57.12.01, rated 220 deg C.
 1. Insulation Temperature Rise: 80 deg C, maximum rise above 40 deg C.
- E. BIL: 60 kV.
- F. Full-Capacity Voltage Taps: Four nominal 2.5 % taps, two above and two below rated primary voltage.
- G. Full-Capacity Voltage Taps: Four nominal 2.5 % taps below rated primary voltage.
- H. Impedance: 5.75%.
- I. High-Temperature Alarm: Sensor at transformer with local audible and visual alarm and contacts for remote alarm.

2.10 SECONDARY DISTRIBUTION SECTION TERMINAL COMPARTMENT

- A. Low-Voltage Terminal Compartment: Bus duct flange for close coupling with busway.

2.11 SECONDARY DISTRIBUTION SECTION SWITCHGEAR

- A. The secondary distribution section shall be drawout, fused where indicated, low-voltage switchgear, complying with IEEE C37.20.1 and UL 1558.
- B. Switchgear Structure:
 1. Match and align the front and back of the switchgear.
 2. Isolate line bus from load bus at each main and tie circuit breaker with bus isolation barriers.
 3. Allow the following circuit-breaker functions to be performed when the compartment door is closed:
 - a. Operate manual charging system.
 - b. Open and close the circuit breaker.
 - c. Examine and adjust the trip unit.
 - d. Read the breaker nameplate.

4. Locate instrumentation transformers within the breaker cell, and make front accessible and removable.

C. Switchgear Bus:

1. Use bus bars to connect compartments and vertical sections. Cable connections are not permitted.
2. Main Phase Bus: Uniform capacity the entire length of section.
3. Neutral Bus: 100 % of phase-bus ampacity, except as indicated. Equip bus with pressure-connector terminations for outgoing circuit neutral conductors. Include braces for neutral-bus extensions for busway feeders.
4. Vertical Section Bus Size: Comply with IEEE C37.20.1, including allowance for spare circuit breakers and spaces for future circuit breakers.
5. Phase- and Neutral-Bus Material: Hard-drawn copper of 98 % minimum conductivity, with copper feeder circuit-breaker line connections.
6. Use silver-plated copper or tin-plated aluminum for connecting circuit-breaker line to aluminum bus.
7. Feeder Circuit-Breaker Load Terminals: Silver-plated copper bus extensions equipped with pressure connectors for outgoing circuit conductors.
8. Ground Bus: Hard-drawn copper of 98 % minimum conductivity, with pressure connector for feeder and branch-circuit ground conductors, minimum size 1/4-by-2 inches.
9. Neutral bus equipped with pressure-connector terminations for outgoing circuit neutral conductors. Neutral-bus extensions for busway feeders are braced.
10. Provide for future extensions from either end of main phase, neutral, and ground bus by means of predrilled bolt-holes and connecting links.

D. Circuit-Breaker Compartment:

1. Drawout Features: Circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in "connected," "test," and "disconnected" positions. Include the following features:
 - a. Interlocks: Prevent movement of circuit breaker to or from "connected" position when it is closed, and prevent closure of circuit breaker unless it is in "connected," "test," or "disconnected" position.
 - b. Circuit-Breaker Positioning: Permit the racking of an open circuit breaker to or from "connected," "test," and "disconnected" positions only when the compartment door is closed unless live parts are covered by a full dead-front shield. Permit the manual withdrawal of an open circuit breaker to a position for removal from the structure. When the compartment door is open, status for connection devices for different positions includes the following:

1. Test Position: Primary disconnects disengaged, and secondary disconnect devices and ground contact engaged.
 2. Disconnected Position: Primary and secondary devices and ground contact disengaged.
2. Primary Disconnect: Mount on the stationary part of the compartment. The disconnect shall consist of a set of contacts extending to the rear through an insulating support barrier, and of corresponding moving finger contacts on the power circuit-breaker studs, which engage in only the "connected" position. The assembly shall provide multiple silver-to-silver full floating, spring-loaded, high-pressure-point contacts with uniform pressure on each finger. Load studs shall connect to bus extensions that terminate in solderless terminals in the rear cable compartment.
 3. Secondary Disconnect: Floating terminals mounted on the stationary part of the compartment that engage mating contacts at the front of the breaker. Disconnecting devices shall be gold plated, and engagement shall be maintained in the "connected" and "test" positions.
- E. Circuit Breakers:
1. Comply with IEEE C37.13 and UL 1066.
 2. Ratings: For continuous, interrupting, and short-time current ratings for each circuit breaker; voltage and frequency ratings same as switchgear.
 3. Operating Mechanism: Mechanically and electrically trip-free, stored-energy operating mechanism with the following features:
 - a. Normal Closing Speed: Independent of both control and operator.
 - b. Slow Closing Speed: Optional with operator for inspection and adjustment.
 - c. Stored-Energy Mechanism: Electrically charged.
 1. Operating Handle: One for each circuit breaker capable of manual operation.
 2. Electric Close Button: One for each electrically operated circuit breaker.
 - d. Operation counter.
 4. Trip Devices: Solid-state, overcurrent trip-device system consisting of one or two current transformers or sensors per phase, a release mechanism, and the following features:
 - a. Functions: Long-time-delay, short-time-delay, and instantaneous-trip functions, independent of each other in both action and adjustment.
 - b. Temperature compensation that ensures accuracy and calibration stability from minus 5 to plus 40 deg C.
 - c. Field-adjustable, time-current characteristics.
 - d. Current Adjustability: Dial settings and rating plugs on trip units, or sensors on circuit breakers, or a combination of these methods.
 - e. Three bands, minimum, for long-time- and short-time-delay functions; marked "minimum," "intermediate," and "maximum."
 - f. Pickup Points:
 1. Five minimum, for long-time- and short-time-trip functions. Equip short-time-trip function for switchable I-squared-t operation.

- 2. Five minimum, for instantaneous-trip functions.
- 5. Trip Indication: Labeled, battery-powered lights or mechanical targets on trip device to indicate type of fault.
- 6. Auxiliary Contacts:
 - a. Contacts and switches required for normal circuit-breaker operation, sufficient for interlocking and remote indication of circuit-breaker position.
 - b. Spare auxiliary switches, at least two, unless other quantity is indicated. Each switch shall consist of two Type A and two Type B contacts wired through secondary disconnect devices to a terminal block in stationary circuit-breaker compartment.
- 7. Arc Chutes: Readily removable from associated circuit breaker when it is in "disconnected" position, and arranged to permit inspection of contacts without removing circuit breaker from switchgear.
- 8. Padlocking Provisions: For installing at least three padlocks on each circuit breaker to secure its enclosure and prevent movement of drawout mechanism.
- F. Key Interlocks: Arranged to prevent opening or closing interlocked circuit breakers, except in a specified sequence. Include mountings and hardware for future installation of key interlocks.
- G. Undervoltage Trip Devices: Adjustable time-delay and pickup voltage.
- H. Indicating Lights: To indicate circuit breaker is open or closed, for main and bus tie circuit breakers interlocked either with each other or with external devices.

2.12 LOW-VOLTAGE INSTRUMENT SECTION

- A. Instrument Transformers: Comply with IEEE C57.13.
 - 1. Potential Transformers: Secondary voltage rating of 120 V and NEMA C 12.11 Accuracy Class of 0.3 with burdens of W, X, and Y.
 - 2. Current Transformers: Burden and Accuracy Class suitable for connected relays, meters, and instruments.
- B. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems.
 - 1. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
 - 2. Switch-selectable digital display with the following features:
 - a. Phase Currents, Each Phase: Plus or minus 1 %.
 - b. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 %.
 - c. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 %.
 - d. Three-Phase Real Power: Plus or minus 2 %.
 - e. Three-Phase Reactive Power: Plus or minus 2 %.
 - f. Power Factor: Plus or minus 2 %.

- g. Frequency: Plus or minus 0.5 %.
 - h. Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 %.
 - i. Accumulated energy, in megawatt hours, plus or minus 2 %; stored values unaffected by power outages for up to 72 hours.
- 3. Communications module suitable for remote monitoring of meter quantities and functions.
 - 4. Mounting: Display and control unit that is flush or semiflush mounted in instrument compartment door.
- C. Relays: Comply with IEEE C37.90, types and settings as indicated; with test blocks and plugs.

2.13 IDENTIFICATION DEVICES

- A. Compartment Nameplates: Engraved, laminated-plastic or metal nameplate for each compartment, mounted with corrosion-resistant screws. Nameplates and label products are specified in Section 16195 "ELECTRICAL IDENTIFICATION."

2.14 SOURCE QUALITY CONTROL

- A. Factory Tests: Perform design and routine tests per standards specified for components. Conduct transformer tests per IEEE C57.12.90. Conduct switchgear and switchboard tests per NEMA C 37.51.
- B. Factory Tests: Perform the following factory-certified tests on each secondary unit substation:
 - 1. Resistance measurements of all windings on the rated voltage connection and on tap extreme connections.
 - 2. Ratios on the rated voltage connection and on tap extreme connections.
 - 3. Polarity and phase relation on the rated voltage connection.
 - 4. No-load loss at rated voltage on the rated voltage connection.
 - 5. Exciting current at rated voltage on the rated voltage connection.
 - 6. Impedance and load loss at rated current on the rated voltage connection and on tap extreme connections.
 - 7. Applied potential.
 - 8. Induced potential.
 - 9. Temperature Test: If a transformer is supplied with auxiliary cooling equipment to provide more than one rating, test at lowest kVA Class ONAN or Class AA rating and highest kVA Class ONAF or Class AFA rating.
 - a. Temperature test is not required if a record of a temperature test on an essentially duplicate unit is available.
 - 10. MBTA will witness all required factory tests. Notify Architect at least 14 days before date of tests and indicate their approximate duration.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and space conditions for compliance with requirements for secondary unit substations and other conditions affecting performance of the Work.
- B. Examine roughing-in of conduits and grounding systems to verify the following:
 - 1. Wiring entries comply with layout requirements.
 - 2. Entries are within conduit-entry tolerances specified by manufacturer, and no feeders shall to cross section barriers to reach load or line lugs.
- C. Examine walls, floors, roofs, and concrete bases for suitable conditions for secondary unit substation installation.
- D. Verify that ground connections are in place and that requirements in Section 16060 "GROUNDING AND BONDING" have been met. Maximum ground resistance shall be 5 ohms at secondary unit substation location.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Comply with applicable portions of NECA 1, NECA 400, NECA 410, NECA 430, and NEMA SG 11.
- B. Install secondary unit substations on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in Section 03300 "CAST-IN-PLACE CONCRETE."
- C. Comply with requirements for vibration isolation and seismic control devices specified in Section 16073 "HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS" and Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS."
- D. Maintain minimum clearances and workspace at equipment per manufacturer's written instructions and NFPA 70.

3.3 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION."
 - 1. Install the number of signs required to be readable from each accessible side, but space the signs a maximum of 30 ft. apart.
 - 2. Install arc-flash warning labels specified in Section 16056 "OVERCURRENT PROTECTIVE DEVICE ARC-FLASH STUDY."

- B. Operating Instructions: Place printed operating instructions for secondary unit substations, including key interlocking, control sequences, elementary single-line diagram, and emergency procedures with the maintenance materials.

3.4 CONNECTIONS

- A. Ground equipment per Section 16060 "GROUNDING AND BONDING."
 - 1. At Interior Locations: For grounding to grounding electrodes, use bare copper cable not smaller than No. 4/0 AWG. Bond surge arrester and neutrals directly to the transformer enclosure and then to the grounding electrode system with bare copper conductors. Keep leads as short as practicable with no kinks or sharp bends. Make joints in grounding conductors and loops by exothermic weld or compression connector.
 - 2. At Exterior Locations:
 - a. For counterpoise, use tinned bare copper cable not smaller than No. 4/0 AWG, buried not less than 30 inches below grade interconnecting the grounding electrodes. Bond surge arrester and neutrals directly to the transformer enclosure and then to the grounding electrode system with bare copper conductors, sized as shown. Keep lead lengths as short as practicable with no kinks or sharp bends.
 - b. Fence and equipment connections shall not be smaller than No. 4 AWG. Ground fence at each gate post and corner post and at intervals not exceeding 10 ft.. Bond each gate section to the fence post using 1/8 by 1 inch tinned flexible braided copper strap and clamps.
 - c. Make joints in grounding conductors and loops by exothermic weld or compression connector.
- B. Connect wiring per Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

3.5 CLEANING

- A. After completing equipment installation and before energizing, inspect unit components. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish. Vacuum interiors of secondary unit substation sections.

3.6 FIELD QUALITY CONTROL

- A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
- D. General Field Testing Requirements:

1. Comply with the provisions of NFPA 70B Ch. "Testing and Test Methods."
2. Perform each visual and mechanical inspection and electrical test. Certify compliance with test parameters.
3. After installing secondary unit substation but before primary is energized, verify that grounding system at the substation is tested at the specified value or less.
4. After installing secondary unit substation and after electrical circuitry has been energized, test for compliance with requirements.
5. Visual and Mechanical Inspection:
 - a. Verify equipment nameplate data complies with Contract Documents.
 - b. Inspect bolted electrical connections for high resistance using one of the following two methods:
 1. Use a low-resistance ohmmeter to compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 % of the lowest value.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method per manufacturer's published data or NETA ATS, Table 100.12. Bolt-torque levels shall be per manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.12.
6. Remove and replace malfunctioning units and retest.
7. Prepare test and inspection reports. Record as-left set points of all adjustable devices.

E. Switchgear Field Tests:

1. Visual and Mechanical Inspection:
 - a. Inspect physical and mechanical condition.
 - b. Inspect anchorage, alignment, grounding, and required area clearances.
 - c. Verify the unit is clean and shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.
 - d. Verify that fuse and circuit-breaker sizes and types correspond to Drawings and coordination study as well as to the address of the circuit breaker that is used to identify it in microprocessor-communication software.
 - e. Verify that current and voltage-transformer ratios correspond to Drawings.
 - f. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
 1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
 2. Make key exchange with devices operated in off-normal positions.
 - g. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
 - h. Inspect insulators for evidence of physical damage or contaminated surfaces.
 - i. Verify correct barrier and shutter installation and operation.

- j. Exercise all active components.
- k. Inspect mechanical indicating devices for correct operation.
- l. Verify that filters are in place and vents are clear.
- m. Inspect control power transformers as follows:
 - 1. Inspect for physical damage, cracked insulation, broken leads, connection tightness, defective wiring, and overall general condition.
 - 2. Verify that primary- and secondary-fuse or circuit-breaker ratings match Drawings and comply with manufacturer's recommendations.
 - 3. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.

2. Electrical Tests:

- a. Perform dc voltage insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute. If the temperature of the bus is other than plus or minus 20 deg. C, adjust the resulting resistance as provided in NETA ATS, Table 100.11.
 - 1. Insulation-resistance values of bus insulation shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.1. Investigate and correct values of insulation resistance less than manufacturer's recommendations or NETA ATS, Table 100.1.
 - 2. Do not proceed to the dielectric-withstand-voltage tests until insulation-resistance levels are raised above minimum values.
- b. Perform a dielectric-withstand-voltage test on each bus section, each phase-to-ground with phases not under test grounded, per manufacturer's published data. If manufacturer has no recommendation for this test, it shall be conducted per NETA ATS, Table 100.2. Apply the test voltage for one minute.
 - 1. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric-withstand-voltage test, the test specimen is considered to have passed the test.
- c. Perform insulation-resistance tests on control wiring with respect to ground. Applied potential shall be 500-V dc for 300-V rated cable and 1000-V dc for 600-V rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow the manufacturer's recommendation.
 - 1. Minimum insulation-resistance values of control wiring shall not be less than 2 megohms.
- d. Voltage Transformers:
 - 1. Perform secondary wiring integrity test. Verify correct potential at all devices.
 - 2. Verify secondary voltages by energizing the primary winding with system voltage.
- e. Perform current-injection tests on the entire current circuit in each section of switchgear.

1. Perform current tests by secondary injection with magnitudes such that a minimum current of 1.0 A flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
 2. Perform current tests by primary injection with magnitudes such that a minimum of 1.0 A flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
- f. Verify operation of space heaters.
 - g. Perform phasing checks on double-ended or dual-source switchgear to ensure correct bus phasing from each source.

F. Medium-Voltage Surge Arrester Field Tests:

1. Visual and Mechanical Inspection:
 - a. Inspect physical and mechanical condition.
 - b. Inspect anchorage, alignment, grounding, and clearances.
 - c. Verify the arresters are clean.
 - d. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
 - e. Verify that the stroke counter is correctly mounted and electrically connected if applicable. Record the stroke counter reading.
2. Electrical Test:
 - a. Perform an insulation-resistance test on each arrester, phase terminal-to-ground. Apply voltage per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.1. Replace units that fail to meet recommended minimum insulation resistance listed in the table.
 - b. Perform a watts-loss test. Evaluate watts-loss values by comparison with similar units and test equipment manufacturer's published data.

G. Medium-Voltage Vacuum Circuit Breaker Field Tests:

1. Visual and Mechanical Inspection:
 - a. Inspect physical and mechanical condition.
 - b. Verify correct connection of transformers with system requirements.
 - c. Verify that adequate clearances exist between primary and secondary circuit wiring.
 - d. Verify the unit is clean.
 - e. Verify that required grounding and shorting connections provide contact.
 - f. Verify correct operation of transformer withdrawal mechanism and grounding operation
 - g. Verify correct primary- and secondary-fuse sizes for voltage transformers.
 - h. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
2. Electrical Tests of Current Transformers:

- a. Perform insulation-resistance test of each current transformer and its secondary wiring with respect to ground at 1000-V dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, comply with manufacturer's recommendations. Insulation-resistance values of instrument transformers shall not be less than values shown in NETA ATS, Table 100.5.
 - b. Perform a polarity test of each current transformer per IEEE C57.13.1. Polarity results shall agree with transformer markings.
 - c. Perform a ratio-verification test using the voltage or current method per IEEE C57.13.1. Ratio errors shall comply with IEEE C57.13.
 - d. Perform an excitation test on transformers used for relaying applications per IEEE C57.13.1. Excitation results shall match the curve supplied by the manufacturer or shall comply with IEEE C57.13.1.
 - e. Measure current circuit burdens at transformer terminals per IEEE C57.13.1. The measured burdens shall match the instrument transformer Accuracy Class rating.
 - f. Perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall comply with NETA ATS, Table 100.5. The insulation-resistance value shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.5.
 - g. Perform dielectric-withstand-voltage tests on the primary winding with the secondary grounded. Test voltages shall comply with NETA ATS, Table 100.9. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application, the primary winding is considered to have passed the test.
 - h. Perform power-factor or dissipation-factor tests per test equipment manufacturer's published data. Power-factor or dissipation-factor values shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with test equipment manufacturer's published data.
 - i. Verify that current-transformer secondary circuits are grounded and have only one grounding point per IEEE C57.13.3.
3. Electrical Tests of Voltage and Potential Transformers:
- a. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply the test voltage for one minute per NETA ATS, Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations. Insulation-resistance values of instrument transformers shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.5.
 - b. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute per NETA ATS, Table 100.5. Insulation-resistance values of the transformers shall not be less than values shown in NETA ATS, Table 100.5.

- c. Perform a polarity test on each transformer to verify the polarity marks or H(1)-X(1) relationship. Polarity results shall agree with transformer markings.
- d. Perform a turns-ratio test on all tap positions. Ratio errors shall not exceed the tolerances specified in IEEE C57.13.
- e. Measure voltage circuit burdens at transformer terminals. Measured burdens shall be compared to instrument transformer ratings. The measured burdens shall match the instrument transformer Accuracy Class rating.
- f. Perform a dielectric-withstand-voltage test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall comply with NETA ATS, Table 100.9. The test voltage shall be applied for one minute. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric-withstand-voltage test, the primary windings are considered to have passed the test.
- g. Perform power-factor or dissipation-factor tests per test equipment manufacturer's published data. Power-factor or dissipation-factor values shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with test equipment manufacturer's published data.
- h. Verify that voltage-transformer secondary circuits are grounded and have only one grounding point per IEEE C57.13.3.

H. Microprocessor-Based Protective Relay Field Tests:

1. Visual and Mechanical Inspection:

- a. Record model number, style number, serial number, firmware revision, software revision, and rated control voltage.
- b. Verify operation of light-emitting diodes, display, and targets.
- c. Record passwords for each access level.
- d. Clean the front panel and remove foreign material from the case.
- e. Check tightness of connections.
- f. Verify that the frame is grounded per manufacturer's instructions.
- g. Set the relay per results in Section 16055 "OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY" and in Section 16056 "OVERCURRENT PROTECTIVE DEVICE ARC-FLASH STUDY."
- h. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.

2. Electrical Tests:

- a. Perform insulation-resistance tests from each circuit to the grounded frame per manufacturer's published data.
- b. Apply voltage or current to analog inputs, and verify correct registration of the relay meter functions.
- c. Functional Operation: Check functional operation of each element used in the protection scheme as follows:

1. Timing Relay:

- a) Determine time delay.
 - b) Verify operation of instantaneous contacts.
2. Volts/Hertz Relay:
- a) Determine pickup frequency at rated voltage.
 - b) Determine pickup frequency at a second voltage level.
 - c) Determine time delay.
3. Undervoltage Relay:
- a) Determine dropout voltage.
 - b) Determine time delay.
 - c) Determine time delay at a second point on the timing curve for inverse time relays.
4. Phase Sequence or Phase Balance Voltage Relay:
- a) Determine positive sequence voltage to close the N.O. contact.
 - b) Determine positive sequence voltage to open the N.C. contact (undervoltage trip).
 - c) Verify negative sequence trip.
 - d) Determine time delay to close the N.O. contact with sudden application of 120 % of pickup.
 - e) Determine time delay to close the N.C. contact upon removal of voltage when previously set to rated system voltage.
5. Temperature (RTD) Relay:
- a) Determine trip resistance.
 - b) Determine reset resistance.
6. Instantaneous Overcurrent Relay:
- a) Determine pickup.
 - b) Determine dropout.
7. Time Overcurrent:
- a) Determine minimum pickup.
 - b) Determine time delay at two points on the time current curve.
8. Power-Factor Relay:
- a) Determine tripping angle.
 - b) Determine time delay.
9. Overvoltage Relay:
- a) Determine overvoltage pickup.
 - b) Determine time delay to close the contact with sudden application of 120 % of pickup.

10. Voltage Balance Relay:
 - a) Determine voltage difference to close the contacts with one source at rated voltage.
 - b) Plot the operating curve for the relay.
 11. Transformer Sudden Pressure Relay:
 - a) Determine rate-of-rise or the pickup level of suddenly applied pressure per manufacturer's published data.
 - b) Verify operation of the 63 FPX seal-in circuit.
 - c) Verify trip circuit to remote operating device.
 12. Ground Detector Relay:
 - a) Determine maximum impedance to ground causing relay pickup.
 13. Frequency Relay:
 - a) Verify frequency set points.
 - b) Determine time delay.
 - c) Determine undervoltage cutoff.
 14. Pilot Wire Monitor:
 - a) Determine overcurrent pickup.
 - b) Determine undercurrent pickup.
 - c) Determine pilot wire ground pickup level.
- d. Control Verification:
1. Functional Tests:
 - a) Check operation of all active digital inputs.
 - b) Check output contacts or SCRs, preferably by operating the controlled device, such as circuit breaker, auxiliary relay, or alarm.
 - c) Check internal logic functions used in protection scheme.
 - d) For pilot schemes, perform a loop-back test to check receive and transmit communication circuits.
 - e) For pilot schemes, perform satellite synchronized end-to-end tests.
 - f) For pilot schemes with direct transfer trip (DTT), perform transmit and received DTT at each terminal.
 - g) Upon completion of testing, reset min/max recorders, communications statistics, fault counters, sequence-of-events recorder, and event records.
 2. In-Service Monitoring: After the equipment is initially energized, measure magnitude and phase angle of inputs and verify expected values.

I. DC System VRLA Batteries Field Test:

1. Visual and Mechanical Inspection:

- a. Verify that batteries are adequately located.
- b. Verify that battery area ventilation system is operable.
- c. Verify existence of suitable eyewash equipment.
- d. Verify equipment nameplate data complies with Contract Documents.
- e. Inspect physical and mechanical condition.
- f. Verify adequacy of battery support racks, mounting, anchorage, alignment, grounding, and clearances.
- g. Verify the units are clean.
- h. Inspect spill containment installation.
- i. Verify application of an oxide inhibitor on battery terminal connections.

2. Electrical Tests:

- a. Measure charger float and equalizing voltage levels. Adjust to battery manufacturer's recommended levels.
- b. Verify charger functions and that alarms comply with system manufacturer's recommendations.
- c. Measure negative post temperature. Negative post temperature shall comply with manufacturer's published data or IEEE 1188.
- d. Measure charger float and equalizing voltage levels. Charger float and equalizing voltage levels shall be per the battery manufacturer's published data.
- e. Measure each monoblock/cell voltage and total battery voltage with charger energized and in float mode of operation. Monoblock/cell voltages shall be per manufacturer's published data.
- f. Measure intercell connection resistances.
- g. Perform internal ohmic measurement tests. Cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 % between identical cells that are in a fully charged state. Monoblock/cell internal ohmic values (resistance, impedance, or conductance) shall not vary by more than 25 % between identical monoblocks/cells in a fully charged state.
- h. Perform a load test per manufacturer's published data or IEEE 1188. Replace units that fail to pass the test.
- i. Measure the battery system voltage from positive-to-ground and negative-to-ground. Voltage measured from positive-to-ground shall be equal in magnitude to the voltage measured from negative-to-ground.

J. DC System Charger Field Test:

1. Visual and Mechanical Inspection:

- a. Inspect for physical and mechanical condition.
- b. Inspect anchorage, alignment, and grounding.
- c. Verify the unit is clean.
- d. Inspect filter and tank capacitors.

- e. Verify operation of cooling fans and presence of filters.
2. Electrical Tests:
- a. Verify float voltage, equalizing voltage, and high-voltage shutdown settings. Float and equalizing voltage settings shall be per battery manufacturer's published data.
 - b. Verify current limit. Current limit shall be within manufacturer's recommended maximum.
 - c. Verify operation of alarms. Results of alarm operation shall be per manufacturer's published data and system design.
 - d. Measure and record input and output voltage and current. Input and output voltage shall be per manufacturer's published data.
 - e. Measure and record ac ripple current and voltage imposed on the battery. AC ripple current and voltage imposed on the battery shall be per manufacturer's published data.
 - f. Perform full-load testing of charger. Charger shall be capable of manufacturer's specified full load.

K. Liquid-Filled Transformer Section Field Tests:

1. Visual and Mechanical Inspection:
- a. Inspect physical and mechanical condition.
 - b. Inspect impact recorder prior to unloading.
 - c. Test dew point of tank gases if applicable.
 - d. Inspect anchorage, alignment, and grounding.
 - e. Verify the presence of PCB content labeling.
 - f. Verify removal of any shipping bracing after placement.
 - g. Verify the bushings are clean.
 - h. Verify that alarm, control, and trip settings on temperature and level indicators are set and operate within manufacturer's recommended settings.
 - i. Verify that cooling fans and pumps operate correctly and have appropriate overcurrent protection.
 - j. Verify that liquid level in tanks and bushings is within manufacturer's published tolerances.
 - k. Perform specific inspections and mechanical tests recommended by the manufacturer.
 - l. Verify presence of transformer surge arresters and that their ratings are as specified.
 - m. Verify that as-left tap connections are as specified.
 - n. Verify the presence of surge arresters and that their ratings are as specified.
2. Electrical Tests:
- a. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.5. Calculate polarization index; the value of the index shall not be less than 1.0.

- b. Perform power-factor or dissipation-factor tests on all windings per test equipment manufacturer's published data. Maximum winding insulation power-factor/dissipation-factor values shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.3.
- c. Measure core insulation resistance at 500-V dc if the core is insulated and the core ground strap is removable. Core insulation-resistance values shall not be less than 1 megohm at 500-V dc.
- d. Perform a power-factor or dissipation-factor tip-up test on windings greater than 2.5 kV.
- e. Perform an excitation-current test on each phase. The typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading. Investigate and correct if the test shows a different pattern.
- f. Measure the resistance of each winding at each tap connection, and record temperature-corrected winding-resistance values in the Operations and Maintenance Manual.
- g. Perform an applied-voltage test on high- and low-voltage windings-to-ground. Comply with IEEE C57.12.91, Sections 10.2 and 10.9.
- h. Verify correct secondary voltage, phase-to-phase and phase-to-neutral, after energization and prior to loading.
- i. Remove a sample of insulating liquid per ASTM D 923. Insulating liquid values shall comply with NETA ATS, Table 100.4. Sample shall be tested for the following:
 - 1. Dielectric Breakdown Voltage: ASTM D 877 or ASTM D 1816.
 - 2. Acid Neutralization Number: ASTM D 974.
 - 3. Interfacial Tension: ASTM D 971.
 - 4. Color: ASTM D 1500.
 - 5. Visual Condition: ASTM D 1524.
- j. Remove a sample of insulating liquid per ASTM D 923 and perform dissolved-gas analysis per IEEE C57.104 or ASTM D 3612.

L. Large Dry-Type Transformer Section Field Tests:

1. Visual and Mechanical Inspection:

- a. Inspect physical and mechanical condition.
- b. Inspect anchorage, alignment, and grounding.
- c. Verify that resilient mounts are free and that any shipping brackets have been removed.
- d. Verify the unit is clean.
- e. Verify that alarm, control, and trip settings on temperature and level indicators are set and operate within manufacturer's recommended settings.
- f. Verify that cooling fans operate and that fan motors have correct overcurrent protection.
- g. Perform specific inspections and mechanical tests recommended by the manufacturer.
- h. Verify that as-left tap connections are as specified.
- i. Verify the presence of surge arresters and that their ratings are as specified.

2. Electrical Tests:

- a. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.5. Calculate polarization index; the value of the index shall not be less than 1.0.
- b. Perform power-factor or dissipation-factor tests on windings per the test equipment manufacturer's published data. Investigate and correct power-factor values that exceed:
 1. 2.0 % for power transformers.
 2. 5.0 % for distribution transformers.
- c. Measure core insulation resistance at 500-V dc if the core is insulated and the core ground strap is removable. Core insulation-resistance values shall not be less than 1 megohm at 500-V dc.
- d. Perform turns-ratio tests at all tap positions. The test results shall not deviate by more than one-half % from either the adjacent coils or the calculated ratio. If the test fails, replace the transformer.
- e. Perform an excitation-current test on each phase. The typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading. Investigate and correct if the test shows a different pattern.
- f. Measure the resistance of each winding at each tap connection.
- g. Perform an applied-voltage test on all high- and low-voltage windings-to-ground. See IEEE C57.12.91, Sections 10.2 and 10.9. The ac dielectric-withstand-voltage test result shall not exceed 75 % of factory test voltage for one-minute duration. The dc dielectric-withstand-voltage test result shall not exceed 100 % of the ac rms test voltage specified in IEEE 57.12.91, Section 10.2, for one-minute duration. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric-withstand-voltage test, the test specimen is considered to have passed the test.
- h. Verify correct secondary voltage, phase-to-phase and phase-to-neutral, after energization and prior to loading.

M. Low-Voltage Power Circuit-Breaker Field Tests:

1. Visual and Mechanical Inspection:

- a. Inspect physical and mechanical condition.
- b. Inspect anchorage, alignment, and grounding.
- c. Verify that all maintenance devices are available for servicing and operating the breaker.
- d. Verify the unit is clean.
- e. Verify that the arc chutes are intact.
- f. Inspect moving and stationary contacts for condition and alignment.
- g. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
- h. Perform mechanical operator and contact alignment tests on both the breaker and its operating mechanism per manufacturer's published data.
- i. Verify cell fit and element alignment.
- j. Verify racking mechanism operation.

- k. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
- l. Perform adjustments for final protective-device settings per coordination study provided by end user.
- m. Record as-found and as-left operation counter readings.

2. Electrical Tests:

- a. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to ground with switch closed, and across each open pole. Apply voltage per manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.1. Insulation-resistance values shall be per manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations shall be investigated.
- b. Measure contact resistance across each power contact of the circuit breaker. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in manufacturer's published data. If manufacturer's published data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 % of the lowest value.
- c. Determine long-time pickup and delay by primary current injection. Long-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current characteristic tolerance band, including adjustment factors. If manufacturer's curves are not available, trip times shall not exceed the value shown in NETA ATS, Table 100.7.
- d. Determine short-time pickup and delay by primary current injection. Short-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.
- e. Determine ground-fault pickup and delay by primary current injection. Ground-fault pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.
- f. Determine instantaneous pickup value by primary current injection. Instantaneous pickup values shall be as specified and within manufacturer's published tolerances. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.8.
- g. Test functions of the trip unit by means of secondary injection. Pickup values and trip characteristic shall be as specified and within manufacturer's published tolerances.
- h. Perform minimum pickup voltage tests on shunt trip and close coils per manufacturer's published data. Minimum pickup voltage of the shunt trip and close coils shall conform to manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.20.
- i. Measure fuse resistance. Investigate fuse-resistance values that deviate from each other by more than 15 %.

- j. Verify correct operation of any auxiliary features, such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free operation, anti-pump function, and trip unit battery condition. Reset trip logs and indicators. Auxiliary features shall operate per manufacturer's published data.
- k. Verify operation of charging mechanism. The charging mechanism shall operate per manufacturer's published data.

N. Metering Device Field Tests:

1. Visual and Mechanical Inspection:

- a. Inspect physical and mechanical condition.
- b. Inspect cover gasket, cover glass, condition of spiral spring, disk clearance, contacts, and case shorting contacts, as applicable.
- c. Verify the unit is clean.
- d. Verify freedom of movement, end play, and alignment of rotating disk(s).

2. Electrical Tests:

- a. Verify accuracy of meters at cardinal points. Meter accuracy shall be per manufacturer's published data.
- b. Calibrate meters per manufacturer's published data. Calibration results shall be within manufacturer's published tolerances.
- c. Verify instrument multipliers. Instrument multipliers shall be per system design specifications.
- d. Verify that current-transformer and voltage-transformer secondary circuits are intact. Test results shall confirm the integrity of the secondary circuits of current and voltage transformers.

3.7 FOLLOW-UP SERVICE

A. Voltage Monitoring and Adjusting: After Substantial Completion, if requested by MBTA, but not more than six months after Final Acceptance, perform the following voltage monitoring:

- 1. During a period of normal load cycles as evaluated by MBTA, perform seven days of three-phase voltage recording at the outgoing section of each secondary unit substation. Use voltmeters with calibration traceable to National Institute of Science and Technology standards and with a chart speed of not less than 1 inch per hour. Voltage unbalance greater than 1 % between phases, or deviation of any phase voltage from the nominal value by more than plus or minus 5 % during the test period, is unacceptable.
- 2. Corrective Action: If test results are unacceptable, perform the following corrective action, as appropriate:
 - a. Adjust transformer taps.
 - b. Rebalance loads.
 - c. Prepare written request for voltage adjustment by electric utility.
- 3. Retests: Repeat monitoring, after corrective action has been performed, until satisfactory results are obtained.

4. Report:
 - a. Prepare a written report covering monitoring performed and corrective action taken.
 - b. For each relay and adjustable circuit breaker, tag the device with adjusting technician's initials and the date of the adjustment. Record the settings and file with test records specified in "Field Quality Control" Article.
- B. Infrared Inspection: Perform the survey during periods of maximum possible loading. Remove all necessary covers prior to the inspection.
 1. After Substantial Completion, but not more than 60 days after Final Acceptance, perform infrared inspection of the electrical power connections of the unit substation.
 2. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchgear 11 months after date of Substantial Completion.
 3. Instrument: Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1°C at 30°C.
 4. Record of Infrared Inspection: Prepare a certified report that identifies the testing technician and equipment used, and lists the following results:
 - a. Description of equipment to be tested.
 - b. Discrepancies.
 - c. Temperature difference between the area of concern and the reference area.
 - d. Probable cause of temperature difference.
 - e. Areas inspected. Identify inaccessible and unobservable areas and equipment.
 - f. Identify load conditions at time of inspection.
 - g. Provide photographs and thermograms of the deficient area.
 5. Act on inspection results per the recommendations of NETA ATS, Table 100.18. Correct possible and probable deficiencies as soon as MBTA's operations permit. Retest until deficiencies are corrected.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain systems.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.
- B. Section 03300 – “Poured in Place Concrete”
- C. Section 16300 – “Ductbanks and Ductbank Manholes for the Traction Power System”. The most stringent requirements shall take precedence.
- D. Where there exist discrepancies between this section and Section 16300, the most stringent requirements shall apply.

1.2 SUMMARY

- A. Section Includes:
 - 1. Concrete-encased conduit, ducts, and duct accessories.
 - 2. Handholes and boxes.
 - 3. Manholes.

1.3 SUBMITTALS

- A. Product Data: For each type of product.
 - 1. Include duct-bank materials, including separators and miscellaneous components.
 - 2. Include ducts and conduits and their accessories, including elbows, end bells, bends, fittings, and solvent cement.
 - 3. Include accessories for manholes, handholes, boxes.
 - 4. Include warning tape.
 - 5. Include warning planks.
- B. Shop Drawings:
 - 1. Precast or Factory-Fabricated Underground Utility Structures:
 - a. Include plans, elevations, sections, details, attachments to other work, and accessories.
 - b. Include duct entry provisions, including locations and duct sizes.
 - c. Include reinforcement details.
 - d. Include frame and cover design and manhole frame support rings.
 - e. Include Ladder details.
 - f. Include grounding details.
 - g. Include dimensioned locations of cable rack inserts, pulling-in and lifting irons, and sumps.
 - h. Include joint details.
 - i. Include coordination drawings.
 - j. Include plans and sections drawn to scale.

2. Factory-Fabricated Handholes and Boxes Other Than Precast Concrete:
 - a. Include dimensioned plans, sections, and elevations, and fabrication and installation details.
 - b. Include duct entry provisions, including locations and duct sizes.
 - c. Include cover design.
 - d. Include grounding details.
 - e. Include dimensioned locations of cable rack inserts, and pulling-in and lifting irons.

C. Reports.

1.4 MAINTENANCE MATERIALS SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Furnish cable-support stanchions, arms, and associated fasteners in quantities equal to 5 % of quantity of each item installed.

1.5 FIELD CONDITIONS

- A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by MBTA or others unless permitted under the following conditions, and then only after arranging to provide temporary electrical service per requirements indicated:
 1. Notify MBTA no fewer than two days in advance of proposed interruption of electrical service.
 2. Do not proceed with interruption of electrical service without MBTA's written permission.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR DUCTS AND RACEWAYS

- A. Comply with ANSI C2.

2.2 CONDUIT

- A. Rigid Steel Conduit: Galvanized. Comply with ANSI C80.1.
- B. Schedule 40 PC concrete encased with 2" concrete enclosure all around..

2.3 NONMETALLIC DUCTS AND DUCT ACCESSORIES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. ARNCO Corp.
 2. Beck Manufacturing.
 3. CANTEX INC.
 4. CertainTeed Corporation.
 5. Condux International, Inc.
 6. ElecSys, Inc.

7. IPEX Inc.
 8. Lamson & Sessions.
 9. Manhattan/CDT.
 10. Spiraduct/AFC Cable Systems, Inc.
- B. Underground Plastic Utilities Duct: NEMA TC 2, UL 651, ASTM F 512, Type EPC-40, with matching fittings complying with NEMA TC 3 by same manufacturer as the duct.
- C. Duct Accessories:
1. Duct Separators: Factory-fabricated rigid PVC interlocking spacers, sized for type and size of ducts with which used, and selected to provide minimum duct spacing indicated while supporting ducts during concreting or backfilling.
 2. Warning Tape
 3. Concrete Warning Planks: Nominal 12 by 24 by 3 inches in size, manufactured from 6000-psi concrete.
 - a. Color: Red dye added to concrete during batching.
 - b. Mark each plank with "ELECTRIC" in 2-inch-high, 3/8-inch-deep letters.

2.4 UNDERGROUND-LINE WARNING TAPE

- A. Tape:
1. Recommended by manufacturer for the method of installation and suitable to identify and locate underground electrical and communications utility lines.
 2. Printing on tape shall be permanent and shall not be damaged by burial operations.
 3. Tape material and ink shall be chemically inert, and not subject to degrading when exposed to acids, alkalis, and other destructive substances commonly found in soils.
- B. Color and Printing:
1. Comply with ANSI Z535.1 through ANSI Z535.5.
 2. Inscriptions for Red-Colored Tapes: ELECTRIC LINE, HIGH VOLTAGE.
- C. Tag:
1. Detectable three-layer laminate, consisting of a printed pigmented polyolefin film, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core, bright-colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
 2. Overall Thickness: 5 mils.
 3. Foil Core Thickness: 0.35 mil.
 4. Weight: 28 lb/1000 sq. ft.
 5. 3-Inch Tensile Per ASTM D 882: 70 lb-ft, and 4600 psi.

2.5 PRECAST CONCRETE HANDHOLES AND BOXES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Christy Concrete Products.
 2. Elmhurst-Chicago Stone Co.
 3. Oldcastle Precast Group.

4. Rinker Group, Ltd.
5. Riverton Concrete Products.
6. Utility Concrete Products, LLC.
7. Utility Vault Co.
8. Wausau Tile Inc.

B. Comply with ASTM C 858 for design and manufacturing processes.

1. Frame and Cover: Weatherproof cast-iron frame, with cast-iron cover with recessed cover hook eyes and tamper-resistant, captive, cover-securing bolts.
2. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
3. Cover Legend: Molded lettering, "ELECTRIC." or as required by utilities and MBTA.
4. Configuration: Units shall be designed for flush burial and have integral closed bottom unless otherwise indicated.
5. Extensions and Slabs: Designed to mate with bottom of enclosure. Same material as enclosure.
 - a. Extension shall provide increased depth of 12 inches.
 - b. Slab: Same dimensions as bottom of enclosure, and arranged to provide closure.
6. Joint Sealant: Asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground-water level at grade.
7. Duct Entrances in Handhole Walls: Cast end-bell or duct-terminating fitting in wall for each entering duct.
 - a. Type and size shall match fittings to duct or conduit to be terminated.
 - b. Fittings shall align with elevations of approaching ducts and be located near interior corners of handholes to facilitate racking of cable.
8. Handholes 12 inches wide by 24 inches long and larger shall have inserts for cable racks and pulling-in irons installed before concrete is poured.

2.6 PRECAST MANHOLES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Carder Concrete Products.
2. Christy Concrete Products.
3. Elmhurst-Chicago Stone Co.
4. Oldcastle Precast Group.
5. Rinker Group, Ltd.
6. Riverton Concrete Products.
7. Utility Concrete Products, LLC.
8. Utility Vault Co.
9. Wausau Tile Inc.

B. Comply with ASTM C 858.

- C. Structural Design Loading: Comply with requirements in "Underground Enclosure Application" Article.
- D. Precast Manholes: One-piece units and units with interlocking mating sections, complete with accessories, hardware, and features.
- E. Duct Entrances in Manhole Walls: Cast end-bell or duct-terminating fitting in wall for each entering duct.
 - 1. Type and size shall match fittings to duct or conduit to be terminated.
 - 2. Fittings shall align with elevations of approaching ducts and be located near interior corners of manholes to facilitate racking of cable.
- F. Concrete Knockout Panels: 1-1/2 to 2 inches thick, for future conduit entrance and sleeve for ground rod.
- G. Ground Rod Sleeve: Provide a 3-inch PVC conduit sleeve in manhole floors 2 inches from the wall adjacent to, but not underneath, the ducts routed from the facility.
- H. Joint Sealant: Asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground-water level at grade.

2.7 UTILITY STRUCTURE ACCESSORIES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Bilco Company (The).
 - 2. Campbell Foundry Company.
 - 3. Carder Concrete Products.
 - 4. Christy Concrete Products.
 - 5. Neenah Foundry Company.
 - 6. Oldcastle Precast Group.
 - 7. Pennsylvania Insert Corporation.
 - 8. Utility Concrete Products, LLC.
 - 9. Utility Vault Co.
 - 10. Wausau Tile Inc.
 - a. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
 - b. Special Covers: Recess in face of cover designed to accept finish material in paved areas.
 - 11. Cover Legend: Cast in. Selected to suit system.
 - a. Legend: "ELECTRIC-LV" for duct systems with power wires and cables for systems operating at 600 V and less.
 - b. Legend: "ELECTRIC-HV" for duct systems with medium-voltage cables.
 - c. As required by utility enclosed and MBTA.
 - 12. Manhole Chimney Components: Precast concrete rings with dimensions matched to those of roof opening.
 - a. Mortar for Chimney Ring and Frame and Cover Joints: Comply with ASTM C 270, Type M, except for quantities less than 2.0 cu. ft. where packaged mix complying with ASTM C 387, Type M, may be used.

- b. Seal joints watertight using preformed plastic or rubber conforming to ASTM C 990. Install sealing material per the sealant manufacturers' printed instructions.
- B. Manhole Sump Frame and Grate: ASTM A 48/A 48M, Class 30B, gray cast iron.
- C. Pulling Eyes in Concrete Walls: Eyebolt with reinforcing-bar fastening insert, 2-inch-diameter eye, and 1-by-4-inch bolt.
 - 1. Working Load Embedded in 6-Inch, 4000-psi Concrete: 13,000-lbf minimum tension.
- D. Pulling-In and Lifting Irons in Concrete Floors: 7/8-inch-diameter, hot-dip galvanized, bent steel rod; stress relieved after forming; and fastened to reinforcing rod. Exposed triangular opening.
 - 1. Ultimate Yield Strength: 40,000-lbf shear and 60,000-lbf tension.
- E. Bolting Inserts for Concrete Utility Structure Cable Racks and Other Attachments: Flared, threaded inserts of noncorrosive, chemical-resistant, nonconductive thermoplastic material; 1/2-inch ID by 2-3/4 inches deep, flared to 1-1/4 inches minimum at base.
 - 1. Tested Ultimate Pullout Strength: 12,000 lbf minimum.
- F. Ground Rod Sleeve: 3-inch, PVC conduit sleeve in manhole floors 2 inches from the wall adjacent to, but not underneath, the ducts routed from the facility.
- G. Expansion Anchors for Installation after Concrete Is Cast: Zinc-plated, carbon-steel-wedge type with stainless-steel expander clip with 1/2-inch bolt, 5300-lbf rated pullout strength, and minimum 6800-lbf rated shear strength.
- H. Cable Rack Assembly: Steel, hot-dip galvanized, except insulators.
 - 1. Stanchions: T-section or channel; 2-1/4-inch nominal size; punched with 14 holes on 1-1/2-inch centers for cable-arm attachment.
 - 2. Arms: 1-1/2 inches wide, lengths ranging from 3 inches with 450-lb minimum capacity to 18 inches with 250-lb minimum capacity. Arms shall have slots along full length for cable ties and be arranged for secure mounting in horizontal position at any vertical location on stanchions.
 - 3. Insulators: High-glaze, wet-process porcelain arranged for mounting on cable arms.
- I. Duct-Sealing Compound: Nonhardening, safe for contact with human skin, not deleterious to cable insulation, and workable at temperatures as low as 35 deg F. Capable of withstanding temperature of 300 deg F without slump and adhering to clean surfaces of plastic ducts, metallic conduits, conduit coatings, concrete, masonry, lead, cable sheaths, cable jackets, insulation materials, and common metals.
- J. Fixed Manhole Ladders: Arranged for attachment to roof or wall and floor of manhole. Ladder and mounting brackets and braces shall be fabricated from nonconductive, structural-grade, fiberglass-reinforced resin.
- K. Cover Hooks: Heavy duty, designed for lifts 60 lbf and greater. Two required.

PART 3 - EXECUTION

2.8 PREPARATION

- A. Coordinate layout and installation of ducts, manholes, handholes, and boxes with final arrangement of other utilities, site grading, and surface features as determined in the field. Notify Architect if there is a conflict between areas of excavation and existing structures or archaeological sites to remain.
- B. Coordinate elevations of ducts and duct-bank entrances into manholes, handholes, and boxes with final locations and profiles of ducts and duct banks, as determined by coordination with other utilities, underground obstructions, and surface features. Revise locations and elevations as required to suit field conditions and to ensure that duct runs drain to manholes and handholes, and as approved by Architect.
- C. Clear and grub vegetation to be removed, and protect vegetation to remain according. Remove and stockpile topsoil for reapplication.

2.9 UNDERGROUND DUCT APPLICATION

- A. Ducts for Electrical Cables: NEMA Type -40-PVC, in 2" concrete-encased duct bank unless otherwise indicated.

2.10 UNDERGROUND ENCLOSURE APPLICATION

- A. Handholes and Boxes for 600 V and Less:
 - 1. Units in Roadways and Other Deliberate Traffic Paths: Precast concrete. AASHTO , H-20 structural load rating.
 - 2. Units in Driveway, Parking Lot, and Off-Roadway Locations, Subject to Occasional, Nondeliberate Loading by Heavy Vehicles: Precast concrete, AASHTO HB 17, H-20 structural load rating.
 - 3. Units in Sidewalk and Similar Applications with a Safety Factor for Nondeliberate Loading by Vehicles: Precast concrete, AASHTO HB 17, H-10 structural load rating.
 - 4. Cover design load shall not exceed the design load of the handhole or box.
- B. Manholes: Precast concrete.
 - 1. Units Located in Roadways and Other Deliberate Traffic Paths by Heavy or Medium Vehicles: H-20 structural load rating per AASHTO HB 17.
 - 2. Units Not Located in Deliberate Traffic Paths by Heavy or Medium Vehicles: H-10 load rating per AASHTO HB 17.

2.11 EARTHWORK

- A. Excavation and Backfill: Comply with Section 02300 "Earthwork," but do not use heavy-duty, hydraulic-operated, compaction equipment.
- B. Restore surface features at areas disturbed by excavation, and re-establish original grades unless otherwise indicated. Replace removed sod immediately after backfilling is completed.
- C. Restore areas disturbed by trenching, storing of dirt, cable laying, and other work. Restore vegetation and include necessary topsoil, fertilizing, liming, seeding, sodding, sprigging, and mulching. Comply with Section 02920-"Seeded Lawns", Section 02930-"Planting" and Section 02932-Planting Soils."
- D. Cut and patch existing pavement in the path of underground ducts and utility structures As specified in Section 2-Site Work.

2.12 DUCT INSTALLATION

- A. Install ducts per NEMA TCB 2.
- B. Slope: Pitch ducts a minimum slope of 1:300 down toward manholes and handholes and away from buildings and equipment. Slope ducts from a high point in runs between two manholes, to drain in both directions.
- C. Curves and Bends: Use 5-degree angle couplings for small changes in direction. Use manufactured long sweep bends with a minimum radius of 48 inches, both horizontally and vertically, at other locations unless otherwise indicated.
- D. Joints: Use solvent-cemented joints in ducts and fittings and make watertight according to manufacturer's written instructions. Stagger couplings so those of adjacent ducts do not lie in same plane.
- E. Installation Adjacent to High-Temperature Steam Lines: Where duct banks are installed parallel to underground steam lines, perform calculations showing the duct bank will not be subject to environmental temperatures above 40 deg C. Where environmental temperatures are calculated to rise above 40 deg C, and anywhere the duct bank crosses above an underground steam line, install insulation blankets listed for direct burial to isolate the duct bank from the steam line.
- F. Duct Entrances to Manholes and Concrete and Polymer Concrete Handholes: Use end bells, spaced approximately 10 inches O. C. for 5-inch ducts, and vary proportionately for other duct sizes.
 - 1. Begin change from regular spacing to end-bell spacing 10 feet from the end bell without reducing duct line slope and without forming a trap in the line.
 - 2. Grout end bells into structure walls from both sides to provide watertight entrances.
- G. Building Wall Penetrations: Make a transition from underground duct to rigid steel conduit at least 10 feet outside the building wall, without reducing duct line slope away from the building, and without forming a trap in the line. Use fittings manufactured for duct-to-conduit transition. Install conduit penetrations of building walls as specified in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."
- H. Sealing: Provide temporary closure at terminations of ducts that have cables pulled. Seal spare ducts at terminations. Use sealing compound and plugs to withstand at least 15-psig hydrostatic pressure.
- I. Pulling Cord: Install 100-lbf-test nylon cord in empty ducts.
- J. Concrete-Encased Ducts: Support ducts on duct separators.
 - 1. Excavate trench bottom to provide firm and uniform support for duct bank. Prepare trench bottoms as specified in Section 312000 "Earth Moving" for pipes less than 6 inches in nominal diameter.
 - 2. Width: Excavate trench 12 inches wider than duct bank on each side.
 - 3. Depth: Install top of duct bank at least 24 inches below finished grade in areas not subject to deliberate traffic, and at least 30 inches below finished grade in deliberate traffic paths for vehicles unless otherwise indicated.
 - 4. Support ducts on duct separators coordinated with duct size, duct spacing, and outdoor temperature.
 - 5. Separator Installation: Space separators close enough to prevent sagging and deforming of ducts, with not less than four spacers per 20 feet of duct. Secure separators to earth and to ducts to prevent floating during concreting. Stagger separators approximately 6 inches between tiers.

Tie entire assembly together using fabric straps; do not use tie wires or reinforcing steel that may form conductive or magnetic loops around ducts or duct groups.

6. Minimum Space between Ducts: 3 inches between ducts and exterior envelope wall, 2 inches between ducts for like services, and 4 inches between power and signal ducts.
 7. Elbows: Use rigid galvanized elbows for stub-ups at poles and equipment, at building entrances through floor, and at changes of direction in duct run unless otherwise indicated. Extend concrete encasement throughout length of elbow.
 8. Reinforcement: Reinforce concrete-encased duct banks where they cross disturbed earth and where indicated. Arrange reinforcing rods and ties without forming conductive or magnetic loops around ducts or duct groups.
 9. Forms: Use walls of trench to form side walls of duct bank where soil is self-supporting and concrete envelope can be poured without soil inclusions; otherwise, use forms.
 10. Concrete Cover: Install a minimum of 3 inches of concrete cover at top and bottom, and a minimum of 2 inches on each side of duct bank.
 11. Concreting Sequence: Pour each run of envelope between manholes or other terminations in one continuous operation.
 - a. Start at one end and finish at the other, allowing for expansion and contraction of ducts as their temperature changes during and after the pour. Use expansion fittings installed per manufacturer's written recommendations, or use other specific measures to prevent expansion-contraction damage.
 - b. If more than one pour is necessary, terminate each pour in a vertical plane and install 3/4-inch reinforcing-rod dowels extending a minimum of 18 inches into concrete on both sides of joint near corners of envelope.
 12. Pouring Concrete: Comply with requirements in "Concrete Placement" Article in Section 03300 "Cast-in-Place Concrete." Place concrete carefully during pours to prevent voids under and between conduits and at exterior surface of envelope. Do not allow a heavy mass of concrete to fall directly onto ducts. Allow concrete to flow to center of bank and rise up in middle, uniformly filling all open spaces. Do not use power-driven agitating equipment unless specifically designed for duct-bank application.
- K. Warning Planks: Bury warning planks approximately 12 inches above direct-buried ducts and duct banks, placing them 24 inches o.c. Align planks along the width and along the centerline of duct bank. Provide an additional plank for each 12-inch increment of duct-bank width over a nominal 18 inches. Space additional planks 12 inches apart, horizontally.
- L. Warning Tape: Bury warning tape approximately 12 inches above all concrete-encased ducts and duct banks. Align tape parallel to and within 3 inches of centerline of duct bank. Provide an additional warning tape for each 12-inch increment of duct-bank width over a nominal 18 inches. Space additional tapes 12 inches apart, horizontally.

2.13 INSTALLATION OF CONCRETE MANHOLES, HANDHOLES, AND BOXES

A. Cast in place installation:

1. Finish interior surfaces with a smooth-troweled finish.
2. Windows for Future Duct Connections: Form and pour concrete knockout panels 1-1/2 to 2 inches thick, arranged as indicated.
3. Comply with requirements in Section 033000 "Cast-in-Place Concrete" for cast-in-place concrete, formwork, and reinforcement.

B. Precast Concrete Handhole and Manhole Installation:

1. Comply with ASTM C 891 unless otherwise indicated.
2. Install units level and plumb and with orientation and depth coordinated with connecting ducts, to minimize bends and deflections required for proper entrances.
3. Unless otherwise indicated, support units on a level bed of crushed stone or gravel, graded from 1-inch sieve to No. 4 sieve and compacted to same density as adjacent undisturbed earth.

C. Elevations:

1. Manhole Roof: Install with rooftop at least 15 inches below finished grade.
2. Manhole Frame: In paved areas and traffic ways, set frames flush with finished grade. Set other manhole frames 1 inch above finished grade.
3. Install handholes with bottom below frost line, 36 inches below grade.
4. Handhole Covers: In paved areas and traffic ways, set surface flush with finished grade. Set covers of other handholes 1 inch above finished grade.
5. Where indicated, cast handhole cover frame integrally with handhole structure.

D. Drainage: Install drains in bottom of manholes where indicated. Coordinate with drainage provisions indicated.

E. Manhole Access: Circular opening in manhole roof; sized to match cover size.

1. Manholes with Fixed Ladders: Offset access opening from manhole centerlines to align with ladder.
2. Install chimney, constructed of precast concrete collars and rings, to support cast-iron frame to connect cover with manhole roof opening. Provide moisture-tight masonry joints and waterproof grouting for frame to chimney.

F. Waterproofing: Apply waterproofing to exterior surfaces of manholes and handholes after concrete has cured at least three days. After ducts have been connected and grouted, and before backfilling, waterproof joints and connections, and touch up abrasions and scars. Waterproof exterior of manhole chimneys after mortar has cured at least three days.

G. Dampproofing: Apply dampproofing to exterior surfaces of manholes and handholes after concrete has cured at least three days. Dampproofing materials and installation are specified in Section 071113 "Bituminous Dampproofing." After ducts are connected and grouted, and before backfilling, dampproof joints and connections, and touch up abrasions and scars. Dampproof exterior of manhole chimneys after mortar has cured at least three days.

H. Hardware: Install removable hardware, including pulling eyes, cable stanchions, and cable arms, as required for installation and support of cables and conductors and as indicated.

I. Fixed Manhole Ladders: Arrange to provide for safe entry with maximum clearance from cables and other items in manholes.

- J. Field-Installed Bolting Anchors in Manholes and Concrete Handholes: Do not drill deeper than 3-7/8 inches for manholes and 2 inches for handholes, for anchor bolts installed in the field. Use a minimum of two anchors for each cable stanchion.

2.14 GROUNDING

- A. Ground underground ducts and utility structures according to Section 16060 "Grounding and Bonding for Electrical Systems."

2.15 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections and prepare test reports:
- B. Demonstrate capability and compliance with requirements on completion of installation of underground ducts and utility structures.
- C. Pull solid aluminum or wood test mandrel through duct to prove joint integrity and adequate bend radii, and test for out-of-round duct. Provide a minimum 6-inch-long mandrel equal to 80 % fill of duct. If obstructions are indicated, remove obstructions and retest.
- D. Test manhole and handhole grounding to ensure electrical continuity of grounding and bonding connections. Measure and report ground resistance as specified in Section 260526 "Grounding and Bonding for Electrical Systems."
- E. Correct deficiencies and retest as specified above to demonstrate compliance.

2.16 CLEANING

- A. Pull leather-washer-type duct cleaner, with graduated washer sizes, through full length of ducts. Follow with rubber duct swab for final cleaning and to assist in spreading lubricant throughout ducts.
- B. Clean internal surfaces of manholes, including sump. Remove foreign material.

PART 4 – MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for work under this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16410

ENCLOSED SWITCHES AND CIRCUIT BREAKERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Fusible switches.
 - 2. Nonfusible switches.
 - 3. Molded-case circuit breakers (MCCBs).
 - 4. Enclosures.

1.3 DEFINITIONS

- A. NC: Normally closed.
- B. NO: Normally open.
- C. SPDT: Single pole, double throw.

1.4 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Enclosed switches and circuit breakers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
 - 1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.5 SUBMITTALS

- A. Product Data: For each type of enclosed switch, circuit breaker, accessory, and component indicated. Include dimensioned elevations, sections, weights, and manufacturers' technical data on features, performance, electrical characteristics, ratings, accessories, and finishes.
 - 1. Enclosure types and details for types other than NEMA 250, Type 1.
 - 2. Current and voltage ratings.
 - 3. Short-circuit current ratings (interrupting and withstand, as appropriate).
 - 4. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices, accessories, and auxiliary components.

5. Include time-current coordination curves (average melt) for each type and rating of overcurrent protective device; include selectable ranges for each type of overcurrent protective device.
- B. Shop Drawings: For enclosed switches and circuit breakers. Include plans, elevations, sections, details, and attachments to other work.
1. Wiring Diagrams: For power, signal, and control wiring.

1.6 SUBMITTALS

- A. Qualification Data: For qualified testing agency.
- B. Seismic Qualification Certificates: For enclosed switches and circuit breakers, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.7 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For enclosed switches and circuit breakers to include in emergency, operation, and maintenance manuals. Include the following:
1. Manufacturer's written instructions for testing and adjusting enclosed switches and circuit breakers.
 2. Time-current coordination curves (average melt) for each type and rating of overcurrent protective device; include selectable ranges for each type of overcurrent protective device.

1.8 QUALITY ASSURANCE

- A. Product Selection for Restricted Space: Drawings indicate maximum dimensions for enclosed switches and circuit breakers, including clearances between enclosures, and adjacent surfaces and other items. Comply with indicated maximum dimensions.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70/MEC, by a qualified testing agency, and marked for intended location and application.
- C. Short circuit interrupting ratings shall be 150% of short circuit available values calculated in Section 13054-Overcurrent Protective Device Short Circuit Study.
- D. Comply with Massachusetts Electrical Code (MEC).

1.9 PROJECT CONDITIONS

- A. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
 - 1. Ambient Temperature: Not less than minus 22 deg F and not exceeding 104 deg F.
 - 2. Altitude: Not exceeding 6600 feet.
- B. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
 - 1. Notify Owner no fewer than seven days in advance of proposed interruption of electric service.
 - 2. Indicate method of providing temporary electric service.
 - 3. Do not proceed with interruption of electric service without Owner's written permission.

1.10 COORDINATION

- A. Coordinate layout and installation of switches, circuit breakers, and components with equipment served and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

PART 2 - PRODUCTS

2.1 FUSIBLE SWITCHES

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following:
 - 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - 2. Siemens Energy & Automation, Inc.
 - 3. Square D; a brand of Schneider Electric.
- B. Type HD, Heavy Duty, Single Throw, 600-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
- C. Accessories:
 - 1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
 - 2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
 - 3. Class R Fuse Kit: Provides rejection of other fuse types when Class R fuses are specified.
 - 4. Service-Rated Switches: Labeled for use as service equipment.

2.2 NONFUSIBLE SWITCHES

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include the following:
 - 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - 2. Siemens Energy & Automation, Inc.
 - 3. Square D; a brand of Schneider Electric.
- B. Type HD, Heavy Duty, Single Throw, 600-V AC, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
- C. Accessories:
 - 1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
 - 2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.

2.3 MOLDED-CASE CIRCUIT BREAKERS

- A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - 1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - 2. Siemens Energy & Automation, Inc.
 - 3. Square D; a brand of Schneider Electric.
- B. General Requirements: Comply with UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents.
- C. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
- D. Ground-Fault, Circuit-Interrupter (GFCI) Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
- E. Features and Accessories:
 - 1. Standard frame sizes, trip ratings, and number of poles.
 - 2. Lugs: Compression type, suitable for number, size, trip ratings, and conductor material.
 - 3. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge lighting circuits.

4. Ground-Fault Protection: Comply with UL 1053; integrally mounted, self-powered type with mechanical ground-fault indicator; relay with adjustable pickup and time-delay settings, push-to-test feature, internal memory, and shunt trip unit; and three-phase, zero-sequence current transformer/sensor.
 5. Shunt Trip: Trip coil energized from separate circuit, with coil-clearing contact.
- F. Electronic Trip Circuit Breakers: Field-replaceable rating plug, rms sensing, with the following field-adjustable settings:
1. Instantaneous trip.
 2. Long- and short-time pickup levels.
 3. Long- and short-time time adjustments.
 4. Ground-fault pickup level, time delay, and I^2t response.
- G. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller, and let-through ratings less than NEMA FU 1, RK-5.
- H. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker and trip activation on fuse opening or on opening of fuse compartment door.
- I. Ground-Fault, Circuit-Interrupter (GFCI) Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
- J. Ground-Fault, Equipment-Protection (GFEP) Circuit Breakers: With Class B ground-fault protection (30-mA trip).
- K. Features and Accessories:
1. Standard frame sizes, trip ratings, and number of poles.
 2. Lugs: Mechanical, or Compression type, suitable for number, size, trip ratings, and conductor material.
 3. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge lighting circuits.
 4. Ground-Fault Protection: Comply with UL 1053

2.4 ENCLOSURES

- A. Enclosed Switches and Circuit Breakers: Indoor: NEMA 1, Outdoor: NEMA 4X stainless steel.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine elements and surfaces to receive enclosed switches and circuit breakers for compliance with installation tolerances and other conditions affecting performance of the Work.

- B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Install individual wall-mounted switches and circuit breakers with tops at uniform height unless otherwise indicated.
- B. Comply with mounting and anchoring requirements specified in Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS."
- C. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
- D. Install fuses in fusible devices.
- E. Comply with NECA 1.

3.3 IDENTIFICATION

- A. Comply with requirements in Section 16050, "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
 - 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 - 2. Label each enclosure with engraved metal or laminated-plastic nameplate.
- B. Comply with the requirements of Section "16195, "ELECTRICAL IDENTIFICATION."

3.4 FIELD QUALITY CONTROL

- A. Tests and Inspections:
 - 1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
 - 3. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.
- B. Enclosed switches and circuit breakers will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports, including a certified report that identifies enclosed switches and circuit breakers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.5 ADJUSTING

- A. Adjust moving parts and operable components to function smoothly, and lubricate as recommended by manufacturer.
- B. Set field-adjustable circuit-breaker trip ranges as specified in Section 16055 "OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY."

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16415

TRANSFER SWITCHES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes transfer switches rated 600 V and less, including the following:
 - 1. Automatic transfer switches.
 - 2. Manual Transfer switches.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated. Include rated capacities, weights, operating characteristics, furnished specialties, and accessories.
- B. Shop Drawings: Dimensioned plans, elevations, sections, and details showing minimum clearances, conductor entry provisions, gutter space, installed features and devices, and material lists for each switch specified.
 - 1. Single-Line Diagram: Show connections between transfer switch, manual transfer switch, power sources, and load; and show interlocking provisions for each combined transfer switch and bypass/isolation switch.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For manufacturer and testing agency.
- B. Manufacturer Seismic Qualification Certification: Submit certification that transfer switches accessories, and components will withstand seismic forces defined in Section 16074 "Seismic Controls for Electrical Systems." Include the following:
 - 1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 - a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
 - 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 - 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For each type of product to include in emergency, operation, and maintenance manuals. In addition to items specified in Section 01782 "Operation and Maintenance Data," include the following:
 - 1. Features and operating sequences, both automatic and manual.
 - 2. List of all factory settings of relays; provide relay-setting and calibration instructions, including software, where applicable.

1.6 QUALITY ASSURANCE

- A. Manufacturer Qualifications: Maintain a service center capable of providing training, parts, and emergency maintenance repairs within a response period of less than eight hours from time of notification.
- B. Comply with Massachusetts Electrical Code.

1.7 COORDINATION

- A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Section 03300 "Cast-in-Place Concrete."

PART 2 - PRODUCTS

2.1 MANUFACTURED UNITS

- A. Contactor Transfer Switches:
 - 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Emerson; ASCO Power Technologies, LP.
 - b. GE Zenith Controls.
 - c. Kohler Power Systems; Generator Division.
 - d. Onan/Cummins Power Generation; Industrial Business Group.
 - e. Russelectric, Inc.
 - f. MTU Onsite Energy

2.2 GENERAL TRANSFER-SWITCH PRODUCT REQUIREMENTS

- A. Indicated Current Ratings: Apply as defined in UL 1008 for continuous loading and total system transfer, including tungsten filament lamp loads not exceeding 30 percent of switch ampere rating, unless otherwise indicated.
- B. Tested Fault-Current Closing and Withstand Ratings: Adequate for duty imposed by protective devices at installation locations in Project under the fault conditions indicated, based on testing according to UL 1008.

- C. Solid-State Controls: Repetitive accuracy of all settings shall be plus or minus 2 percent or better over an operating temperature range of minus 20 to plus 70 deg C.
- D. Resistance to Damage by Voltage Transients: Components shall meet or exceed voltage-surge withstand capability requirements when tested according to IEEE C62.41. Components shall meet or exceed voltage-impulse withstand test of NEMA ICS 1.
- E. Electrical Operation: Accomplish by a nonfused, momentarily energized solenoid or electric-motor-operated mechanism, mechanically and electrically interlocked in both directions.
- F. Switch Characteristics: Designed for continuous-duty repetitive transfer of full-rated current between active power sources.
 - 1. Limitation: Switches using molded-case switches or circuit breakers or insulated-case circuit-breaker components are not acceptable.
 - 2. Switch Action: Double throw; mechanically held in both directions.
 - 3. Contacts: Silver composition or silver alloy for load-current switching. Conventional automatic transfer-switch units, rated 225 A and higher, shall have separate arcing contacts.
- G. Neutral Switching. Provide neutral pole switched simultaneously with phase poles.
- H. Neutral Terminal: Solid and fully rated.
- I. Annunciation, Control, and Programming Interface Components: Devices at transfer switches for communicating with remote programming devices, annunciators, or annunciator and control panels shall have communication capability matched with remote device.
- J. Factory Wiring: Train and bundle factory wiring and label, consistent with Shop Drawings, either by color-code or by numbered or lettered wire and cable tape markers at terminations. Color-coding and wire and cable tape markers are specified in Section 16075 "Electrical Identification."
 - 1. Designated Terminals: Pressure type, suitable for types and sizes of field wiring indicated.
 - 2. Power-Terminal Arrangement and Field-Wiring Space: Suitable for top, side, or bottom entrance of feeder conductors as indicated.
 - 3. Control Wiring: Equipped with lugs suitable for connection to terminal strips.
- K. Enclosures: General-purpose NEMA1 for indoor units, NEMA 4X for outdoor units.

2.3 AUTOMATIC TRANSFER SWITCHES

- A. Comply with Level 1 equipment according to NFPA 110.
- B. Switching Arrangement: Double-throw type, incapable of pauses or intermediate position stops during normal functioning, unless otherwise indicated.
- C. Make then break contact arrangement.
- D. Signal-Before-Transfer Contacts: A set of normally open/normally closed dry contacts operates in advance of retransfer to normal source. Interval is adjustable from 1 to 30 seconds.
- E. Digital Communication Interface: Matched to existing MBTA's remote control system.

- F. In-Phase Monitor: Factory-wired, internal relay controls transfer so it occurs only when the two sources are synchronized in phase. Relay compares phase relationship and frequency difference between normal and emergency sources and initiates transfer when both sources are within 15 electrical degrees, and only if transfer can be completed within 60 electrical degrees. Transfer is initiated only if both sources are within 2 Hz of nominal frequency and 70 percent or more of nominal voltage.
- G. Automatic Transfer-Switch Features:
1. Undervoltage Sensing for Each Phase of Normal Source: Sense low phase-to-ground voltage on each phase. Pickup voltage shall be adjustable from 85 to 100 percent of nominal, and dropout voltage is adjustable from 75 to 98 percent of pickup value. Factory set for pickup at 90 percent and dropout at 85 percent.
 2. Adjustable Time Delay: For override of normal-source voltage sensing to delay transfer and engine start signals. Adjustable from zero to six seconds, and factory set for one second.
 3. Voltage/Frequency Lockout Relay: Prevent premature transfer to generator. Pickup voltage shall be adjustable from 85 to 100 percent of nominal. Factory set for pickup at 90 percent. Pickup frequency shall be adjustable from 90 to 100 percent of nominal. Factory set for pickup at 95 percent.
 4. Time Delay for Retransfer to Normal Source: Adjustable from 0 to 30 minutes, and factory set for 10 minutes to automatically defeat delay on loss of voltage or sustained undervoltage of emergency source, provided normal supply has been restored.
 5. Test Switch: Simulate normal-source failure.
 6. Switch-Position Pilot Lights: Indicate source to which load is connected.
 7. Source-Available Indicating Lights: Supervise sources via transfer-switch normal- and emergency-source sensing circuits.
 - a. Normal Power Supervision: Green light with nameplate engraved "Normal Source Available."
 - b. Emergency Power Supervision: Red light with nameplate engraved "Emergency Source Available."
 8. Unassigned Auxiliary Contacts: Two normally open, single-pole, double-throw contacts for each switch position, rated 10 A at 240-V ac.
 9. Transfer Override Switch: Overrides automatic retransfer control so automatic transfer switch will remain connected to emergency power source regardless of condition of normal source. Pilot light indicates override status.
 10. Engine Starting Contacts: One isolated and normally closed, and one isolated and normally open; rated 10 A at 32-V dc minimum.
 11. Engine Shutdown Contacts: Time delay adjustable from zero to five minutes, and factory set for five minutes. Contacts shall initiate shutdown at remote engine-generator controls after retransfer of load to normal source.

12. Engine-Generator Exerciser: Solid-state, programmable-time switch starts engine generator and transfers load to it from normal source for a preset time, then retransfers and shuts down engine after a preset cool-down period. Initiates exercise cycle at preset intervals adjustable from 7 to 30 days. Running periods are adjustable from 10 to 30 minutes. Factory settings are for 7-day exercise cycle, 20-minute running period, and 5-minute cool-down period. Exerciser features include the following:
 - a. Exerciser Transfer Selector Switch: Permits selection of exercise with and without load transfer.
 - b. Push-button programming control with digital display of settings.
 - c. Integral battery operation of time switch when normal control power is not available.

2.4 MANUAL TRANSFER SWITCHES

- A. Comply with requirements for Level 1 equipment according to NFPA 110.
- B. Description: Manual type, arranged to select and connect either source of power directly to load, isolating transfer switch from load and from both power sources. Include the following features for each combined automatic transfer switch and bypass/isolation switch:
 1. Means to lock bypass/isolation switch in the position that isolates transfer switch with an arrangement that permits complete electrical testing of transfer switch while isolated. While isolated, interlocks prevent transfer-switch operation, except for testing or maintenance.
 2. Drawout Arrangement for Transfer Switch: Provide physical separation from live parts and accessibility for testing and maintenance operations.
 3. Bypass/Isolation Switch Current, Voltage, Closing, and Short-Circuit Withstand Ratings: Equal to or greater than those of associated automatic transfer switch, and with same phase arrangement and number of poles.
 4. Contact temperatures of bypass/isolation switches shall not exceed those of automatic transfer-switch contacts when they are carrying rated load.
 5. Operability: Constructed so load bypass and transfer-switch isolation can be performed by 1 person in no more than 2 operations in 15 seconds or less.
 6. Legend: Manufacturer's standard legend for control labels and instruction signs shall describe operating instructions.
 7. Maintainability: Fabricate to allow convenient removal of major components from front without removing other parts or main power conductors.

2.5 SOURCE QUALITY CONTROL

- A. Factory test and inspect components, assembled switches, and associated equipment. Ensure proper operation. Check transfer time and voltage, frequency, and time-delay settings for compliance with specified requirements. Perform dielectric strength test complying with NEMA ICS 1.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Section 16074 "Seismic Controls for Electrical Systems."
- B. Identify components according to Section 16075 "Electrical Identification."
- C. Set field-adjustable intervals and delays, relays, and engine exerciser clock.

3.2 CONNECTIONS

- A. Wiring to Remote Components: Match type and number of cables and conductors to control and communication requirements of transfer switches as recommended by manufacturer. Increase raceway sizes at no additional cost to MBTA if necessary to accommodate required wiring.
- B. Ground equipment according to Section 16060 "Grounding and Bonding."
- C. Connect wiring according to Section 16120 "Conductors and Cables."

3.3 FIELD QUALITY CONTROL

- A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- B. he following Tests and Inspections:
 - 1. After installing equipment and after electrical circuitry has been energized, test for compliance with requirements.
 - 2. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
 - 3. Measure insulation resistance phase-to-phase and phase-to-ground with insulation-resistance tester. Include external annunciation and control circuits. Use test voltages and procedure recommended by manufacturer. Comply with manufacturer's specified minimum resistance.
 - a. Check for electrical continuity of circuits and for short circuits.
 - b. Inspect for physical damage, proper installation and connection, and integrity of barriers, covers, and safety features.
 - c. Verify that manual transfer warnings are properly placed.
 - d. Perform manual transfer operation.

4. After energizing circuits, demonstrate interlocking sequence and operational function for each switch at least three times.
 - a. Simulate power failures of normal source to automatic transfer switches and of emergency source with normal source available.
 - b. Simulate loss of phase-to-ground voltage for each phase of normal source.
 - c. Verify time-delay settings.
 - d. Verify pickup and dropout voltages by data readout or inspection of control settings.
 - e. Test bypass/isolation unit functional modes and related automatic transfer-switch operations.
 - f. Perform contact-resistance test across main contacts and correct values exceeding 500 microhms and values for 1 pole deviating by more than 50 percent from other poles.
 - g. Verify proper sequence and correct timing of automatic engine starting, transfer time delay, retransfer time delay on restoration of normal power, and engine cool-down and shutdown.
 5. Ground-Fault Tests: Coordinate with testing of ground-fault protective devices for power delivery from both sources.
 - a. Verify grounding connections and locations and ratings of sensors.
- C. Coordinate tests with tests of generator and run them concurrently.
- D. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation and contact resistances and time delays. Attach a label or tag to each tested component indicating satisfactory completion of tests.
- E. Remove and replace malfunctioning units and retest as specified above.
- F. Prepare test and inspection reports.
- G. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switch. Remove all access panels so joints and connections are accessible to portable scanner.
 1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switch 11 months after date of Substantial Completion.
 2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
 3. Record of Infrared Scanning: Prepare a certified report that identifies switches checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.4 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain transfer switches and related equipment, as specified below. Coordinate this training with that for generator equipment.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16420
ENCLOSED CONTROLLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes the following enclosed controllers rated 600 V and less:
 - 1. Full-voltage manual.
 - 2. Full-voltage magnetic.
 - 3. Reduced-voltage magnetic.
 - 4. Reduced-voltage solid state.
 - 5. Multispeed.

- B. Related Section:

1.3 DEFINITIONS

- A. CPT: Control power transformer.
- B. MCCB: Molded-case circuit breaker.
- C. MCP: Motor circuit protector.
- D. N.C.: Normally closed.
- E. N.O.: Normally open.
- F. OCPD: Overcurrent protective device.
- G. SCR: Silicon-controlled rectifier.

1.4 PERFORMANCE REQUIREMENTS

- A. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

1.5 ACTION SUBMITTALS

- A. Product Data: For each type of enclosed controller. Include manufacturer's technical data on features, performance, electrical characteristics, ratings, and enclosure types and finishes.
- B. Shop Drawings: For each enclosed controller. Include dimensioned plans, elevations, sections, details, and required clearances and service spaces around controller enclosures.
 - 1. Show tabulations of the following:
 - a. Each installed unit's type and details.
 - b. Factory-installed devices.
 - c. Nameplate legends.
 - d. Short-circuit current rating of integrated unit.
 - e. Listed and labeled for integrated short-circuit current (withstand) rating of OCPDs in combination controllers by an NRTL acceptable to authorities having jurisdiction.
 - f. Features, characteristics, ratings, and factory settings of individual OCPDs in combination controllers.
 - 2. Wiring Diagrams: For power, signal, and control wiring.

1.6 SUBMITTALS

- A. Operation and Maintenance Data: For enclosed controllers to include in emergency, operation, and maintenance manuals include the following:
 - 1. Routine maintenance requirements for enclosed controllers and installed components.
 - 2. Manufacturer's written instructions for testing and adjusting circuit breaker and MCP trip settings.
 - 3. Manufacturer's written instructions for setting field-adjustable overload relays.
 - 4. Manufacturer's written instructions for testing, adjusting, and reprogramming reduced-voltage solid-state controllers.

1.7 QUALITY ASSURANCE

- A. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Section 16074 "SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS."

1.8 DELIVERY, STORAGE, AND HANDLING

- A. Store enclosed controllers indoors in clean, dry space with uniform temperature to prevent condensation. Protect enclosed controllers from exposure to dirt, fumes, water, corrosive substances, and physical damage.
- B. If stored in areas subject to weather, cover enclosed controllers to protect them from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside controllers; install temporary electric heating, with at least 250 W per controller.

1.9 PROJECT CONDITIONS

- A. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
 - 1. Ambient Temperature: Not less than minus 22 deg F and not exceeding 104 deg F.
 - 2. Altitude: Not exceeding 6600 feet.

- B. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by MBTA or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
 - 1. Notify MBTA no fewer than two days in advance of proposed interruption of electrical systems.
 - 2. Indicate method of providing temporary utilities.
 - 3. Do not proceed with interruption of electrical systems without MBTA's written permission.
 - 4. Comply with NFPA 70E.

1.10 COORDINATION

- A. Coordinate layout and installation of enclosed controllers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

- B. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

- C. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

PART 2 - PRODUCTS

2.1 FULL-VOLTAGE CONTROLLERS

- A. General Requirements for Full-Voltage Controllers: Comply with NEMA ICS 2, general purpose, Class A.

- B. Motor-Starting Switches: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off or on.
 - 1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. Rockwell Automation, Inc.; Allen-Bradley brand.
 - c. Siemens Energy & Automation, Inc.
 - d. Square D; a brand of Schneider Electric.

 - 2. Configuration: Nonreversing.
 - 3. Surface mounting.

4. Green pilot light.
 5. Red Light
- C. Fractional Horsepower Manual Controllers: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. Rockwell Automation, Inc.; Allen-Bradley brand.
 - c. Siemens Energy & Automation, Inc.
 - d. Square D; a brand of Schneider Electric.
 2. Configuration: Nonreversing.
 3. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, Class 10 tripping characteristics; heaters matched to nameplate full-load current of actual protected motor; external reset push button; bimetallic type.
 4. Surface mounting.
 5. Green pilot light.
 6. Red Laght
- D. Magnetic Controllers: Full voltage, across the line, electrically held.
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. Rockwell Automation, Inc.; Allen-Bradley brand.
 - c. Siemens Energy & Automation, Inc.
 - d. Square D; a brand of Schneider Electric.
 2. Configuration: Nonreversing.
 3. Contactor Coils: Pressure-encapsulated type.
 - a. Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
 4. Power Contacts: Totally enclosed, double-break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
 5. Control Circuits: 24-V ac; obtained from integral CPT, with primary and secondary fuses, with CPT of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.
 - a. CPT Spare Capacity: 200 VA.
 6. Melting Alloy Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. Class 20 tripping characteristic.

- c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
 - 7. Bimetallic Overload Relays:
 - a. Inverse-time-current characteristic.
 - b. Class 20 tripping characteristic.
 - c. Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
 - d. Ambient compensated.
 - e. Automatic resetting.
 - 8. Solid-State Overload Relay:
 - a. Switch or dial selectable for motor running overload protection.
 - b. Sensors in each phase.
 - c. Class 10/20 selectable tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
 - d. . Analog communication module.
 - 9. N.C. and N.O., isolated overload alarm contact.
 - 10. External overload reset push button.
- E. Combination Magnetic Controller: Factory-assembled combination of magnetic controller, OCPD, and disconnecting means.
- 1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - a. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
 - b. Rockwell Automation, Inc.; Allen-Bradley brand.
 - c. Siemens Energy & Automation, Inc.
 - d. Square D; a brand of Schneider Electric.
 - 2. Fusible Disconnecting Means:
 - a. NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate Class R fuses.
 - b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
 - 3. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.
 - 4. Nonfusible Disconnecting Means:
 - a. NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
 - b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
 - c. Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.
 - 5. MCP Disconnecting Means:

- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
 - b. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
 - c. Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
 - d. N.C. and N.O. alarm contact that operates only when MCP has tripped.
 - e. Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.
6. MCCB Disconnecting Means:
- a. UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
 - b. Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
 - c. Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
 - d. Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
 - e. N.C. and N.O. alarm contact that operates only when MCCB has tripped.

2.2 ENCLOSURES

- A. Enclosed Controllers: NEMA ICS 6, to comply with environmental conditions at installed location.
- 1. Dry and Clean Indoor Locations: NEMA 1.
 - 2. Outdoor Locations: Type 4X stainless steel.
 - 3. Other Wet or Damp Indoor Locations: Type 4X Stainless Steel.
 - 4. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.

2.3 ACCESSORIES

- A. General Requirements for Control Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.
- 1. Push Buttons, Pilot Lights, and Selector Switches: Heavy-duty, oiltight type.
 - a. Push Buttons: Shielded types; momentary as indicated.
 - b. Pilot Lights: LED types; colors as indicated; push to test.
 - c. Selector Switches: Rotary type.

2. Meters: Panel type, 2-1/2-inch minimum size with 90- or 120-degree scale and plus or minus two percent accuracy. Where indicated, provide selector switches with an off position.
- B. Reversible N.C./N.O. auxiliary contact(s).
 - C. Control Relays: Auxiliary and adjustable solid-state time-delay relays.
 - D. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.
 - E. Breather and drain assemblies, to maintain interior pressure and release condensation in Type 4X, stainless steel enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
 - F. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
 - G. Cover gaskets for Type 1 enclosures.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and surfaces to receive enclosed controllers, with Installer present, for compliance with requirements and other conditions affecting performance of the Work.
- B. Examine enclosed controllers before installation. Reject enclosed controllers that are wet, moisture damaged, or mold damaged.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Wall-Mounted Controllers: Install enclosed controllers on walls with tops at uniform height unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not at walls, provide freestanding racks complying with Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
- B. Floor-Mounted Controllers: Install enclosed controllers on 4-inch nominal-thickness concrete base. Comply with requirements for concrete base specified in Section 03300 "CAST IN PLACE CONCRETE."
 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- C. Seismic Bracing: Comply with requirements specified in Section 16074 "SEISMIC CONTROL FOR ELECTRICAL SYSTEMS."
 - D. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
 - E. Install fuses in each fusible-switch enclosed controller.
 - F. Install fuses in control circuits if not factory installed. Comply with requirements in Section 16491 "FUSES."
 - G. Install heaters in thermal overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.
 - H. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
 - I. Comply with NECA 1.

3.3 IDENTIFICATION

- A. Identify enclosed controllers, components, and control wiring. Comply with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION."
 1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
 2. Label each enclosure with engraved nameplate.
 3. Label each enclosure-mounted control and pilot device.

3.4 CONTROL WIRING INSTALLATION

- A. Install wiring between enclosed controllers and remote devices and facility's central control system. Comply with requirements in Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."
- B. Bundle, train, and support wiring in enclosures.
- C. Connect selector switches and other automatic-control selection devices where applicable.
 1. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switch is in manual-control position.
 2. Connect selector switches with enclosed-controller circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

3.5 FIELD QUALITY CONTROL

A. Acceptance Testing Preparation:

1. Test insulation resistance for each enclosed controller, component, connecting supply, feeder, and control circuit.
2. Test continuity of each circuit.

B. Tests and Inspections:

1. Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
2. Test insulation resistance for each enclosed-controller element, component, connecting motor supply, feeder, and control circuits.
3. Test continuity of each circuit.
4. Verify that voltages at controller locations are within plus or minus 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify MBTA before starting the motor(s).
5. Test each motor for proper phase rotation.
6. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
7. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
8. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
 - a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multi-pole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
 - b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multi-pole enclosed controller 11 months after date of Substantial Completion.
 - c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
9. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

C. Enclosed controllers will be considered defective if they do not pass tests and inspections.

- D. Prepare test and inspection reports including a certified report that identifies enclosed controllers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.6 ADJUSTING

- A. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
- B. Adjust overload-relay heaters or settings if power factor correction capacitors are connected to the load side of the overload relays.
- C. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable instantaneous trip elements. Initially adjust to six times the motor nameplate full-load ampere ratings and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify MBTA before increasing settings.
- D. Set field-adjustable circuit-breaker trip ranges as specified in Section 16055 "OVERCURRENT PROTECTIVE DEVICE COORDINATION STUDY."

3.7 PROTECTION

- A. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until enclosed controllers are ready to be energized and placed into service.
- B. Replace controllers whose interiors have been exposed to water or other liquids prior to Substantial Completion.

3.8 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain enclosed controllers.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16426

METAL-ENCLOSED DRAWOUT SWITCHGEAR

PART 1- GENERAL

1.1. RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2. SCOPE

- A. The Design-Builder shall furnish and install, where indicated on the drawings, a deadfront type, low voltage metal-enclosed switchgear assembly utilizing Cutler-Hammer Magnum DS drawout power circuit breakers, as specified herein and shown on the contract drawings.

1.3. RELATED SECTION

- A. Section 16289 – SURGE PROTECTION FOR LOW-VOLTAGE ELECTRICAL POWER CIRCUITS

1.4. REFERENCES

- A. The low voltage metal-enclosed switchgear assembly and all components shall be designed, manufactured and tested in accordance with the following latest applicable standards:
 - 1. ANSI-C37.20 – Switchgear assemblies
 - 2. ANSIANSI-C37.17 – Trip devices
 - 3. C37.13 – Low voltage power circuit breakers
 - 4. NEMA SG-5 – Switchgear assemblies
 - 5. NEMA SG-3 – Low voltage power circuit breakers.
 - 6. UL 1558

1.5. SUBMITTALS – FOR REVIEW/APPROVAL

- A. The following information shall be submitted to MBTA
 - 1. Master drawing index
 - 2. Front view and plan view of the assembly
 - 3. Three-line diagram
 - 4. Schematic diagram

5. Nameplate schedule
 6. Component list
 7. Conduit space locations within the assembly
 8. Assembly ratings including:
 - a. Short-circuit rating
 - b. Voltage
 - c. Continuous current rating
 9. Major component rating including:
 - a. Voltage
 - b. Continuous current rating
 - c. Interrupting ratings
 10. Cable terminal sizes
 11. Product data sheets
- B. Where applicable, the following additional information shall be submitted to MBTA:
1. Busway connection
 2. Composite front view and plan view of close-coupled assemblies
 3. Key interlock scheme drawing and sequence of operations
 4. Mimic bus size and color

1.6. SUBMITTALS – FOR CONSTRUCTION

- A. The following information shall be submitted for record purposes:
1. Final as-built drawings and information for items listed in Paragraph 1.04, and shall incorporate all changes made during the manufacturing process.
 2. Wiring diagrams
 3. Certified production test reports
 4. Installation information
 5. Seismic certification as specified.

1.7. QUALIFICATIONS

- A. The manufacturer of the assembly shall be the manufacturer of the major components within the assembly.

- B. For the equipment specified herein, the manufacturer shall be ISO 9001 or 9002 certified.
- C. The manufacturer of this equipment shall have produced similar electrical equipment for a minimum period of five (5) years. When requested by MBTA, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.
- D. Provide Seismic tested equipment as follows:

- 1. The equipment and major components shall be suitable for and certified to meet all applicable seismic requirements of the 2009 International Building Code (IBC) Site Classification Enter classification from above website.

The site coefficients F_a = Enter value from above website, and spectral response accelerations of S_S = Enter value from above website, S_1 = Enter value from above website are used. The test response spectrum shall be based upon a 5% damping factor, and a peak (S_{DS}) of at least Enter value from above website's (3 -12 Hz) applied at the base of the equipment in the horizontal direction. The forces in the vertical direction shall be at least 66% of those in the horizontal direction. The tests shall cover a frequency range from 1 to 100Hz. Guidelines for the installation consistent with these requirements shall be provided by the equipment manufacturer and based upon testing of representative equipment. Equipment certification acceptance criteria shall be based upon the ability for the equipment to be returned to service immediately after a seismic event within the above requirements without the need for repairs.

- OR -

- 1. The manufacturer shall certify the equipment based upon a dynamic and/or static structural **computer analysis** of the entire assembly structure and its components, provided it is based upon **actual seismic testing** from similar equipment. The analysis shall be based upon all applicable seismic requirements of the 2009 International Building Code (IBC) Site Classification Enter classification from above website, site Coefficient F_a = Enter classification from above website, F_v = Enter classification from above website and spectral response accelerations of S_S = Enter classification from above website, S_1 = Enter classification from above website. The analysis shall be based upon a 5% damping factor, and a peak (S_{DS}) of at least Enter classification from above website's (3 -12 Hz), applied at the base of the equipment in the horizontal direction. The forces in the vertical direction shall be at least 66% of those in the horizontal direction. The analysis shall cover a frequency range from 1 to 100Hz. Guidelines for the installation consistent with these requirements shall be provided by the equipment manufacture and based upon testing of representative equipment. Equipment certification acceptance criteria shall be based upon the ability for the equipment to be returned to service immediately after a seismic event within the above requirements without the need for repairs
- 2. The following minimum mounting and installation guidelines shall be met, unless specifically modified by the above referenced standards.
 - a. The Design-Builder shall provide equipment anchorage details, coordinated with the equipment mounting provision, prepared and stamped by a licensed civil engineer in the state. Mounting recommendations shall be provided by the manufacturer based upon the above criteria to verify the seismic design of the equipment.

- b. The equipment manufacturer shall certify that the equipment can withstand, that is, function following the seismic event, including both vertical and lateral required response spectra as specified in above codes.
- c. The equipment manufacturer shall document the requirements necessary for proper seismic mounting of the equipment. Seismic qualification shall be considered achieved when the capability of the equipment, meets or exceeds the specified response spectra.

1.8. REGULATORY REQUIREMENTS

- A. The switchgear shall bear a UL 1558 label. Certified copies of production test reports shall be supplied demonstrating compliance with these standards.

1.9. DELIVERY, STORAGE AND HANDLING

- A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

1.10. OPERATION AND MAINTENANCE MANUALS

- A. Equipment operation and maintenance manuals shall be provided with each assembly shipped, and shall include instruction leaflets and instruction bulletins for the complete assembly and each major component.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Eaton
- B. General Electric
- C. Westinghouse
- D. Siemens
- E. The listing of specific manufacturers above does not imply acceptance of their products that do not meet the specified ratings, features and functions. Manufacturers listed above are not relieved from meeting these specifications in their entirety. Products in compliance with the specification and manufactured by others not named will be considered only if pre-approved by MBTA ten (10) days prior to bid date

2.2 RATINGS

- A. Voltage rating shall be as indicated on the drawings. The entire assembly shall be suitable for 600 volts maximum ac service.
- B. The assembly shall be rated to withstand mechanical forces exerted during short-circuit conditions when connected directly to a power source having available fault current as shown on the drawings.

- C. The bus system shall have a minimum ANSI short-circuit withstand rating of 100,000 amperes symmetrical tested in accordance with ANSI C37.20.1 and UL1558.
- D. All circuit breakers shall have a minimum symmetrical interrupting capacity of 65,000 amperes. To ensure a fully selective system, all circuit breakers shall have 30 cycle short-time withstand ratings equal to their symmetrical interrupting ratings through 85,000 amperes, regardless of whether equipped with instantaneous trip protection or not.
- E. All ratings shall be tested to the requirements of ANSI C37.20.1, C37.50 and C37.51 and UL witnessed and approved.

2.3 CONSTRUCTION

- A. The switchgear shall consist of the required number of vertical sections bolted together to form a rigid assembly. The sides shall be covered with removable bolt-on covers. All edges of front covers or hinged front panels shall be formed. Provide ventilators located on the top of the switchgear over the breaker and bus compartments to ensure adequate ventilation within the enclosure. Hinged rear doors, complete with provisions for padlocking, shall be provided.
- B. The assembly shall be provided with adequate lifting means and shall be capable of being moved into installation position and bolted directly to the floor without the use of floor sills providing the floor is level to 1/8 inch per 3-foot distance in any direction. Provisions shall be made for jacking of shipping groups, for removal of skids or insertion of equipment rollers. Base of assembly shall be suitable for rolling directly on pipes without skids. The base shall be equipped with slots in the base frame members to accommodate the use of pry bars for moving the equipment to its final position.
- C. Each vertical steel unit forming part of the switchgear line-up shall be a self-contained housing having one or more individual breaker or instrument compartments, a centralized bus compartment and a rear cable compartment. Each individual circuit breaker compartment, or cell, shall be segregated from adjacent compartments and sections by means of steel barriers to the maximum extent possible. It shall be equipped with drawout rails and primary and secondary disconnecting contacts. Removable hinge pins shall be provided on the breaker compartment door hinges. Current transformers for feeder instrumentation, where shown on the plans, shall be located within the appropriate breaker cells and be front accessible and removable.
- D. The stationary part of the primary disconnecting devices for each power circuit breaker shall be breaker mounted and consist of a set of contacts extending to the rear through a glass polyester insulating support barrier; corresponding moving finger contacts, suitably spaced, shall be furnished on the power circuit breaker studs which engage in only the connected position. The assembly shall provide multiple silver-to-silver full floating high pressure point contacts with uniform pressure on each finger maintained by springs. Each circuit shall include the necessary three-phase bus connections between the section bus and the breaker line side studs. Load studs shall be equipped with insulated copper load extension buses terminating in solderless type terminals in the rear cable compartment of each structure. Bus extensions shall be silver-plated where outgoing terminals are attached.
- E. The circuit breaker door design shall be such that the following functions may be performed without the need to open the circuit breaker door: lever circuit breaker between positions, operate manual charging system, close and open circuit breaker, examine and adjust trip unit, and read circuit breaker rating nameplate.

- F. The secondary disconnecting devices shall consist of floating terminals mounted on the stationary unit and engaging mating contacts at the front of the breaker. The secondary disconnecting devices shall be gold-plated and engagement shall be maintained in the “connected” and “test” positions
- G. The removable power circuit breaker element shall be equipped with disconnecting contacts and interlocks for drawout application. It shall have four positions, “connected,” “test,” “disconnected” and “removed.” The breaker drawout element shall contain a worm gear levering “in” and “out” mechanism with removable lever crank. Levering shall be accomplished via the use of conventional tools. Mechanical interlocking shall be provided so that the breaker is in the tripped position before levering “in” or “out” of the cell. Interlocking that trips the breaker will not be accepted. The breaker shall include an optional provision for key locking open to prevent manual or electric closing. Padlocking shall provide for securing the breaker in the connected, test, or disconnected position by preventing levering.
- H. An insulating flash shield shall be mounted above each circuit breaker to prevent flashover from the arc chutes to ground
- I. The switchgear shall be Cutler-Hammer Magnum DS low voltage metal-enclosed switchgear, utilizing Magnum DS power circuit breakers as herein specified.
- J. The switchgear shall be suitable for use as service entrance equipment and be labeled in accordance with UL requirements.
- K. Provide a rear compartment barrier between the cable compartment and the main bus to protect against inadvertent contact with main or vertical bus bars.
- L. Provide in the cell when the circuit breaker is withdrawn, a safety shutter which automatically covers the line and load stabs and protects against incidental contact.
- M. Provide a metal barrier full height and depth between adjacent vertical structures in the cable compartment.
- N. Provide a glass polyester full height and depth barrier between adjacent vertical structures in the bus compartment with appropriate slots for main bus.

2.4 BUS

- A. All bus bars shall be tin-plated copper. Main horizontal bus bars shall be mounted with all three phases arranged in the same vertical plane. Bus sizing shall be based on ANSI standard temperature rise criteria of 65 degrees C over a 40 degrees C ambient (outside the enclosure). .
- B. Provide a full capacity neutral bus where a neutral bus is indicated on the drawings.
- C. A copper ground bus shall be furnished firmly secured to each vertical section structure and shall extend the entire length of the switchgear. The ground bus short-time withstand rating shall meet that of the largest circuit breaker within the assembly.
- D. All hardware used on conductors shall be high-tensile strength and zinc-plated. All bus joints shall be provided with Belleville-type washers.

2.5 WIRING/TERMINATIONS

- A. Small wiring, necessary fuse blocks and terminal blocks within the switchgear shall be furnished as required. Control components mounted within the assembly shall be suitably marked for identification corresponding to the appropriate designations on manufacturer's wiring diagrams.
- B. Provide a front accessible, isolated vertical wireway for routing of factory and field wiring. Factory provisions shall be made for securing field wiring without the need for adhesive wire anchors.
- C. Front access to all circuit breaker secondary connection points shall be provided for ease of troubleshooting and connection to external field connections without the need of removing the circuit breaker for access.
- D. All control wire shall be type SIS. Control wiring shall be 14 ga for control circuits and 12 ga for current transformer circuits. Wire bundles shall be secured with nylon ties and anchored to the assembly with the use of pre-punched wire lances or nylon non-adhesive anchors. All current transformer secondary leads shall first be connected to conveniently accessible shorting terminal blocks before connecting to any other device. Shorting screws with provisions for storage shall be provided. All groups of control wires leaving the switchgear shall be provided with terminal blocks with suitable numbering strips and provisions for #10 AWG field connections. Each control wire shall be marked to the origin zone/wire name/destination zone over the entire length of the wire using a cured ink process.
- E. Provide wire markers at each end of all control wiring. Plug-in terminal blocks shall be provided for all shipping split wires. Terminal connections to remote devices or sources shall be front accessible via doors above each circuit breaker.
- F. Lugs shall be provided in the incoming line section for connection of the main grounding conductor. Additional lugs for connection of other grounding conductors shall be provided as indicated on the drawings.
- G. Reusable insulating boots shall be provided to cover all power cable terminations.

2.6 CIRCUIT BREAKERS

- A. All protective devices shall be low voltage power circuit breakers, Cutler-Hammer type Magnum DS or approved equal. All breakers shall be UL listed for application in their intended enclosures for 100% of their continuous ampere rating.
- B. All power circuit breakers shall be constructed and tested in accordance with ANSI C37.13, C37.16, C37.17, C37.50, UL 1066 and NEMA SG-3 standard. The breaker shall carry a UL label.
- C. Breakers shall be provided in drawout configuration. The 800, 1600, 2000 and 3200 ampere frame power circuit breakers shall be provided in the same physical frame size, while 4000, 5000 and 6000 ampere frame power circuit breakers shall be provided in a second physical frame size. Both physical frame sizes shall have a common height and depth.
- D. Power circuit breakers shall utilize a two-step stored-energy mechanism to charge the closing springs. The closing of the breaker contacts shall automatically charge the opening springs to ensure quick-break operation.

- E. Breakers shall be electrically operated (EO).
- F. Electrically operated breakers shall be complete with 120 Vac motor operators. The charging time of the motor shall not exceed 6 seconds.
- G. To facilitate lifting, the power circuit breaker shall have integral handles on the side of the breaker.
- H. The power circuit breaker shall have a closing time of not more than 3 cycles.
- I. The primary contacts shall have an easily accessible wear indicator to indicate contact erosion.
- J. The power circuit breaker shall have three windows in the front cover to clearly indicate any electrical accessories that are mounted in the breaker. The accessory shall have a label that will indicate its function and voltage. The accessories shall be plug and lock type and UL listed for easy field installation. They shall be modular in design and shall be common to all frame sizes and ratings.
- K. The breaker control interface shall have color-coded visual indicators to indicate contact open or closed positions, as well as mechanism charged and discharged positions. Manual control pushbuttons on the breaker face shall be provided for opening and closing the breaker. The power circuit breaker shall have a "Positive On" feature. The breaker flag will read "Closed" if the contacts are welded and the breaker is tripped or opened.
- L. The current sensors shall have a back cover window that will permit viewing the sensor rating on the back of the breaker. A rating plug will offer indication of the rating on the front of the trip unit.
- M. A position indicator shall be located on the faceplate of the breaker. This indicator shall provide color indication of the breaker position in the cell. These positions shall be Connect (Red), Test (Yellow), and Disconnect (Green). The levering door shall be interlocked so that when the breaker is in the closed position, the breaker levering-in door shall not open.
- N. Each power circuit breaker shall offer sixty (60) front-mounted dedicated secondary wiring points. Each wiring point shall have finger safe contacts, which will accommodate #10 AWG maximum field connections with ring tongue or spade terminals or bare wire.

2.7 TRIP UNITS

- A. Each low voltage power circuit breaker shall be equipped with a solid-state tripping system consisting of three current sensors, microprocessor-based trip device and flux-transfer shunt trip. Current sensors shall provide operation and signal function. The trip unit shall use microprocessor-based technology to provide the basic adjustable time-current protection functions. True rms sensing circuit protection shall be achieved by analyzing the secondary current signals received from the circuit breaker current sensors and initiating trip signals to the circuit breaker trip actuators when predetermined trip levels and time delay settings are reached. Interchangeable current sensors with their associated rating plug shall establish the continuous trip rating of each circuit breaker. The trip unit shall be Cutler-Hammer type Digitrip RMS 520 MC.
- B. The trip unit shall have an information system that utilizes battery backup LEDs to indicate mode of trip following an automatic trip operation. The indication of the mode of trip shall be retained after an automatic trip. A reset button shall be provided to turn off the LED indication after an automatic trip. A test pushbutton shall energize a LED to indicate the battery status.

- C. The trip unit shall be provided with a display panel, including a representation of the time/current curve that will indicate the protection functions. The unit shall be continuously self-checking and provide a visual indication that the internal circuitry is being monitored and is fully operational.
- D. The trip unit shall be provided with a making-current release circuit. The circuit shall be armed for approximately two cycles after breaker closing and shall operate for all peak fault levels above 25 times the ampere value of the rating plug.
- E. Trip unit shall have selectable powered and unpowered thermal memory for enhanced circuit protection.
- F. Complete system selective coordination shall be provided by the addition of the following individually adjustable time/current curve shaping solid-state elements:
 - 1. All circuit breakers shall have adjustments for long delay pickup and time.
 - 2. All circuit breakers shall have individual adjustments for short delay pickup and time, and include I²t settings.
 - 3. All circuit breakers shall have an adjustable instantaneous pickup.
 - 4. Circuit breakers, where indicated on the drawings, shall have individually adjustable ground fault current pickup and time, and include I²t settings or ground alarm only.
- G. The trip unit shall have provisions for a single test kit to test each of the trip functions.
- H. The trip unit shall provide zone interlocking for the short-time delay and ground fault delay trip functions for improved system coordination. The zone interlocking system shall restrain the tripping of an upstream breaker and allow the breaker closest to the fault to trip with no intentional time delay. In the event that the downstream breaker does not trip, the upstream breaker shall trip after the present time delay.
- I. The trip unit shall have a 4-character LCD display showing phase, neutral, and ground current. The accuracy of these readings shall be +/- 2% of full scale.
- J. The trip unit shall be equipped to permit communication via a network twisted pair for remote monitoring and control.
- K. The trip unit shall include a power/relay module which shall supply control to the readout display. Following an automatic trip operation of the circuit breaker, the trip unit shall maintain the cause of trip history and the mode of trip LED indication as long as its internal power supply is available. An internal relay shall be programmable to provide contacts for remote ground alarm indication.
- L. The trip unit shall include a voltage transformer module, suitable for operation up to 600V, 50/60 Hz. The primary of the voltage transformer module shall be connected internally to the line side of the circuit breaker through a dielectric test disconnect plug.
- M. System coordination shall be provided by the following microprocessor-based programmable time-current curve shaping adjustments. The short-time pickup adjustment shall be dependent on the long delay setting.
 - 1. Programmable long-time setting.
 - 2. Programmable long-time delay with selectable I²t or I⁴t curve shaping.
 - 3. Programmable short-time setting

4. Programmable short-time delay with selectable flat or I²t curve shaping, and zone selective interlocking.
5. Programmable instantaneous setting.
6. Programmable ground fault setting trip or ground fault setting alarm.
7. Programmable ground fault delay with selectable flat or I²t curve shaping and zone selective interlocking.

2.8 CENTRAL DISPLAY UNIT

- A. Provide a central display unit capable of displaying information and data from trip units specified above.

2.9 WIRELESS COMMUNICATION

- A. Provide wireless transceiver (IRMINT) to provide communication from a PDA to multiple communicating trip units and meters.
- B. IRMINT shall be capable of communication with up to 64 Digitrip 520MC and Digitrip + trip units and/or INCOM communication capable meters.
- C. IRMINT can be mounted on the switchgear or be remotely mounted up to 10,000 feet away and connected via twisted pair shielded cable.

2.10 MISCELLANEOUS DEVICES

- A. Key interlocks shall be provided as indicated on the drawings. These interlocks shall keep the circuit breakers trip-free when actuated.
- B. Fused control power transformers shall be provided as indicated on the drawings or as required for proper operation of the equipment. A manual disconnect shall be provided ahead of the primary fuses.

2.11 UTILITY METERING

- A. Where required, provide a separate barriered-off utility metering compartment, complete with hinged sealable door. Bus work shall include provisions for mounting utility company current transformers and potential transformers, or potential taps as required by the utility company. Provide service entrance label and necessary applicable service entrance features per NEC and local code requirements.

2.12 MBTA METERING

- A. Where required, provide a separate MBTA metering compartment with front hinged door.
- B. Provide current transformers for each meter. Current transformers shall be wired to shorting-type terminal blocks.
- C. Provide potential transformers including primary and secondary fuses with disconnecting means for metering as shown on the drawings
- D. Microprocessor-Based Metering System.

- E. Web-Enabled Communications.
 - 1. Where indicated on the drawings, provide a separate compartment with a front facing hinged door as a central point of connection for all internally located communicating devices to an external Ethernet network and allow close monitoring of the power infrastructure with real-time, web-enabled data.
 - 2. The compartment shall have a lockable, hinged door with a functional through-the-door RJ45 network access port. Power for the components in the compartment shall be supplied by a pre-wired, bus-connected control transformer in the compartment that is fused and has a disconnecting means.
 - 3. The included communications components shall be a Power Xpert Ethernet Switch(es) .
 - 4. The communication system network shall be Cutler-Hammer type PowerXpert Architecture.

2.13 ENCLOSURES

- A. NEMA 1 Enclosure-Indoors
- B. NEMA 3R Enclosure Outdoors or Wet Locations

2.14 NAMEPLATES

- A. Engraved nameplates, mounted on the face of the assembly, shall be furnished for all main and feeder circuits as indicated on the drawings. Nameplates shall be laminated plastic, black characters on white background, and secured with screws. Characters shall be 3/16-inch high, minimum.
- B. Furnish master nameplate giving switchgear designation, voltage ampere rating, short-circuit rating, and manufacturer's name.
- C. Control components mounted within the assembly, such as fuse blocks, relays, pushbuttons, switches, etc., shall be suitably marked for identification corresponding to appropriate designations on manufacturer's drawings,

2.15 FINISH

- A. All exterior and interior steel surfaces of the switchgear shall be properly cleaned and provided with a rust-inhibiting phosphatized coating. Color and finish of the switchgear shall be ANSI 61.

2.16 ACCESSORIES

- A. Provide a traveling type circuit breaker lifter, rail-mounted on top of switchgear.

2.17 SURGE PROTECTIVE DEVICES

- A. Provide surge protective devices as specified in Section 16289 "SURGE PROTECTION FOR LOW-VOLTAGE ELECTRIC POWER CIRCUITS."

PART 3 - EXECUTION

3.1 FACTORY TESTING

- A. The switchgear shall be completely assembled, wired, adjusted and tested at the factory. After assembly, the complete switchgear shall be tested to ensure the accuracy of the wiring and the functioning of all equipment. The main bus system shall be given a dielectric test of 2200 volts for one minute between live parts and ground and between opposite polarities.
- B. The wiring and control circuits shall be given a dielectric test of 1500 volts for one minute, or 1800 volts for one second, between live parts and ground, in accordance with ANSI C37.20.1.
- C. A certified test report of all standard production tests shall be shipped with each assembly.
- D. Factory test as outlined above shall be witnessed by the MBTA's representative.
 - 1. The manufacturer shall notify MBTA two (2) weeks prior to the date the tests are to be performed
 - 2. The manufacturer shall include the cost of transportation and lodging for up to three (3) manufacturer's representatives. The cost of meals and incidental expenses shall be the manufacturer's responsibility.

3.2 FIELD QUALITY CONTROL

- A. Provide the services of a qualified factory-trained manufacturer's representative to assist the Design-Builder in installation and start-up of the equipment specified under this section for a period of 10 working days. The manufacturer's representative shall provide technical direction and assistance to the Design-Builder in general assembly of the equipment, connections and adjustments, and testing of the assembly and components contained therein.
- B. The Design-Builder shall provide three (3) copies of the manufacturer's field startup report.

3.3 MANUFACTURER'S CERTIFICATION

- A. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations.
- B. The Design-Builder shall provide three (3) copies of the manufacturer's representative's certification before final payment.

3.4 TRAINING

- A. The Design-Builder shall provide a training session for up to five (5) MBTA's representatives for 5 normal workdays at a job site location determined by MBTA.
- B. The training session shall be conducted by a manufacturer's qualified representative. The training program shall consist of the instruction on the operation of the assembly, circuit breakers, and major components within the assembly.

3.5 INSTALLATION

- A. The Design-Builder shall install all equipment per the manufacturer's recommendations and the contract drawings.
- B. All necessary hardware to secure the assembly in place shall be provided by the Design-Builder.
- C. The equipment shall be installed and checked in accordance with the manufacturer's recommendations. This shall include but not limited to:
 - 1. Checking to ensure that the pad location is level to within 0.125 inches per three foot of distance in any direction.
 - 2. Checking to ensure that all bus bars are torqued to the manufacturer's recommendations.
 - 3. Assembling all shipping sections, removing all shipping braces and connecting all shipping split mechanical and electrical connections.
 - 4. Securing assemblies to foundation or floor channels.
 - 5. Measuring and recording Megger readings phase-to-phase, phase-to-ground, and neutral-to-ground (four wire systems only).
 - 6. Inspecting and installing all circuit breakers in their proper compartments.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16460

LOW VOLTAGE TRANSFORMERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 DESCRIPTION

- A. Work Included: This Section specifies furnishing and installing lighting and secondary power distribution transformers.

1.3 SUBMITTALS

- A. Prior to purchase, submit for approval certified manufacturer's test data for each type and rating of transformer from each manufacturer, of the following tests conducted within the past two years:
 - 1. Applicable ANSI/IEEE Std. 462 routine and optional tests.
 - 2. Noise Level Tests
- B. Performance and Test Data. Submit guaranteed performance data consisting of losses, no load and full load, % impedance, % regulation at 1.0 and 0.8 power factor, and the average and maximum sound level in db; and all test data. Data must be corrected to the appropriate NEMA reference temperatures.
- C. Shop Drawings. Include physical drawings or catalog cuts showing all dimensions, weight, wiring diagrams or catalog cuts showing primary and secondary connections, taps, ratings and characteristics, anchor bolt plan or mounting brackets or platforms furnished separate from the transformer, and grounding requirements.
- D. Submit evidence of UL listing or label.

1.4 QUALITY ASSURANCE

- A. Perform the following shop tests at the transformer manufacturer's plant:
 - 1. Prior to Purchase: As specified in Part 1 "Submittals" Article.
 - 2. Prior to Delivery: All applicable routine tests specified in ANSI/IEEE Std. 62 and all applicable optional tests on one of each type and rating by the same manufacturer; ANSI/UL 506 and ANSI/NEMA Pub. No. ST 1 requirements as applicable; noise level test on each transformer.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS

- A. Flux Density: Sufficiently below saturation to allow a minimum of 10 % over-voltage excitation.
- B. Noise Level: Not exceeding limits set by cited standards or local regulations, and not exceeding the following:

Equipment Rating, kva	Average Sound Level, db
0-9	40
10-50	45
51-150	50
151-300	55
above 300	58

- C. Finishes: Thoroughly cleaned, degreased, coated with hot phosphate chemical bath, corrosion inhibiting primer or undercoat, and overall finish coat of manufacturer's standard electrical grey pigmented paint, as approved.

2.2 GENERAL PURPOSE TRANSFORMERS

A. General Requirements

1. All applicable ANSI/IEEE Std. 462 and UL requirements; and NEMA TR 1, TR 11, or ST 1-4 requirements, as applicable. Indoor dry type, primary and secondary copper windings, self-cooled, with class H insulation at 40 degree C ambient temperature, but with winding rise limited to 115 degrees C.
2. Transformer coils: Vacuum impregnated with non-hygroscopic, thermosetting varnish, final wrap of electric insulating material designed to prevent injury to the magnet wire. Transformers having coils with magnet wire visible will not be acceptable.
3. The core and coil: Completely isolated from the enclosure by means of vibration absorbing mounts with no metal-to-metal contact between the core and coil and the enclosure. On units 500 KVA and smaller, the vibration isolating system shall be designed to provide continual securement of the core and coil unit to the enclosure. Sound isolating systems requiring the removal of all tie-down facilities will not be acceptable.
4. All ventilating openings: Louvered type; expanded metal coverings will not be accepted. The base of the transformers shall be constructed of twelve gauge steel minimum with stamped openings for ventilation.
5. Provide lifting eyes or provisions on transformer enclosures, holes in the enclosures requiring the use of spreader bars will not be acceptable.
6. Core and coils: Visibly grounded to the frame of the transformer cubicle by means of a flexible grounding strap of adequate size.

B. Ratings

1. Voltage: Primary, 480 unless otherwise indicated. Secondary, single phase, 240/120; three phase, 208Y/120.
2. KVA Rating: Single or three-phase as indicated, 60 hz.
3. Class: AA
4. Rise Rating: 15 kva and above, 150 degrees C; below 15 kva, 80 degrees C.
5. Enclosure: Totally enclosed; non-ventilating through 15 kva, 3-phase and 25 kva, single-phase; non-ventilated or ventilated or ventilated dripproof at higher kva ratings.
6. Mounting: 45 kva and below, wall mounting type unless otherwise indicated; above 45 kva, floor or platform mounting type.
7. Taps
 - a. Single phase, less than 15 kva, two 5 % taps below rated voltage; 15 kva and above, six 2-1/2 % increment taps on primary, two above and four below rated voltage.
 - b. Three phase, below 30 kva, four 2-1/2 % increment taps on primary, two above and two below rated voltage on primary; 30 kva and above, two above and four below rated voltage.
8. Busses: Tinned copper.

PART 3 - EXECUTION

3.1 GENERAL

- A. Install transformers in accordance with manufacturer's instructions.
- B. Conduit Connections. Use flexible metal conduit not less than 18 inches or more than 36 inches in length unless otherwise indicated.
- C. Comply with NFPA 70, Article 450 and ANSI C2, Section 15.
- D. Comply with manufacturer's instructions and ANSI C57.94. Mount 5 kva and larger transformers on vibration damping and noise reducing supports or devices to further reduce the noise level below that above specified.
- E. Grounding: Section 16060 - Grounding and Bonding.
- F. Wiring and Miscellaneous Electrical Work: Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK. Bring primary service to transformer as necessary. Take secondary service to panelboards or other equipment. Wire transformers and related equipment as indicated and in accordance with mini power centers as specified for panelboards, Section 16471 - DISTRIBUTION AND BRANCH CIRCUIT PANELBOARDS.
- G. Apply approved touch-up paint as necessary.

3.2 ENERGIZING AND TESTING

- A. Verify that circuits are connected as indicated.

- B. Perform insulation and circuit continuity tests prior to connecting primary service.
- C. Test all circuit breakers, switches and miniature unit power centers as specified for panelboards, Section 16471 - DISTRIBUTION AND BRANCH CIRCUIT PANELBOARDS.

3.3 DIELECTRIC TESTS

- A. Ensure that the resistance of transformer and equipment enclosures to ground is not over two ohms.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16471
PANELBOARDS
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 DESCRIPTION OF WORK

- A. Work Included: This Section specifies distribution and branch circuit panelboards and panelboard enclosures.

1.3 SUBMITTALS

- A. Submit for approval catalog cuts, drawings, and data, for each item, indicating the following:
 - 1. Manufacturer's model number or item identification.
 - 2. UL listing and rating.
 - 3. Critical dimensions and mounting arrangements.
 - 4. Complete replacement parts list.
- B. Enclosures: Materials and methods of construction, door arrangement, conduit hub and knockout locations, and identification of intended panelboard.
- C. Circuit Breakers: Circuit for which intended, voltage ratings, insulation level, current rating, and interrupting ratings.
- D. Panelboards: Base material, general arrangement, location and identification of each circuit breaker and the circuit breaker information specified above, location and identification of all terminals, location of barriers, applicable UL 67 Tables A through F information, wiring diagrams, and identification of the enclosure for which intended.

1.4 QUALITY ASSURANCE

- A. Manufacturing: Manufacturer's and UL standard inspecting and testing procedures.
- B. UL Labels
 - 1. Each factory-assembled enclosure panelboard.
 - 2. Each panelboard shipped separately.
 - 3. Each circuit breaker shipped for field mounting.
- C. Panels shall be fully Rated. Series rating will not be accepted.

- D. Emergency system must be fully coordinated. The panels shall be fused type to conform.
- E. . Listing and Special Marking
 - 1. Each enclosure shipped separate from panelboard shall be UL listed and marked with the identification of the panelboard for which intended.
 - 2. Raintight marking for all enclosures exposed to weather or unusual spray or moisture conditions.

PART 2 - PRODUCTS

2.1 GENERAL

- A. Approved manufacturers:
 - 1. Eaton
 - 2. GE
 - 3. Siemens
 - 4. Cutler-Hammer
- B. Distribution and branch circuit panels shall be enclosed, completely factory assembled type, dead-front grounded enclosure complete with circuit breakers as required. Design and assemble interiors so that any individual breaker can be replaced without disturbing adjacent units or without removing main bus connectors. Design main buses and back pans of distribution panelboards such that branch circuits may be changed without additional machining, drilling or tapping.
- C. Materials of construction: UL 67; appropriate NEMA Standards, UL listed.
- D. Field Wiring and Miscellaneous Hardware: Section 16050 – “BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK” and Section 16060 – “GROUNDING AND BONDING”.
- E. A minimum of 25% spare breakers shall be provided in each panelboard.
- F. Field Touch-up or Repainting Paint: As recommended by enclosure manufacturer..

2.2 CIRCUIT BREAKERS

- A. Circuit Breakers of the Same Ratings: Interchangeable, quick-make, quick-break.
- B. Circuit Breakers shall have an interrupting rating not less than 150% of calculated RMS ampere at each location.
- C. Circuit breakers shall be of the indicating type, providing "on", "off", and "tripped" positions of the operating handle. When the breaker is tripped automatically, the handle shall assume a middle position between "on" and "off". All multi-pole breakers shall be so designed that an overload on one pole automatically causes all poles to open. The circuit breaker shall be quick-make and quick-break on manual as well as automatic operation and shall have inverse time characteristics secured using a bimetallic tripping element supplemented by a magnetic trip.

- D. The branch circuit breakers shall have fixed thermal-magnetic trips. All breakers shall be bolt-on type.
- E. Provide handle "lock-on" devices on the circuit breakers indicated on the schedules. "Lock-on" devices shall prevent accidental de-energization of critical circuits. These devices shall be trip-free, permitting the circuit breaker to trip automatically on overload. Provide one "lock/on" device for every four circuit breakers indicated in the lighting and power panels. Furnish the Authority for future use all "lock-on" devices not installed.
- F. Panels shall be fully rated. Series rating will not be accepted.

2.3 ENCLOSURES

- A. Panel type with butt hinged door on door with cylinder housing capable of receiving keyed cylinder type lock. Trim must also be hinged.
- B. Mark enclosures for easy identification of intended panelboard unless panelboard is shipped factory installed.
- C. Enclosures for mounting exposed to the weather or in unusually wet locations shall be, NEMA Type 4X, Stainless Steel. All indoor panels enclosures shall be standard NEMA Type 1.
- D. Directory: Card type, suitable for typewriting directory of circuits, mounted under unbreakable transparent protective cover set in metal frame on inside of door, with provisions for:
 - 1. Panel designation and panel or switchboard from which panel is fed.
 - 2. For each circuit breaker, complete information concerning the circuit controlled, including the voltage and the area, room number, or appliances served; or Main or Spare as applicable.
- E. Finish: Thoroughly cleaned, phosphatized or equivalent, coated with at least one coat of corrosion resisting paint inside and out suitable for the material, and painted with manufacturer's standard electrical grey paint suitable for touch-up or repainting in the field.

2.4 PANELBOARDS

- A. UL listed and UL labeled unless shipped as a factory-mounted component of a UL labeled enclosed type panelboard with bases not over 48 inches' top edge to bottom edge.
- B. Interrupting Devices: Circuit breaker type except where cutouts, meter fuses, or switches are specifically indicated. All cutouts, fuses and pull-out type, UL listed.
- C. Panelboards, shall be equipped with a main protective device consisting of a three-pole circuit breaker. Ratings shall be indicated on the panelboard schedules.
- D. Panelboards shall be furnished with an insulated solid 100% neutral bus, and a suitable grounding, bus-connected to interior of panel enclosure for termination of green equipment grounding conductor.
- E. Panelboards shall be provided with identification nameplate as specified in Section 16553- "IDENTIFICATION FOR ELECTRICAL SYSTEMS".

- F. Terminals: Rated solderless type, suitable for copper conductors sized at maximum rated terminal capacity.
- G. Buses and Connecting Straps: Solid copper, main bus rated at the sum of the branch circuit ratings, including motor loads in accordance with Section 430-24 of the National Electrical Code plus 100% of the sum of the trip ratings of the spares specified in paragraphs above, but in no case less than specified in UL 67. Full neutral bus and separate ground bus.
- H. Color markings per optional provision UL 67, Paragraph 143.
- I. Marking for easy identification of intended enclosure unless shipped factory mounted in enclosure.
- J. Permanent numerical identification by each breaker space.
- K. Panelboard cabinets shall have means for securing, supporting, and adjusting the panelboards and trim.
- L. Panelboard gutter space shall be as required by the MEC.
- M. Where gutter spaces are occupied by feeder cables, gutter spaces shall be increased as required.
- N. Panelboard cabinets shall be ordered without knockouts.
- O. All panelboard covers and doors must be hinged (DOOR-IN-DOOR construction).

2.5 PANELBOARDS

- A. Panelboards shall be 480/277 Volt or 208/120 Volt, three phase, four wire, and shall have bolt-in type molded case circuit breakers.

PART 3 - EXECUTION

3.1 GENERAL

- A. Prior to commencing installation, verify that all surfaces upon or in which enclosures are to be mounted are properly prepared and that all pre-mounting wire pulling has been completed and properly tagged. Take corrective action if necessary.
- B. Verify that enclosure mounting provisions are suitable for intended mounting. Make corrective adjustments, if necessary.
- C. Verify that all factory-installed circuit breakers are correct rating for the applicable circuit application as indicated. Take corrective action if necessary.
- D. Install panelboards in enclosures in accordance with manufacturer's instructions, if practicable before mounting enclosure.
- E. Complete all directory cards with the information indicated in Part 2 "Enclosures" Article above. Typewrite information on directory cards.

3.2 ENCLOSURES AND PANELBOARDS

- A. Install at approved locations in accordance with manufacturer's instructions, and at convenient operating height such that no manually operable device will be within 2- 1/2 feet of the floor or more than 6-1/2 feet above the floor, and so that the mid-point of all manually operable devices is as nearly as practicable 5-1/2 feet above the floor without exceeding the above maximum height limitations.
- B. Adjust straight and plumb and fasten securely in place. Align and securely and independently fasten each section of multi-section enclosures.

3.3 WIRING

- A. Perform wiring in accordance with Section 16519-“LOW VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES”, and UL 67; Massachusetts Electrical Code (MEC), and manufacturer's instructions.
- B. Ground as specified Section 16060 – “GROUNDING AND BONDING”.
- C. Neatly route, harness and support conductors in gutters, wiring spaces and compartments. Bending radii not less than recommended by conductor manufacturer.
- D. Verify that circuits are wired as indicated and are continuous and free of shorts. Energize, as permitted by Owner, and test each circuit, including lights and outlets. Check voltage at outlets. Test other electrical equipment as recommended by manufacturer. Measure ground bus and grounded conductor resistance to true ground, resistance between enclosure and ground bus, between pairs of bus bars, and between insulation and ground bus. Resistances shall be within limits specified in Part 3 “Acceptance Tests” Article. If resistances are not within the limits specified, the cause of such resistances shall be determined and corrective action shall be taken to obtain the acceptable resistances specified.
- E. Install bonding jumpers from conduits entering cabinets to ground bus.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 “Payment”

END OF SECTION

SECTION 16491

FUSES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Cartridge fuses rated 600-V ac and less for use in control circuits, enclosed switches panelboards, switchboards, enclosed controllers, and motor-control centers.
 - 2. Plug fuses rated 125-V ac and less for use in plug-fuse-type enclosed switches fuseholders and panelboards.
 - 3. Plug-fuse adapters for use in Edison-base, plug-fuse sockets.
 - 4. Spare-fuse cabinet at VMF.

1.3 SUBMITTALS

- A. Product Data: For each type of product indicated. Include construction details, material, dimensions, descriptions of individual components, . Include the following for each fuse type:
 - 1. Ambient Temperature Adjustment Information: If ratings of fuses have been adjusted to accommodate ambient temperatures, provide list of fuses with adjusted ratings.
 - a. For each fuse having adjusted ratings, include location of fuse, original fuse rating, local ambient temperature, and adjusted fuse rating.
 - b. Provide manufacturer's technical data on which ambient temperature adjustment calculations are based.
 - 2. Dimensions and manufacturer's technical data on features, performance, electrical characteristics, and ratings.
 - 3. Current-limitation curves for fuses with current-limiting characteristics.
 - 4. Time-current curves and current-limitation curves (instantaneous peak let-through current) for each type and rating of fuse.
 - 5. Fuse sizes for elevator feeders and elevator disconnect switches.

1.4 QUALITY ASSURANCE

- A. Source Limitations: Obtain fuses, for use within a specific product or circuit, from single source from single manufacturer.

- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- C. Comply with NEMA FU 1 for cartridge fuses.
- D. Comply with Massachusetts Electrical Code (MEC).

1.5 PROJECT CONDITIONS

- A. Where ambient temperature to which fuses are directly exposed is less than 40 deg F or more than 100 deg F, apply manufacturer's ambient temperature adjustment factors to fuse ratings.
- B. Coordinate fuse ratings with utilization equipment nameplate limitations of maximum fuse size and with system short-circuit current levels.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. Cooper Bussmann, Inc.
 - 2. Edison Fuse, Inc.
 - 3. Ferraz Shawmut, Inc.
 - 4. Littelfuse, Inc.

2.2 CARTRIDGE FUSES

- A. Characteristics: NEMA FU 1, nonrenewable cartridge fuses with voltage ratings consistent with circuit voltages.

2.3 PLUG FUSES

- A. Characteristics: UL 248-11, nonrenewable plug fuses; 125-V ac.

2.4 PLUG-FUSE ADAPTERS

- A. Characteristics: Adapters for using Type S, rejection-base plug fuses in Edison-base fuseholders or sockets; ampere ratings matching fuse ratings; irremovable once installed.

2.5 SPARE-FUSE CABINET

- A. Characteristics: Wall-mounted steel unit with full-length, recessed piano-hinged door and key-coded cam lock and pull.

1. Size: Adequate for storage of spare fuses specified with 15 % spare capacity minimum.
2. Finish: Gray, baked enamel.
3. Identification: "SPARE FUSES" in 1-1/2-inch-high letters on exterior of door.
4. Fuse Pullers: For each size of fuse, where applicable and available, from fuse manufacturer.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine fuses before installation. Reject fuses that are moisture damaged or physically damaged.
- B. Examine holders to receive fuses for compliance with installation tolerances and other conditions affecting performance, such as rejection features.
- C. Examine utilization equipment nameplates and installation instructions. Install fuses of sizes and with characteristics appropriate for each piece of equipment.
- D. Evaluate ambient temperatures to determine if fuse rating adjustment factors must be applied to fuse ratings.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 FUSE APPLICATIONS

- A. Cartridge Fuses:
 1. Service Entrance: Class RK1.
 2. Feeders: Class RK5.
 3. Motor Branch Circuits: Class RK5, Dual element, time delay.
 4. Other Branch Circuits: Class J, dual element, time delay.
 5. Control Circuits: Class CC, fast acting.

3.3 INSTALLATION

- A. Install fuses in fusible devices. Arrange fuses so rating information is readable without removing fuse.

3.4 IDENTIFICATION

- A. Install labels complying with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION" and indicating fuse replacement information on inside door of each fused switch and adjacent to each fuse block, socket, and holder.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16510
INTERIOR LIGHTING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Interior lighting fixtures, lamps, and ballasts.
 - 2. Emergency lighting units.
 - 3. Exit signs.
 - 4. Lighting fixture supports.
- B. Related Sections:
 - 1. Section 16145 "Lighting Control Devices" for automatic control of lighting, including time switches, photoelectric relays, occupancy sensors, and multipole lighting relays and contactors.

1.3 DEFINITIONS

- A. BF: Ballast factor.
- B. CCT: Correlated color temperature.
- C. CRI: Color-rendering index.
- D. HID: High-intensity discharge.
- E. LER: Luminaire efficacy rating.
- F. Lumen: Measured output of lamp and luminaire, or both.
- G. Luminaire: Complete lighting fixture, including ballast housing if provided.

1.4 SUBMITTALS

- A. Product Data: For each type of lighting fixture, arranged in order of fixture designation. Include data on features, accessories, finishes, and the following:
 - 1. Physical description of lighting fixture including dimensions.
 - 2. Emergency lighting units including battery and charger.

3. Ballast, including BF.
 4. Energy-efficiency data.
 5. Life, output (lumens, CCT, and CRI), and energy-efficiency data for lamps.
 6. Photometric data and adjustment factors based on laboratory tests, complying with IESNA Lighting Measurements Testing & Calculation Guides, of each lighting fixture type. The adjustment factors shall be for lamps, ballasts, and accessories identical to those indicated for the lighting fixture as applied in this Project.
 - a. Manufacturer Certified Data: Photometric data shall be certified by a manufacturer's laboratory with a current accreditation under the National Voluntary Laboratory Accreditation Program for Energy Efficient Lighting Products.
- B. Installation instructions.

1.5 QUALITY ASSURANCE

- A. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by manufacturers' laboratories that are accredited under the National Volunteer Laboratory Accreditation Program for Energy Efficient Lighting Products.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in Massachusetts Electrical Code, by a qualified testing agency, and marked for intended location and application.

1.6 COORDINATION

- A. Coordinate layout and installation of lighting fixtures and suspension system with other construction that penetrates ceilings or is supported by them, including HVAC equipment, fire-suppression system, and partition assemblies.

1.7 WARRANTY

- A. All equipment shall be guaranteed for a period of one year after final acceptance by MBTA.
- B. Warranty shall include all labor and material.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Products: Products that meet the project requirements.

2.2 GENERAL REQUIREMENTS FOR LIGHTING FIXTURES AND COMPONENTS

- A. All lighting fixtures shall be IP66 rated as approved by MBTA.
- B. Recessed Fixtures: Comply with NEMA LE 4 for ceiling compatibility for recessed fixtures.

- C. Fluorescent Fixtures: Comply with UL 1598. Where LER is specified, test according to NEMA LE 5 and NEMA LE 5A as applicable.
- D. LED: Refer to section 16511.
- E. Metal Parts: Free of burrs and sharp corners and edges.
- F. Sheet Metal Components: Steel unless otherwise indicated. Form and support to prevent warping and sagging.
- G. Doors, Frames, and Other Internal Access: Smooth operating, free of light leakage under operating conditions, and designed to permit re-lamping without use of tools. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position.
- H. Diffusers and Globes:
 - 1. Acrylic Lighting Diffusers: 100 % virgin acrylic plastic. High resistance to yellowing and other changes due to aging, exposure to heat, and UV radiation.
 - a. Lens Thickness: At least [**0.125 inch**] minimum unless otherwise indicated.
 - b. UV stabilized.
 - 2. Glass: Annealed crystal glass unless otherwise indicated.
- I. Factory-Applied Labels: Comply with UL 1598. Include recommended lamps and ballasts. Labels shall be located where they will be readily visible to service personnel, but not seen from normal viewing angles when lamps are in place.
 - 1. Label shall include the following lamp and ballast characteristics:
 - a. "USE ONLY" and include specific lamp type.
 - b. Lamp diameter code (T-4, T-5, T-8, T-12, etc.), tube configuration (twin, quad, triple, etc.), base type, and nominal wattage for fluorescent and compact fluorescent luminaires.
 - c. Lamp type, wattage, bulb type (ED17, BD56, etc.) and coating (clear or coated) for HID luminaires.
 - d. Start type (preheat, rapid start, instant start, etc.) for fluorescent and compact fluorescent luminaires.
 - e. ANSI ballast type (M98, M57, etc.) for HID luminaires.
 - f. CCT and CRI for all luminaires.
- J. Electromagnetic-Interference Filters: Factory installed to suppress conducted electromagnetic interference as required by MIL-STD-461E. Fabricate lighting fixtures with one filter on each ballast indicated to require a filter.
 - 1. BALLASTS FOR FLUORESCENT Ballasts shall be new, UL listed and as required for intended use.
 - 2. Electronic ballasts shall be provided.

2.3 EXIT SIGNS

- A. General Requirements for Exit Signs: Comply with authorities having jurisdiction (AHJ) and MBTA's standards.

- B. EXIT signs shall be LED type.

2.4 FLUORESCENT LAMPS

- A. T8 rapid-start lamps, rated 32 W maximum, nominal length of 48 inches, 2800 initial lumens (minimum), CRI 75 (minimum), color temperature [3500] K, and average rated life 20,000 hours unless otherwise indicated.
- B. T8 rapid-start lamps, rated 17 W maximum, nominal length of 24 inches, 1300 initial lumens (minimum), CRI 75 (minimum), color temperature [3500] K, and average rated life of 20,000 hours unless otherwise indicated.
- C. T5 rapid-start lamps, rated 28 W maximum, nominal length of 45.2 inches, 2900 initial lumens (minimum), CRI 85 (minimum), color temperature [3000] K, and average rated life of 20,000 hours unless otherwise indicated.
- D. T5HO rapid-start, high-output lamps, rated 54 W maximum, nominal length of 45.2 inches, 5000 initial lumens (minimum), CRI 85 (minimum), color temperature [4100] K, and average rated life of 20,000 hours unless otherwise indicated.
- E. Compact Fluorescent Lamps: 4-Pin, CRI 80 (minimum), color temperature [3500] K, average rated life of 10,000 hours at three hours operation per start.
 - 1. 13 W: T4, double or triple tube, rated 900 initial lumens (minimum).
 - 2. 18 W: T4, double or triple tube, rated 1200 initial lumens (minimum).
 - 3. 26 W: T4, double or triple tube, rated 1800 initial lumens (minimum).
 - 4. 32 W: T4, triple tube, rated 2400 initial lumens (minimum).
 - 5. 42 W: T4, triple tube, rated 3200 initial lumens (minimum).
 - 6. 57 W: T4, triple tube, rated 4300 initial lumens (minimum).
 - 7. 70 W: T4, triple tube, rated 5200 initial lumens (minimum).

2.5 LIGHTING FIXTURE SUPPORT COMPONENTS

- A. Comply with Section 16073 "Hangers and Supports for Electrical Systems" for channel- and angle-iron supports and nonmetallic channel and angle supports.
- B. Single-Stem Hangers: 1/2-inch steel tubing with swivel ball fittings and ceiling canopy. Finish same as fixture.
- C. Twin-Stem Hangers: Two, 1/2-inch steel tubes with single canopy designed to mount a single fixture. Finish same as fixture.
- D. Wires: ASTM A 641/A 641M, Class 3, soft temper, zinc-coated steel, [12 gage].
- E. Rod Hangers: 3/16-inch minimum diameter, cadmium-plated, threaded steel rod.
- F. Hook Hangers: Integrated assembly matched to fixture and line voltage and equipped with threaded attachment, cord, and locking-type plug.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Lighting fixtures:
 - 1. Set level, plumb, and square with ceilings and walls unless otherwise indicated.
 - 2. Install lamps in each luminaire.
- B. Remote Mounting of Ballasts: Distance between the ballast and fixture shall not exceed that recommended by ballast manufacturer. Verify, with ballast manufacturers, maximum distance between ballast and luminaire.
- C. Lay-in Ceiling Lighting Fixtures Supports:
 - 1. Fixtures shall be independently supported from the ceiling grid.
 - 2. Supports shall meet the seismic requirements for the seismic area.
- D. Suspended Lighting Fixture Support:
 - 1. Pendants and Rods: Where longer than 48 inches, brace to limit swinging.
 - 2. Stem-Mounted, Single-Unit Fixtures: Suspend with twin-stem hangers.
 - 3. Continuous Rows: Use tubing or stem for wiring at one point and tubing or rod for suspension for each unit length of fixture chassis, including one at each end.
 - 4. Do not use ceiling grid as support for pendant luminaires. Connect support wires or rods to building structure.
- E. Connect wiring per Section 16519 "Low-Voltage Electrical Power Conductors and Cables."

3.2 IDENTIFICATION

- A. Install labels with panel and circuit numbers on concealed junction and outlet boxes. Comply with requirements for identification specified in Section 16195 "Electrical Identification."

3.3 FIELD QUALITY CONTROL

- A. Test for Emergency Lighting: Interrupt power supply to demonstrate proper operation. Verify transfer from normal power to battery UPS and retransfer to normal.
- B. Prepare a written report of tests, inspections, observations, and verifications indicating and interpreting results. If adjustments are made to lighting system, retest to demonstrate compliance with standards.
- C. Properly clean all fixtures at end of construction period.

3.4 ADJUSTING

- A. Occupancy Adjustments: Adjust amiable fixtures as required for proper illumination.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16511

LED INTERIOR LIGHTING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes the following types of LED luminaires:
 - 1. Cylinder.
 - 2. Downlight.
 - 3. Linear industrial.
 - 4. Low
 - 5. Recessed linear.
 - 6. Strip light.
 - 7. Surface mount, linear.
 - 8. Surface mount, nonlinear.
 - 9. Suspended, linear.
 - 10. Suspended, nonlinear.
 - 11. Materials.
 - 12. Finishes.
 - 13. Luminaire support.

1.3 DEFINITIONS

- A. CCT: Correlated color temperature.
- B. CRI: Color Rendering Index.
- C. Fixture: See "Luminaire."
- D. IP: International Protection or Ingress Protection Rating.
- E. LED: Light-emitting diode.
- F. Lumen: Measured output of lamp and luminaire, or both.
- G. Luminaire: Complete lighting unit, including lamp, reflector, and housing.

1.4 SUBMITTALS

- A. Product Data: For each type of product.

1. Arrange in order of luminaire designation.
2. Include data on features, accessories, and finishes.
3. Include physical description and dimensions of luminaires.
4. Include emergency lighting units, including batteries and chargers.
5. Include life, output (lumens, CCT, and CRI), and energy efficiency data.
 - a. Photometric data and adjustment factors based on laboratory tests Manufacturers' Certified Data: Photometric data certified by manufacturer's laboratory with a current accreditation under the National Voluntary Laboratory Accreditation Program for Energy Efficient Lighting Products.
 - b. Testing Agency Certified Data: For indicated luminaires, photometric data certified by a qualified independent testing agency. Photometric data for remaining luminaires shall be certified by manufacturer.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
 1. Luminaires.
 2. Suspended ceiling components.
 3. Partitions and millwork that penetrate the ceiling or extend to within 12 inches of the plane of the luminaires.
 4. Structural members to which luminaires will be attached.
 5. Initial access modules for acoustical tile, including size and locations.
 6. Items penetrating finished ceiling, including the following:
 - a. Other luminaires.
 - b. Air outlets and inlets.
 - c. Speakers.
 - d. Sprinklers.
 - e. Access panels.
 - f. Ceiling-mounted projectors.
 - g. Foot candle levels

1.6 QUALITY ASSURANCE

- A. Luminaire Photometric Data Testing Laboratory Qualifications: Luminaire manufacturer's laboratory that is accredited under the NVLAP for Energy Efficient Lighting Products.
- B. Provide luminaires from a single manufacturer for each luminaire type.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Protect finishes of exposed surfaces by applying a strippable, temporary protective covering before shipping.

1.8 WARRANTY

- A. Warranty: Manufacturer and Installer agree to repair or replace components of luminaires that fail in materials or workmanship within specified warranty period.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Luminaires and lamps shall be G3 labeled vibration and shock resistant.

2.2 LUMINAIRE REQUIREMENTS

- A. All luminaires shall be IP66 rated as approved by MBTA.
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in Massachusetts Electrical Code (MEC), by a qualified testing agency, and marked for intended location and application.
- C. Standards:
 - 1. UL listed.
- D. 3500K

2.3 MATERIALS

- A. Metal Parts:
 - 1. Free of burrs and sharp corners and edges.
 - 2. Sheet metal components shall be steel unless otherwise indicated.
 - 3. Form and support to prevent warping and sagging.
- B. Doors, Frames, and Other Internal Access: Smooth operating, free of light leakage under operating conditions, and designed to permit relamping without use of tools. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position.
 - a. CCT and CRI for all luminaires.

2.4 LUMINAIRE SUPPORT

- A. Comply with requirements in Section 16073 "Hangers and Supports " for channel and angle iron supports and nonmetallic channel and angle supports.
- B. Single-Stem Hangers: 1/2-inch steel tubing with swivel ball fittings and ceiling canopy. Finish same as luminaire.

- C. Rod Hangers: 3/16-inch minimum diameter, stainless steel, threaded steel rod.
- D. Hook Hangers: Integrated assembly matched to luminaire, line voltage, and equipment with threaded attachment, cord, and locking-type plug.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for luminaire to verify actual locations of luminaire and electrical connections before luminaire installation. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Comply with NECA 1.
- B. Install luminaires level, plumb, and square with ceilings and walls unless otherwise indicated.
- C. Install lamps in each luminaire.

3.3 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195, "ELECTRICAL IDENTIFICATION".

3.4 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting the direction of aim of luminaires to suit occupied conditions
 - 1. During adjustment visits, inspect all luminaires. Replace lamps or luminaires that are defective.
 - 2. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.
 - 3. Adjust the aim of luminaires in the presence of the Architect.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16519

LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Copper building wire rated 600 V or less.
 - 2. Metal-clad cable, Type MC, rated 600 V or less.
 - 3. Mineral-insulated cable, Type MI, rated 600 V or less.
 - 4. Connectors, splices, and terminations rated 600 V and less.
- B. Related Requirements:
 - 1. Section 16523 "Control-Voltage Electrical Power Cables" for control systems communications cables and Classes 1, 2, and 3 control cables.

1.3 DEFINITIONS

- A. VFC: Variable-frequency controller.

1.4 SUBMITTALS

- A. Product Data: For each type of product.

1.5 QUALITY ASSURANCE

- A. Product shall be new and UL listed.

PART 2 - PRODUCTS

2.1 COPPER BUILDING WIRE

- A. Description: Flexible, insulated and uninsulated, drawn copper current-carrying conductor with an overall insulation layer or jacket, or both, rated 600 V or less.
- B. All conductor sizes shall be stranded.

C. Standards:

1. Listed and labeled as defined in Massachusetts Electrical Code (MEC), by a qualified testing agency, and marked for intended location and use.
2. Conductor and Cable Marking: Comply with wire and cable marking per UL's "Wire and Cable Marking and Application Guide."

D. Conductors: Copper, complying with ASTM B 3 for bare annealed copper and with [ASTM B 8] [ASTM B 496] for stranded conductors.

E. Conductor Insulation:

1. Type XHHW-2: Comply with UL 44.

F. Shield:

1. Type TC-ER: Cable designed for use with VFCs, with oversized crosslinked polyethylene insulation and sunlight- and oil-resistant outer PVC jacket.

2.2 METAL-CLAD CABLE, TYPE MC

A. Standards:

1. Listed and labeled as defined in MEC, by a qualified testing agency, and marked for intended location and use.
2. Comply with UL 1569.
3. Conductor and Cable Marking: Comply with wire and cable marking according to UL's "Wire and Cable Marking and Application Guide."

B. Conductors: [**Copper**]

C. Ground Conductor: [**Insulated**].

D. Conductor Insulation:

1. Type XHHW-2: Comply with UL 44.

E. Armor: [**Steel**] interlocked.

2.3 CONNECTORS AND SPLICES

- A. Description: Factory-fabricated connectors and splices of size, ampacity rating, material, type, and class for application and service indicated; and marked for intended location and use.

PART 3 - EXECUTION

3.1 CONDUCTOR MATERIAL APPLICATIONS

- A. Copper, stranded

3.2 CONDUCTOR INSULATION AND MULTICONDUCTOR CABLE APPLICATIONS AND WIRING METHODS

- A. Insulation type XHHW-2.
- B. Mineral-insulated, metal-sheathed cable, Type MI shall be used for life safety feeders unless otherwise separated from normal feeders by an approved 2-hour rated separation.
- C. Cord Drops and Portable Appliance Connections: Type SO, hard service cord with stainless-steel, wire-mesh, strain relief device at terminations to suit application.

3.3 INSTALLATION OF CONDUCTORS AND CABLES

- A. Conceal cables in finished walls, ceilings, and floors unless otherwise indicated.
- B. Complete raceway installation between conductor and cable termination points prior to pulling conductors and cables.
- C. Use manufacturer-approved pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
- D. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips, that will not damage cables or raceway.
- E. Install exposed conduit and cables parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible.
- F. Support cables per Section 16073 "Hangers and Supports for Electrical Systems."
- G. Complete cable tray systems installation according to Section 16536 "Cable Trays for Electrical Systems" prior to installing conductors and cables.

3.4 CONNECTIONS

- A. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A-486B.
- B. Make splices, terminations, and taps that are compatible with conductor material.
 - 1. Use oxide inhibitor in each splice, termination, and tap for aluminum conductors.
- C. Wiring at Outlets: Install conductor at each outlet, with at least [**6 inches**] of slack.

3.5 IDENTIFICATION

- A. Identify and color-code conductors and cables according to Section 260553 "Identification for Electrical Systems."
- B. Identify each spare conductor at each end with identity number and location of other end of conductor, and identify as spare conductor.

3.6 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 16544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.7 FIRESTOPPING

- A. Apply firestopping to electrical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly.

3.8 FIELD QUALITY CONTROL

- 1. Perform each of the following visual and electrical tests:
 - a. Inspect exposed sections of conductor and cable for physical damage and correct connection according to the single-line diagram.
 - b. Test bolted connections for high resistance using one of the following:
 - 1) A low-resistance ohmmeter.
 - 2) Calibrated torque wrench.
 - 3) Thermographic survey.
 - c. Inspect compression-applied connectors for correct cable match and indentation.
 - d. Inspect for correct identification.
 - e. Inspect cable jacket and condition.
 - f. Insulation-resistance test on each conductor for ground and adjacent conductors. Apply a potential of 500-V dc for 300-V rated cable and 1000-V dc for 600-V rated cable for a one-minute duration.
 - g. Continuity test on each conductor and cable.
 - h. Uniform resistance of parallel conductors.
- B. Cables will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports to record the following:
 - 1. Procedures used.
 - 2. Results that comply with requirements.
 - 3. Results that do not comply with requirements, and corrective action taken to achieve compliance with requirements.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16521

EXIT LIGHTING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions

1.2 SUMMARY

- A. Section Includes:
 - 1. Emergency lighting units.
 - 2. Exit signs.
 - 3. Luminaire supports.

1.3 DEFINITIONS

- A. CCT: Correlated color temperature.
- B. CRI: Color Rendering Index.
- C. Lumen: Measured output of lamp and luminaire, or both.
- D. Luminaire: Complete lighting unit, including lamp, reflector, and housing.

1.4 SUBMITTALS

- A. Product Data: For each type of emergency lighting unit, exit sign, and emergency lighting support.
 - 1. Include data on features, accessories, and finishes.
 - 2. Include physical description of the unit and dimensions.
 - 3. Include life, output of luminaire (lumens, CCT, and CRI), and energy-efficiency data.
 - 4. Include photometric data and adjustment factors based on laboratory tests, complying with IES LM-45, for each luminaire type.
 - a. Manufacturers' Certified Data: Photometric data certified by manufacturer's laboratory with a current accreditation under the National Voluntary Laboratory Accreditation Program for Energy Efficient Lighting Products.

1.5 CLOSEOUT SUBMITTALS

- A. Provide a list of all lamp types used on Project; use ANSI and manufacturers' codes.

1.6 QUALITY ASSURANCE

- A. Luminaire Photometric Data Testing Laboratory Qualifications: Luminaire manufacturer's laboratory that is accredited under the National Volunteer Laboratory Accreditation Program for Energy Efficient Lighting Products.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Protect finishes of exposed surfaces by applying a strippable, temporary protective covering before shipping.

1.8 WARRANTY

- A. Warranty: Design Builder agrees to repair or replace components of luminaires that fail in materials or workmanship within one year of acceptance by Owner.

PART 2 - PRODUCTS

2.1 GENERAL REQUIREMENTS FOR EMERGENCY LIGHTING

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- B. NRTL Compliance: Fabricate and label emergency lighting units, exit signs, and batteries to comply with UL 924.
- C. Comply with Massachusetts Electrical Code (MEC) and NFPA 101.
- D. Comply with NEMA LE 4 for recessed luminaires.

2.2 EXIT SIGNS

- A. General Requirements for Exit Signs: EXIT signs shall be LED type with green letters.
- B. Internally Lighted Signs:
 - 1. Lamps for AC Operation: LEDs; 50,000 hours minimum rated lamp life.

2.3 MATERIALS

- A. Metal Parts:
 - 1. Free of burrs and sharp corners and edges.
 - 2. Sheet metal components shall be steel unless otherwise indicated.
 - 3. Form and support to prevent warping and sagging.
- B. Doors, Frames, and Other Internal Access:

1. Smooth operating, free of light leakage under operating conditions.
2. Designed to permit relamping without use of tools.
3. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position.

2.4 LUMINAIRE SUPPORT COMPONENTS

- A. Comply with requirements in Section 16073 "Hangers and Supports .

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for conditions affecting performance of luminaires.
- B. Examine roughing-in for luminaire to verify actual locations of luminaire and electrical connections before luminaire installation.
- C. Examine walls, floors, roofs, and ceilings for suitable conditions where emergency lighting luminaires will be installed.
- D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

- A. Comply with NECA 1.
- B. Install luminaires level, plumb, and square with ceilings and walls unless otherwise indicated.
- C. Install lamps in each luminaire.
- D. Supports:
 1. Sized and rated for luminaire weight.
 2. Able to maintain luminaire position when testing emergency power unit.
 3. Provide support for luminaire and emergency power unit without causing deflection of ceiling or wall.
 4. Luminaire-mounting devices shall be capable of supporting a horizontal force of 100 percent of luminaire and emergency power unit weight and vertical force of 400 percent of luminaire weight.
- E. Wall-Mounted Luminaire Support:
 1. **[Attached to structural members in walls] [Attached to a minimum 20-gage backing plate attached to wall structural members] [Attached using through bolts and backing plates on either side of wall] <Insert means of attachment>.**
 2. Do not attach luminaires directly to gypsum board.

F. Suspended Luminaire Support:

1. Pendants and Rods: Where longer than 48 inches, brace to limit swinging.
2. Stem-Mounted, Single-Unit Luminaires: Suspend with twin-stem hangers. Support with approved outlet box and accessories that hold stem and provide damping of luminaire oscillations. Support outlet box vertically to building structure using approved devices.
3. Continuous Rows of Luminaires: Use tubing or stem for wiring at one point and [**tubing or rod**] [**wire support**] for suspension for each unit length of luminaire chassis, including one at each end.
4. Do not use ceiling grid as support for pendant luminaires. Connect support wires or rods to building structure.

G. Ceiling Grid Mounted Luminaires:

1. Secure to any required outlet box.
2. Secure emergency power unit using approved fasteners in a minimum of four locations, spaced near corners of emergency power unit.
3. Use approved devices and support components to connect luminaire to ceiling grid and building structure in a minimum of four locations, spaced near corners of luminaire.

3.3 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "ELECTRICAL IDENTIFICATION".

3.4 FIELD QUALITY CONTROL

- A. Perform the following tests and inspections:
1. Test for Emergency Lighting: Interrupt power supply to demonstrate proper operation. Verify transfer from normal power to UPS power and retransfer to normal.
- B. Luminaire will be considered defective if it does not pass operation tests and inspections.
- C. Prepare test and inspection reports.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment"

END OF SECTION

SECTION 16523

CONTROL-VOLTAGE ELECTRICAL POWER CABLES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Backboards.
 - 2. Category 6 twisted pair cable.
 - 3. Category 6a twisted pair cable.
 - 4. Twisted pair cabling hardware.
 - 5. RS-485 cabling.
 - 6. Low-voltage control cabling.
 - 7. Control-circuit conductors.
 - 8. Identification products.

1.3 DEFINITIONS

- A. EMI: Electromagnetic interference.
- B. Low Voltage: As defined in Massachusetts Electrical Code (MEC) for circuits and equipment operating at less than 50 V or for remote-control and signaling power-limited circuits.
- C. Plenum: A space forming part of the air distribution system to which one or more air ducts are connected. An air duct is a passageway, other than a plenum, for transporting air to or from heating, ventilating, or air-conditioning equipment.
- D. RCDD: Registered Communications Distribution Designer.

1.4 SUBMITTALS

- A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in MEC, by a qualified testing agency, and marked for intended location and application.

2.2 BACKBOARDS

- A. Description: Plywood, [**fire-retardant treated**] 3/4 by 48 by 96 inches. Comply with requirements for plywood backing panels in Section 061000 "Rough Carpentry."
- B. Painting: Paint plywood on all sides and edges with [**flat**] [**eggshell**] [**alkyd**] paint

2.3 CATEGORY 6 TWISTED PAIR CABLE

- A. Description: Four-pair, balanced-twisted pair cable, [**with internal spline,**] certified to meet transmission characteristics of Category 6 cable at frequencies up to 250MHz.
- B. Standard: Comply with NEMA WC 66/ICEA S-116-732 and TIA-568-C.2 for Category 6 cables.
- C. Conductors: 100-ohm, 23 AWG solid copper.
- D. Shielding/Screening: [**Shielded twisted pairs (FTP)**].
- E. Cable Rating: [**Riser**] [**Plenum**].
- F. Jacket: [**White**] [**Gray**] [**Blue**] [**Yellow**] thermoplastic.

2.4 CATEGORY 6a TWISTED PAIR CABLE

- A. Description: Four-pair, balanced-twisted pair cable [**with internal spline,**] certified to meet transmission characteristics of Category 6a cable at frequencies up to 500MHz.
- B. Standard: Comply with TIA-568-C.2 for Category 6a cables.
- C. Conductors: 100-ohm, 23 AWG solid copper.
- D. Shielding/Screening: [**Shielded twisted pairs (FTP)**].
- E. Cable Rating: [**Riser**] [**Plenum**].
- F. Jacket: [**White**] [**Gray**] [**Blue**] [**Yellow**] thermoplastic.

2.5 TWISTED PAIR CABLE HARDWARE

- A. General Requirements for Twisted Pair Cable Hardware:
 - 1. Comply with the performance requirements of [**Category 6**] [**Category 6a**] [**Category 7**].

2. Comply with TIA-568-C.2, IDC type, with modules designed for punch-down caps or tools.
 3. Cables shall be terminated with connecting hardware of same category or higher.
- B. Source Limitations: **[Obtain twisted pair cable hardware from same manufacturer as twisted pair cable, from single source]**.
- C. Jacks and Jack Assemblies:
1. Female; eight position; modular; fixed telecommunications connector designed for termination of a single four-pair 100-ohm unshielded or shielded twisted pair cable.
 2. Designed to snap-in to a patch panel or faceplate.
 3. Standards:
 - a. Category 5e, shielded twisted pair cable shall comply with IEC 60603-7-3.
 - b. Category 6, unshielded twisted pair cable shall comply with IEC 60603-7-4.
 - c. Category 6, shielded twisted pair cable shall comply with IEC 60603-7.5.
 - d. Category 6a, unshielded twisted pair cable shall comply with IEC 60603-7-41.
 - e. Category 6a, shielded twisted pair cable shall comply with IEC 60603-7.51.
 4. Marked to indicate transmission performance.
- D. Faceplate:
1. **[Two][Four]** port, vertical single-gang faceplates designed to mount to single-gang wall boxes.
 2. Faceplate: High-impact plastic. Coordinate color with Section 13272 "Wiring Devices."
 3. For use with snap-in jacks accommodating any combination of twisted pair, optical fiber, and coaxial work area cords.
 - a. Flush mounting jacks, positioning the cord at a 45-degree angle.
- E. Legend:
1. Machine printed, in the field, using adhesive-tape label.
 2. Snap-in, clear-label covers and machine-printed paper inserts.

2.6 TWIN-AXIAL DATA HIGHWAY CABLE

- A. Plenum-Rated Cable: MEC, Type CMP.
1. Paired pairs, **[No. 20]** AWG, stranded tinned-copper conductors. Size for each application, as required.
 2. Plastic insulation.
 3. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
 4. Plastic jacket.
 5. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned-copper drain wire.
 6. Flame Resistance: Comply with NFPA 262.

2.7 RS-485 CABLE

- A. Standard Cable: Massachusetts Electrical Code (MEC), Article 800.
 - 1. Paired, [**one pair**] [**two pairs**], twisted, No. 22 AWG, stranded (7x30) tinned-copper conductors.
 - 2. PVC insulation.
 - 3. Unshielded.
 - 4. PVC jacket.
 - 5. Flame Resistance: Comply with UL 1685.

- B. Plenum-Rated Cable: MEC, Type CMP.
 - 1. Paired, [**one pair**] [**two pairs**], No. 22 AWG, stranded (7x30) tinned-copper conductors.
 - 2. Fluorinated ethylene propylene insulation.
 - 3. Unshielded.
 - 4. Fluorinated ethylene propylene jacket.
 - 5. Flame Resistance: NFPA 262.

2.8 LOW-VOLTAGE CONTROL CABLE

2.9 CONTROL-CIRCUIT CONDUCTORS

- A. Class 1 Control Circuits: Stranded copper, [**Type THHN/THWN-2, complying with UL 83 in raceway**] [**Type THW, complying with UL 83 in raceway**] [**Type XHHW-2, complying with UL 44 in raceway**] [**Type TC, complying with UL 1277 in raceway**] [**Type MC, complying with UL 1569**].

- B. Class 2 Control Circuits: Stranded copper, [**Type THHN/THWN-2, complying with UL 83 in raceway**] [**Type XHHW-2, complying with UL 44 in raceway**] [**power-limited cable, concealed in building finishes**] [**power-limited tray cable, in cable tray**].

- C. Class 3 Remote-Control and Signal Circuits: Stranded copper, [**Type THHN/THWN-2, complying with UL 83 in raceway**] [**Type XHHW-2, complying with UL 44 in raceway**] [**power-limited cable, concealed in building finishes**] [**power-limited tray cable, in cable tray**] [**Type TW or Type TF, complying with UL 83, in raceway**].

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Test cables on receipt at Project site.
 - 1. Test cable for open and short circuits.

3.2 INSTALLATION OF RACEWAYS AND BOXES

- A. Comply with requirements in Section 16533 "Raceways and Boxes for Electrical Systems" for raceway selection and installation requirements for boxes, conduits.
 - 1. Outlet boxes shall be no smaller than 2 inches wide, 3 inches high, and 2-1/2 inches deep.
 - 2. Outlet boxes for cables shall be no smaller than 4 inches square by [**1-1/2 inches**] [**2-1/8 inches**] deep with extension ring sized to bring edge of ring to within 1/8 inch of the finished wall surface.
 - 3. Flexible metal conduit shall not be used.
- B. Comply with TIA-569-D for pull-box sizing and length of conduit and number of bends between pull points.
- C. Install manufactured conduit sweeps and long-radius elbows if possible.
- D. Raceway Installation in Equipment Rooms:
 - 1. Position conduit ends adjacent to a corner on backboard if a single piece of plywood is installed, or in the corner of the room if multiple sheets of plywood are installed around perimeter walls of the room.
 - 2. Install cable trays to route cables if conduits cannot be located in these positions.
 - 3. Secure conduits to backboard if entering the room from overhead.
 - 4. Extend conduits [**3 inches**] above finished floor.
 - 5. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.
- E. Backboards: Install backboards with 96-inch dimension vertical. Butt adjacent sheets tightly and form smooth gap-free corners and joints. Backboards shall be fire retardant treated.

3.3 INSTALLATION OF CONDUCTORS AND CABLES

- A. Comply with NECA 1.
- B. General Requirements for Cabling:
 - 1. Comply with TIA-568-C Series of standards.
 - 2. Comply with BICSI ITSIMM, Ch. 5, "Copper Structured Cabling Systems."
 - 3. Terminate all conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, and cross-connect and patch panels.
 - 4. Cables shall not be spliced.
 - 5. Secure and support cables at intervals not exceeding 30 inches and not more than 6 inches from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
 - 6. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIMM, Ch. 5, "Copper Structured Cabling Systems." Install lacing bars and distribution spools.
 - 7. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
 - 8. Cold-Weather Installation: Bring cable to room temperature before de-reeling. Do not use heat lamps for heating.

9. Pulling Cable: Comply with BICSI ITSIMM, Ch. 5, "Copper Structured Cabling Systems." Monitor cable pull tensions.
 10. Support: Do not allow cables to lie on removable ceiling tiles.
 11. Secure: Fasten securely in place with hardware specifically designed and installed so as to not damage cables.
- C. Twisted Pair Cable Installation:
1. Comply with TIA-568-C.2.
 2. Install termination hardware as specified in Section 271513 "Communications Copper Horizontal Cabling" unless otherwise indicated.
 3. Do not untwist UTP cables more than 1/2 inch at the point of termination to maintain cable geometry.
- D. Installation of Control-Circuit Conductors:
1. Install wiring in raceways. Comply with requirements specified in Section 260533 "Raceways and Boxes for Electrical Systems."
- E. Open-Cable Installation:
1. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
 2. Suspend copper cable not in a wireway or pathway a minimum of 8 inches above ceilings by cable supports not more than [30 inches] <Insert dimension> apart.
 3. Cable shall not be run through or on structural members or in contact with pipes, ducts, or other potentially damaging items. Do not run cables between structural members and corrugated panels.
- F. Installation of Cable Routed Exposed under Raised Floors:
1. Install plenum-rated cable only.
 2. Install cabling after the flooring system has been installed in raised floor areas.
 3. Below each feed point, neatly coil a minimum of [72 inches] <Insert dimension> of cable in a coil not less than [12 inches] <Insert dimension> in diameter.
- G. Separation from EMI Sources:
1. Comply with BICSI TDMM and TIA-569-D recommendations for separating unshielded copper voice and data communications cable from potential EMI sources including electrical power lines and equipment.
 2. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
 - a. Electrical Equipment or Circuit Rating Less Than 2 kVA: A minimum of 5 inches.
 - b. Electrical Equipment or Circuit Rating between 2 and 5 kVA: A minimum of 12 inches.
 - c. Electrical Equipment or Circuit Rating More Than 5 kVA: A minimum of 24 inches.
 3. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
 - a. Electrical Equipment or Circuit Rating Less Than 2 kVA: A minimum of 2-1/2 inches.
 - b. Electrical Equipment or Circuit Rating between 2 and 5 kVA: A minimum of 6 inches.

- c. Electrical Equipment or Circuit Rating More Than 5 kVA: A minimum of 12 inches.
- 4. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
 - a. Electrical Equipment or Circuit Rating Less Than 2 kVA: No requirement.
 - b. Electrical Equipment or Circuit Rating between 2 and 5 kVA: A minimum of 3 inches.
 - c. Electrical Equipment or Circuit Rating More Than 5 kVA: A minimum of 6 inches.
- 5. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or 5 HP and Larger: A minimum of 48 inches.
- 6. Separation between Communications Cables and Fluorescent Fixtures: A minimum of 5 inches.

3.4 CONTROL-CIRCUIT CONDUCTORS

A. Minimum Conductor Sizes:

- 1. Class 1 remote-control and signal circuits; [**No 14**] AWG.
- 2. Class 2 low-energy, remote-control, and signal circuits; [**No. 16**] AWG.
- 3. Class 3 low-energy, remote-control, alarm, and signal circuits; [**No 12**] AWG.

3.5 FIRESTOPPING

- A. Comply with requirements in Section 078413 "Penetration Firestopping."
- B. Comply with TIA-569-D, Annex A, "Firestopping."
- C. Comply with BICSI TDMM, "Firestopping" Chapter.

3.6 GROUNDING

- A. For data communication wiring, comply with TIA-607-B and with BICSI TDMM, "Bonding and Grounding (Earthing)" Chapter.
- B. For low-voltage control wiring and cabling, comply with requirements in Section 260526 "Grounding and Bonding for Electrical Systems."

3.7 IDENTIFICATION

- A. Comply with requirements for identification specified in Section 16553 "Identification for Electrical Systems."

3.8 FIELD QUALITY CONTROL

- A. Tests and Inspections:

1. Visually inspect cable jacket materials for UL or third-party certification markings. Inspect cabling terminations to confirm color-coding for pin assignments, and inspect cabling connections to confirm compliance with TIA-568-C.1.
 2. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.
 3. Test cabling for direct-current loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination, but not after cross-connection.
 - a. Test instruments shall meet or exceed applicable requirements in TIA-568-C.2. Perform tests with a tester that complies with performance requirements in its "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in its "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
- B. Document data for each measurement. Print data for submittals in a summary report that is formatted using Table 10.1 in BICSI TDMM as a guide, or transfer the data from the instrument to the computer, save as text files, print, and submit.
- C. End-to-end cabling will be considered defective if it does not pass tests and inspections.
- D. Prepare test and inspection reports.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16533

RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Metal conduits, tubing, and fittings.
 - 2. Nonmetal conduits, tubing, and fittings.
 - 3. Metal wireways and auxiliary gutters.
 - 4. Nonmetal wireways and auxiliary gutters.
 - 5. Surface raceways.
 - 6. Boxes, enclosures, and cabinets.
 - 7. Handholes and boxes for exterior underground cabling.

1.3 DEFINITIONS

- A. GRC: Galvanized rigid steel conduit.
- B. IMC: Intermediate metal conduit.
- C. EMT-Electrical Metallic Conduit

1.4 SUBMITTALS

- A. Product Data: For surface raceways, wireways and fittings, floor boxes, hinged-cover enclosures, and cabinets.

PART 2 - PRODUCTS

2.1 METAL CONDUITS, TUBING, AND FITTINGS

- A. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in Massachusetts Electrical Code (MEC) and UL, and marked for intended location and application.
- B. GRC: Comply with ANSI C80.1 and UL 6.
- C. IMC: Comply with ANSI C80.6 and UL 1242.

- D. PVC-Coated Steel Conduit: PVC-coated rigid steel conduit.
 - 1. Comply with NEMA RN 1.
 - 2. Coating Thickness: 0.040 inch, minimum.
- E. EMT: Comply with ANSI C80.3 and UL 797.
- F. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.
- G. Fittings for Metal Conduit: Comply with NEMA FB 1 and UL 514B.
 - 1. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 1203 and MEC.
 - 2. Fittings for EMT:
 - a. Material: Steel, galvanized.
 - b. Type: Setscrew
 - 3. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions were installed, and including flexible external bonding jumper.
 - 4. Coating for Fittings for PVC-Coated Conduit: Minimum thickness of 0.040 inch, with overlapping sleeves protecting threaded joints.

2.2 NONMETALLIC CONDUITS AND FITTINGS

- A. Listing and Labeling: Nonmetallic conduits, tubing, and fittings shall be listed and labeled as defined in MEC, UL, and marked for intended location and application.
- B. Fiberglass:
 - 1. Comply with NEMA TC 14.
 - 2. Comply with UL 2515 for aboveground raceways.
 - 3. Comply with UL 2420 for belowground raceways.
- C. Fittings for ENT and RNC: Comply with NEMA TC 3; match to conduit or tubing type and material.

2.3 METAL WIREWAYS AND AUXILIARY GUTTERS

- A. Description: Sheet metal, complying with UL 870 and NEMA 250, Type 3R, Type 4, Type 12 unless otherwise indicated, and sized according to MEC.
 - 1. Metal wireways installed outdoors shall be listed and labeled as defined in MEC and UL, and marked for intended location and application.
- B. Wireway Covers: Hinged type
- C. Finish: Manufacturer's standard enamel finish.

2.4 SURFACE RACEWAYS

- A. Listing and Labeling: Surface raceways and tele-power poles shall be listed and labeled as defined in MEC and UL, and marked for intended location and application.
- B. Surface Metal Raceways: Galvanized steel with hinged covers complying with UL 5. Manufacturer's standard enamel finish in color selected by Architect.

2.5 BOXES, ENCLOSURES, AND CABINETS

- A. General Requirements for Boxes, Enclosures, and Cabinets: Boxes, enclosures, and cabinets installed in wet locations shall be listed for use in wet locations.
- B. Sheet Metal Outlet and Device Boxes: Comply with NEMA OS 1 and UL 514A.
- C. Nonmetallic Outlet and Device Boxes: Comply with NEMA OS 2 and UL 514C.
- D. Metal Floor Boxes:
 - 1. Material: Cast metal.
 - 2. Type: Fully adjustable.
 - 3. Shape: Rectangular.
 - 4. Listing and Labeling: Metal floor boxes shall be listed and labeled as defined in MEC, by a qualified testing agency, and marked for intended location and application.
- E. Nonmetallic Floor Boxes: Nonadjustable, round or rectangular.
 - 1. Listing and Labeling: Nonmetallic floor boxes shall be listed and labeled as defined in MEC, by a qualified testing agency, and marked for intended location and application.
- F. Luminaire Outlet Boxes: Nonadjustable, designed for attachment of luminaire weighing 50 lb. Outlet boxes designed for attachment of luminaires weighing more than 50 lb shall be listed and marked for the maximum allowable weight.
- G. Small Sheet Metal Pull and Junction Boxes: NEMA OS 1.
- H. Box extensions used to accommodate new building finishes shall be of same material as recessed box.
- I. Device Box Dimensions: As required by MEC.
- J. Gangable boxes are allowed in framed, unrated partition walls only.
- K. Hinged-Cover Enclosures: Comply with UL 50 and NEMA 250, Type 4 with continuous-hinge cover with flush latch unless otherwise indicated.
 - 1. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
 - 2. Nonmetallic Enclosures: Plastic.
 - 3. Interior Panels: Steel; all sides finished with manufacturer's standard enamel.

- L. Cabinets:
 - 1. NEMA Type 1 indoors NEMA Type 4X-stainless steel outdoor or wet locations. with removable interior panel and removable front, finished inside and out with manufacturer's standard finish.
 - 2. Hinged door in front cover with flush latch and concealed hinge.
 - 3. Key latch to match panelboards.
 - 4. Metal barriers to separate wiring of different systems and voltage.
 - 5. Accessory feet where required for freestanding equipment.
 - 6. Non.

2.6 HANDHOLES AND BOXES FOR EXTERIOR UNDERGROUND WIRING

- A. General Requirements for Handholes and Boxes:
 - 1. Boxes and handholes for use in underground systems shall be designed and identified as defined in MEC, for intended location and application.
 - 2. Boxes installed in wet areas shall be listed and labeled as defined in MEC, by a qualified testing agency, and marked for intended location and application.
- B. Polymer-Concrete Handholes and Boxes with Polymer-Concrete Cover: Molded of sand and aggregate, bound together with polymer resin, and reinforced with steel, fiberglass, or a combination of the two.
 - 1. Standard: Comply with SCTE 77.
 - 2. Configuration: Designed for flush burial with integral closed bottom.
 - 3. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure and handhole location.
 - 4. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
 - 5. Cover Legend: Molded lettering, "ELECTRIC." "LIGHTING" as applicable.
 - 6. Conduit Entrance Provisions: Conduit-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
- C. Fiberglass Handholes and Boxes: Molded of fiberglass-reinforced polyester resin, with frame and covers of cast iron or fiberglass with cover construction to suit roadway duty.
 - 1. Standard: Comply with SCTE 77.

PART 3 - EXECUTION

3.1 RACEWAY APPLICATION

- A. Outdoors: Apply raceway products as specified below:
 - 1. Exposed Conduit: GRC.
 - 2. Concealed Conduit, Aboveground: GRC.
 - 3. Underground Conduit: Type EPC-40-PVC concrete encased.
 - 4. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): liquidtight flexible metallic conduit with PVC coating.

- B. Indoors: Apply raceway products as specified:
 - 1. Exposed, Not Subject to Physical Damage: EMT.
 - 2. Exposed and Subject to Physical Damage: GRC. Raceway locations include the following:
 - a. Corridors used for traffic of mechanized carts, forklifts, and pallet-handling units.
 - b. Mechanical rooms.
 - 3. Concealed in Ceilings and Interior Walls and Partitions: EMT.
 - 4. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment flexible metallic conduit with PVC coating.
- C. Minimum Raceway Size: 3/4-inch trade size.
- D. Raceway Fittings: Compatible with raceways and suitable for use and location.

3.2 INSTALLATION

- A. Work shall be done in a workmanlike manner and as approved by AHJ having jurisdiction. .
- B. Keep raceways at least 6 inches away from parallel runs of flues and steam or hot-water pipes. Install horizontal raceway runs above water and steam piping.
- C. Complete raceway installation before starting conductor installation.
- D. Comply with requirements in Section 16073 "Hangers and Supports for Electrical Systems" for hangers and supports.
- E. Arrange stub-ups so curved portions of bends are not visible above finished slab.
- F. Install no more than the equivalent of three 90-degree bends in any conduit run except for control wiring conduits, for which fewer bends are allowed. Support within 12 inches of changes in direction.
- G. Conceal conduit and EMT within finished walls, ceilings, and floors where possible. Install conduits parallel or perpendicular to building lines.
- H. Support conduit within 12 inches of enclosures to which attached.

3.3 INSTALLATION OF UNDERGROUND HANDHOLES AND BOXES

- A. Install handholes and boxes level and plumb and with orientation and depth coordinated with connecting conduits to minimize bends and deflections required for proper entrances.
- B. Elevation: In paved areas, set so cover surface will be flush with finished grade.
- C. Install removable hardware, including pulling eyes, cable stanchions, cable arms, and insulators, as required for installation and support of cables and conductors. Select arm lengths to be long enough to provide spare space for future cables but short enough to preserve adequate working clearances in enclosure.

3.4 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 16091 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.5 FIRESTOPPING

- A. Install firestopping at penetrations of fire-rated floor and wall assemblies. Comply with requirements in Section 07840 "Firestopping."

3.6 PROTECTION

- A. Protect coatings, finishes, and cabinets from damage and deterioration.
 - 1. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
 - 2. Repair damage to PVC coatings or paint finishes with matching touchup coating recommended by manufacturer.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16561

LED EXTERIOR LIGHTING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Exterior solid-state luminaires that are designed for and exclusively use LED lamp technology.
 - 2. Luminaire supports.
 - 3. Luminaire-mounted photoelectric relays.
 - 4. Poles and accessories.

1.3 DEFINITIONS

- A. CCT: Correlated color temperature.
- B. CRI: Color rendering index.
- C. Fixture: See "Luminaire."
- D. IP: International Protection or Ingress Protection Rating.
- E. Lumen: Measured output of lamp and luminaire, or both.
- F. Luminaire: Complete lighting unit, including lamp, reflector, and housing.

1.4 STRUCTURAL ANALYSIS CRITERIA FOR POLE SELECTION

- A. Dead Load: Weight of luminaire and its horizontal and vertical supports, lowering devices, and supporting structure, applied as stated in AASHTO LTS-4-M and Massachusetts Building Code, whichever is more stringent.
- B. Live Load: Single load As listed in Massachusetts Building Code and FOR BOSTON, MA and as stated in AASHTO LTS-4-M. Whichever is more stringent.
- C. Ice Load: As listed in Massachusetts Building Code FOR BOSTON, MA and as stated in AASHTO LTS-4-M Ice Load Map. Whichever is more stringent
- D. Wind Load: Pressure of wind on pole and luminaire and banners and banner arms, calculated and applied as stated in AASHTO LTS-4-M and Massachusetts building Code.

1.5 SUBMITTALS

- E. Product Data: For each type of luminaire.
1. Arrange in order of luminaire designation.
 2. Include data on features, accessories, and finishes.
 3. Include physical description and dimensions of luminaire.
 4. Lamps, include life, output (lumens, CCT, and CRI), and energy-efficiency data.
 5. Photometric data and adjustment factors based on laboratory tests, complying with IES.
 - a. Manufacturer's Certified Data: Photometric data certified by manufacturer's laboratory with a current accreditation under the NVLAP for Energy Efficient Lighting Products.
 - b. Testing Agency Certified Data: For indicated luminaires, photometric data certified by a qualified independent testing agency. Photometric data for remaining luminaires shall be certified by manufacturer.
 6. Wiring diagrams for power, control, and signal wiring.
 7. Photoelectric relays.
 8. Means of attaching luminaires to supports and indication that the attachment is suitable for components involved.
 9. Anchor bolts for poles.
 10. Manufactured pole foundations.

1.4 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
1. Luminaires.
 2. Structural members to which luminaires will be attached.
 3. Underground utilities and structures.
 4. Existing underground utilities and structures.
 5. Above-grade utilities and structures.
 6. Existing above-grade utilities and structures.
 7. Building features.
 8. Pole layouts and foundations.
 9. Layout and footcandle levels.
- B. Seismic Qualification Certificates: For luminaires, accessories, and components, from manufacturer.
1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
 2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
 3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
- C. Product Certificates: For each type of the following:

1. Luminaire.

1.5 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For luminaires to include in operation and maintenance manuals.
 1. Provide a list of all lamp types used on Project. Use ANSI and manufacturers' codes.
 2. Provide a list of all photoelectric relay types used on Project; use manufacturers' codes.

1.6 QUALITY ASSURANCE

- A. Luminaire Photometric Data Testing Laboratory Qualifications: Luminaire manufacturers' laboratory that is accredited under the NVLAP for Energy Efficient Lighting Products.
- B. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by an independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910.7, accredited under the NVLAP for Energy Efficient Lighting Products and complying with applicable IES testing standards.
- C. Provide luminaires from a single manufacturer for each luminaire type.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Protect finishes of exposed surfaces by applying a strippable, temporary protective covering prior to shipping.

1.8 FIELD CONDITIONS

- A. Verify existing conditions prior to the start of work associated with luminaire installation.
- B. Mark locations of exterior luminaires for approval by Architect prior to the start of luminaire installation.

1.9 WARRANTY

- A. Warranty: Manufacturer and Installer agree to repair or replace components of luminaires that fail in materials or workmanship within specified warranty period.
 1. Failures include, but are not limited to, the following:
 - a. Structural failures, including luminaire support components.
 - b. Faulty operation of luminaires and accessories.
 - c. Deterioration of metals, metal finishes, and other materials beyond normal weathering.
 2. Warranty Period: 1 year from date of acceptance by MBTA. Warranty to include material and labor.

1.10 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 - 1. Lamps: One for every 100 of each type and rating installed. Furnish at least one of each type.
 - 2. Glass and Plastic Lenses, Covers, and Other Optical Parts: One for every 100 of each type and rating installed. Furnish at least one of each type.
 - 3. Globes and Guards: One for every 100 of each type and rating installed. Furnish at least one of each type.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Luminaires and lamps shall be G3 labeled vibration and shock resistant.

2.2 GENERAL LUMINAIRE REQUIREMENTS

- A. Luminaires shall be IP66 Rated as approved by MBTA.
- B. Luminaires and poles shall comply with MassDOT Design Lighting Levels and Fixture, Design Directive.
- C. Poles bases shall extend a minimum of 12" above platforms and/or grade.
- D. Incandescent, halogen, induction, high pressure sodium, low pressure sodium and mercury vapor lamps shall not be utilized.
- E. Metal Parts: Free of burrs and sharp corners and edges.
- F. Sheet Metal Components: Corrosion-resistant aluminum unless otherwise indicated. Form and support to prevent warping and sagging.
- G. Housings: Rigidly formed, weather- and light-tight enclosures that will not warp, sag, or deform in use. Provide filter/breather for enclosed luminaires.
- H. Doors, Frames, and Other Internal Access: Smooth operating, free of light leakage under operating conditions, and designed to permit relamping without use of tools. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position. Doors shall be removable for cleaning or replacing lenses. Designed to disconnect ballast when door opens.
- I. Exposed Hardware Material: Stainless steel.
- J. Plastic Parts: High resistance to yellowing and other changes due to aging, exposure to heat, and UV radiation.
- K. Light Shields: Metal baffles, factory installed and field adjustable, arranged to block light distribution to indicated portion of normally illuminated area or field.

- L. Reflecting surfaces shall have minimum reflectance as follows unless otherwise indicated:
 - 1. White Surfaces: 85 percent.
 - 2. Specular Surfaces: 83 percent.
 - 3. Diffusing Specular Surfaces: 75 percent.
- M. Lenses and Refractors Gaskets: Use heat- and aging-resistant resilient gaskets to seal and cushion lenses and refractors in luminaire doors.
- N. Luminaire Finish: Manufacturer's standard baked enamel paint applied to factory-assembled and -tested luminaire before shipping. Where indicated, match finish process and color of pole or support materials.
- O. Factory-Applied Finish for Steel luminaires: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - 1. Surface Preparation: Clean surfaces to comply with SSPC-SP 1, "Solvent Cleaning," to remove dirt, oil, grease, and other contaminants that could impair paint bond. Grind welds and polish surfaces to a smooth, even finish. Remove mill scale and rust, if present, from uncoated steel, complying with SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning," or SSPC-SP 8, "Pickling."
 - 2. Exterior Surfaces: Manufacturer's standard finish consisting of one or more coats of primer and two finish coats of high-gloss, high-build polyurethane enamel.
 - a. Color: As selected from manufacturer's standard catalog of colors.
 - b. Color shall be subject to approval of Architect and MBTA.
- P. Factory-Applied Finish for Aluminum luminaires: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - 1. Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.

Finish and color subject to the approval of the Architect and MBTA.
- Q. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
- R. Nominal Operating Voltage: [**120 V ac**].
- S. Source Limitations: Obtain luminaires from single source from a single manufacturer.
- T. All poles at each location shall have the same shape, round or square.

2.3 LUMINAIRE-MOUNTED PHOTOELECTRIC RELAYS

- A. Comply with UL 773 or UL 773A.
- B. Contact Relays: Factory mounted, single throw, designed to fail in the on position, and factory set to turn light unit on at 1.5 to 3 fc and off at 4.5 to 10 fc with 15-second minimum time delay.[**Relay**

shall have directional lens in front of photocell to prevent artificial light sources from causing false turnoff.]

1. Relay with locking-type receptacle shall comply with ANSI C136.10.
2. Adjustable window slide for adjusting on-off set points.

2.4 LUMINAIRE TYPES

A. Area and Site:

1. Luminaire-Mounting Height: Mounting heights shall be between 10' and 12'.
2. Coordinate lighting pollution (spill) requirements with MBTA and locality where luminaires are installed.
3. Distribution: [**Type I**] [**Type II**] [**Type III**] [**Type IV**] [**Type V**] as required.

2.5 MATERIALS

A. Metal Parts: Free of burrs and sharp corners and edges.

B. Sheet Metal Components: [Epoxy-coated steel**]. Form and support to prevent warping and sagging.**

C. Doors, Frames, and Other Internal Access: Smooth operating, free of light leakage under operating conditions, and designed to permit relamping without use of tools. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position. Doors shall be removable for cleaning or replacing lenses.

D. Lens and Refractor Gaskets: Use heat- and aging-resistant resilient gaskets to seal and cushion lenses and refractors in luminaire doors.

E. Reflecting surfaces shall have minimum reflectance as follows unless otherwise indicated:

1. White Surfaces: 85 percent.
2. Specular Surfaces: 83 percent.
3. Diffusing Specular Surfaces: 75 percent.

F. Housings:

1. Rigidly formed, weather- and light-tight enclosure that will not warp, sag, or deform in use.
2. Provide filter/breather for enclosed luminaires.

G. Factory-Applied Labels: Comply with UL 1598. Include recommended lamps. Labels shall be located where they will be readily visible to service personnel, but not seen from normal viewing angles when lamps are in place.

1. Label shall include the following lamp characteristics:
 - a. "USE ONLY" and include specific lamp type.
 - b. Lamp diameter, shape, size, wattage and coating.
 - c. CCT and CRI for all luminaires.

2.6 FINISHES

- A. Variations in Finishes: Noticeable variations in same piece are unacceptable. Variations in appearance of adjoining components are acceptable if they are within the range of approved Samples and are assembled or installed to minimize contrast.
- B. Luminaire Finish: Manufacturer's standard baked enamel paint applied to factory-assembled and -tested luminaire before shipping. Where indicated, match finish process and color of pole or support materials.
- C. Factory-Applied Finish for Steel luminaires: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - 1. Surface Preparation: Clean surfaces to comply with SSPC-SP 1, to remove dirt, oil, grease, and other contaminants that could impair paint bond. Grind welds and polish surfaces to a smooth, even finish. Remove mill scale and rust, if present, from uncoated steel, complying with SSPC-SP 5/NACE No. 1 or SSPC-SP 8.
 - 2. Exterior Surfaces: Manufacturer's standard finish consisting of one or more coats of primer and two finish coats of high-gloss, high-build polyurethane enamel.
 - a. Color: As selected by Architect from manufacturer's full range.

2.7 LUMINAIRE SUPPORT COMPONENTS

- A. Comply with requirements in Section 16073 "Hangers and Supports for Electrical Systems" for channel and angle iron supports and nonmetallic channel and angle supports.

2.8 GENERAL REQUIREMENTS FOR POLES AND SUPPORT COMPONENTS

- A. Structural Characteristics: Comply with AASHTO LTS-4-M.
 - 1. Wind-Load Strength of Poles: Adequate at indicated heights above grade without failure, permanent deflection, or whipping in winds speeds as listed in Massachusetts Building Code.
- B. Luminaire Attachment Provisions: Comply with luminaire manufacturers' mounting requirements. Use stainless-steel fasteners and mounting bolts unless otherwise indicated.
- C. Mountings, Fasteners, and Appurtenances: Corrosion-resistant items compatible with support components.
 - 1. Materials: Shall not cause galvanic action at contact points.
 - 2. Anchor Bolts, Leveling Nuts, Bolt Caps, and Washers: Hot-dip galvanized after fabrication unless otherwise indicated.
 - 3. Anchor-Bolt Template: Plywood or steel.
- D. Handhole: Oval-shaped, with minimum clear opening of 2-1/2 by 5 inches (65 by 130 mm), with cover secured by stainless-steel captive screws.
- E. Concrete Pole Foundations: Cast in place, with anchor bolts to match pole-base flange. Concrete, reinforcement, and formwork are specified in Section 033000 "Cast-in-Place Concrete." Foundation shall extend a minimum of 12" above grade and/or platform.

- F. Breakaway Supports: Frangible breakaway supports, tested by an independent testing agency acceptable to authorities having jurisdiction, according to AASHTO LTS-4-M.
- G. Pole length shall be 10' minimum, 12' maximum.

2.9 STEEL POLES

- A. Poles: Comply with ASTM A 500, Grade B, carbon steel with a minimum yield of 46,000 psig (317 MPa); one-piece construction up to 40 feet (12 m) in height with access handhole in pole wall.
 - 1. Shape: [**Round, tapered**] [**Round, straight**] [**Square, tapered**] [**Square, straight**]. All poles shall be same shape.
 - 2. Mounting Provisions: Butt flange for bolted mounting on foundation or breakaway support.
- B. Brackets for Luminaires: Detachable, cantilever, without underbrace.
 - 1. Adapter fitting welded to pole, allowing the bracket to be bolted to the pole mounted adapter, then bolted together with stainless-steel bolts.
 - 2. Cross Section: Tapered oval, with straight tubular end section to accommodate luminaire.
 - 3. Match pole material and finish.
- C. Pole-Top Tenons: Fabricated to support luminaire or luminaires and brackets indicated, and securely fastened to pole top..
- D. Grounding and Bonding Lugs: Welded 1/2-inch (13-mm) threaded lug, complying with requirements in Section 260526 "Grounding and Bonding for Electrical Systems," listed for attaching grounding and bonding conductors of type and size listed in that Section, and accessible through handhole.
- E. Cable Support Grip: Wire-mesh type with rotating attachment eye, sized for diameter of cable and rated for a minimum load equal to weight of supported cable times a 5.0 safety factor.
- F. Prime-Coat Finish: Manufacturer's standard prime-coat finish ready for field painting.
- G. Galvanized Finish: After fabrication, hot-dip galvanize complying with ASTM A 123/A 123M.
- H. Factory-Painted Finish: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - 1. Surface Preparation: Clean surfaces to comply with SSPC-SP 1, "Solvent Cleaning," to remove dirt, oil, grease, and other contaminants that could impair paint bond. Grind welds and polish surfaces to a smooth, even finish. Remove mill scale and rust, if present, from uncoated steel, complying with SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning," or with SSPC-SP 8, "Pickling."
 - 2. Interior Surfaces of Pole: One coat of bituminous paint, or otherwise treat for equal corrosion protection.
 - 3. Exterior Surfaces: Manufacturer's standard finish consisting of one or more coats of primer and two finish coats of high-gloss, high-build polyurethane enamel.
 - a. Color: Standard manufacture's colors as approved by the architect and MBTA.

2.10 ALUMINUM POLES

- A. Poles: Seamless, extruded structural tube complying with ASTM B 429/B 429M, Alloy 6063-T6 with access handhole in pole wall.
- B. Poles: ASTM B 209 (**ASTM B 209M**), 5052-H34 marine sheet alloy with access handhole in pole wall.
 - 1. Shape: [**Round, tapered**] [**Round, straight**] [**Square, tapered**] [**Square, straight**]. All poles shall be same shape.
 - 2. Mounting Provisions: Butt flange for bolted mounting on foundation or breakaway support.
- C. Pole-Top Tenons: Fabricated to support luminaire or luminaires and brackets indicated, and securely fastened to pole top.
- D. Grounding and Bonding Lugs: Welded 1/2-inch (**13-mm**) threaded lug, complying with requirements in Section 260526 "Grounding and Bonding for Electrical Systems," listed for attaching grounding and bonding conductors of type and size listed in that Section, and accessible through handhole.
- E. Prime-Coat Finish: Manufacturer's standard prime-coat finish ready for field painting.
- F. Aluminum Finish: Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
 - 1. Finish shall be as approved by the Architect and MBTA.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
- B. Examine roughing-in for luminaire electrical conduit to verify actual locations of conduit connections before luminaire installation.
- C. Examine conditions where luminaires will be installed and provide proper installation.

3.2 GENERAL INSTALLATION REQUIREMENTS

- A. Comply with NECA 1.
- B. Use fastening methods and materials selected to resist seismic forces defined for the application and approved by manufacturer.
- C. Install lamps in each luminaire.
- D. Fasten luminaire to structural support.

- E. Supports:
 - 1. Sized and rated for luminaire weight.
 - 2. Able to maintain luminaire position after cleaning and relamping.
 - 3. Support luminaires without causing deflection of finished surface.
 - 4. Luminaire-mounting devices shall support a horizontal force of 100 percent of luminaire weight and a vertical force of 400 percent of luminaire weight.
- F. Wall-Mounted Luminaire Support:
 - 1. Attached to structural members in frame walls, with a minimum 1/8 inch backing plate attached to wall structural members. In unfinished areas attached using through bolts and backing plates on either side of wall.
- G. Wiring Method: Install cables in raceways. Conceal raceways and cables.
- H. Install luminaires level, plumb, and square with finished grade.
- I. Coordinate layout and installation of luminaires with other construction.
- J. Adjust luminaires that require field adjustment or aiming. Including adjustment of photoelectric device to prevent false operation of relay by artificial light sources, favoring a north orientation.

3.3 POLE INSTALLATION.

- A. Alignment: Align pole foundations and poles for optimum directional alignment of luminaires and their mounting provisions on the pole.
- B. Clearances: Maintain the following minimum horizontal distances of poles from surface and underground features:
 - 1. Fire Hydrants and Storm Drainage Piping: [**60 inches (1520 mm)**].
 - 2. Water, Gas, Electric, Communication, and Sewer Lines: [**10 feet (3 m)**].
 - 3. Trees: [**15 feet (5 m)**] from tree trunk.
- C. Foundation-Mounted Poles: Mount pole with leveling nuts, and tighten top nuts to torque level recommended by pole manufacturer.
 - 1. Use anchor bolts and nuts selected to resist seismic forces defined for the application and approved by manufacturer.
 - 2. Grout void between pole base and foundation. Use non-shrink or expanding concrete grout firmly packed to fill space.
 - 3. Install base covers unless otherwise indicated.
 - 4. Use a short piece of 1/2-inch- (**13-mm-**) diameter pipe to make a drain hole through grout. Arrange to drain condensation from interior of pole.
- D. Poles and Pole Foundations Set in Concrete Paved Areas: Install poles with minimum of 6-inch- (**150-mm-**) wide, unpaved gap between the pole or pole foundation and the edge of adjacent concrete slab. Fill unpaved ring with material as approved by the Architect and MBTA. to a level 1 inch (**25 mm**) below top of concrete slab.
- E. Pole concrete foundation shall extend a minimum of 12 inches above grade or platform.

3.4 INSTALLATION OF INDIVIDUAL GROUND-MOUNTED LUMINAIRES

- A. Aim to provide proper illumination.
- B. Install on concrete base with top 12 inches above finished grade or surface at luminaire location. Cast conduit into base, and finish by troweling and rubbing smooth. Concrete materials, installation, and finishing are specified in Section 03300 "Cast-in-Place Concrete."

3.5 CORROSION PREVENTION

- A. Steel Conduits: Use Galvanized Rigid Metal conduit.

3.6 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "Electrical Identification"

3.7 FIELD QUALITY CONTROL

- A. Inspect each installed luminaire for damage. Replace damaged luminaires and components.
- B. Illumination Tests:
 - 1. Measure light intensities at night. Use photometers with calibration referenced to NIST standards.
 - 2. Operational Test: After installing luminaires, switches, and accessories, and after electrical circuitry has been energized, test units to confirm proper operation.
- C. Luminaire will be considered defective if it does not pass tests and inspections.
- D. Prepare a written report of tests, inspections, observations, and verifications indicating and interpreting results. If adjustments are made to lighting system, retest to demonstrate compliance with standards.

3.8 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting the direction of aim of luminaires and shielding to suit occupied conditions. Some of this work may be required during hours of darkness.
 - 1. During adjustment visits, inspect all luminaires. Replace lamps or luminaires that are defective.
 - 2. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.
 - 3. Adjust the aim of luminaires in the presence of the Architect.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16630

EMERGENCY GENERATOR

PART 1 – GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 GENERAL DESCRIPTION

- A. Provide complete factory assembled generator set equipment with digital electronic controls.
- B. Provide factory test, startup by a supplier authorized by the manufacturer, and on-site testing of the system.
- C. The generator set manufacturer shall warranty all equipment provided under this section, whether or not is manufactured by the generator set manufacturer, so that there is one source for warranty and product service. Technicians specifically trained and certified by the manufacturer to support the product and employed by the generator set supplier shall service the generator sets.

1.3 CODES AND STANDARDS

- A. The generator set and its installation and on-site testing shall conform to the requirements of the following codes and standards:
 - 1. ISO 8528 part 4. Reciprocating internal combustion engine driven alternating current generating sets – Part 4: Control gear and switchgear.
 - 2. IEEE 446-1995(R2000) – Recommended Practice for Emergency and Standby Power Systems for Commercial and Industrial Applications.
 - 3. NEMA ICS10 – Industrial Control and Systems Part 1: Electromechanical AC Transfer Switch Equipment.
 - 4. NFPA 54 – National Fuel Gas Code.
 - 5. MEC– Massachusetts Electrical Code (MEC).
 - 6. NFPA 99 – Essential Electrical Systems for Health Care Facilities (2005).
 - 7. NFPA 110 – Emergency and Standby Power Systems (2010). The generator set shall meet all requirements for Level 1 systems. Level 1 prototype tests required by this standard shall have been performed on a complete and functional unit, component level type tests will not substitute for this requirement.
 - 8. UL 508. The entire control system of the generator set shall be UL 508 listed and labeled.
 - 9. UL 2200(2009). The genset shall be listed to UL 2200 or submit to an independent third party certification process to verify compliance as installed.
 - 10. 310 CMR-Massachusetts DEP Regulations.
- B. The generator set manufacturer shall be certified to ISO 9001 International Quality Standard and shall have third party certification verifying quality assurance in design/development, production, installation, and service, in accordance with ISO 9001.

1.4 RELATED SECTIONS

- A. 16050 - Basic Materials and Methods for Electrical Work
- B. 16415 –Transfer Switches
- C. 16060 – Grounding and Bonding

1.5 ACCEPTABLE MANUFACTURERS

- A. The natural gas powered generator must be on the approved product list of the Massachusetts State Plumbing Board and shall comply with MADEP CMR 310 regulations. Equipment by other suppliers that meets the requirement of this specification is acceptable, if approved not less than 2 weeks before scheduled bid date. Proposals must include a line by line compliance statement based on this specification.

1.6 SUBMITTALS

- A. Manufacturer's product literature and performance data, sufficient to verify compliance to specification requirements including.
- B. Certification of MA DEP regulations.
- C. A paragraph by paragraph specification compliance statement, describing the differences between the specified and the proposed equipment.
- D. Manufacturer's certification of prototype testing.
- E. Manufacturer's published warranty documents.
- F. Shop drawings showing plan and elevation views with certified overall dimensions, as well as wiring and piping interconnection details.
- G. Shop drawings of the generator exhaust piping including supports and insulation.
- H. Interconnection wiring and piping diagrams showing all external connections required; with field wiring terminals marked in a consistent point-to-point manner.
- I. Manufacturer's installation instructions including recommended spare parts list.
- J. Design-Builder to submit the following electric load calculations:
 - 1. Generator Load Design;
 - 2. Load calculation while running all emergency station equipment.
 - 2. Available power left on generator for future use.
- K. O&M manual

1.7 WARRANTY

- A. The generator set and associated equipment shall be warranted for a period of not less than 5 years from the date of commissioning against defects in materials and workmanship.
- B. The warranty shall be comprehensive. No deductibles shall be allowed for travel time, service hours, repair parts cost, etc.

PART 2 - PRODUCTS

2.1 GENERATOR SET

A. Ratings

1. The generator set shall operate at 1800 rpm and at a voltage of: 277/480 Volts AC (or 208/120 Volts as required), Three phase, Four-wire, 60 hertz.
2. Unit shall be diesel engine driven, skid mounted with diesel tank below generator sized to allow full operation of the station for 5 days.
2. The generator engines shall be in conformance with the Massachusetts DEP Regulations 310 CMR Chapter 7, including the emission limitations and fuel sulfur content. be 27 inch
- 3 The generator set rating shall be minimum of 100 kW/125 kVA. Final sizing shall be determined from site load analysis. The generator shall properly supply station full operation, including elevators.
4. Unit shall be outdoor type, with all required appurtenances to yield a fully operable system.
5. Exhaust piping shall be provided.

B. Performance

1. Voltage regulation shall be plus or minus 0.5 percent for any constant load between no load and rated load for both parallel and non-parallel applications. Random voltage variation with any steady load from no load to full load shall not exceed plus or minus 0.5 percent.
2. Frequency regulation shall be isochronous from steady state no load to steady state rated load. Random frequency variation with any steady load from no load to full load shall not exceed plus or minus 0.25%.
- 3 The natural gas engine-generator set shall be capable of single step load pick up of 100% nameplate kW and power factor, less applicable derating factors, with the engine-generator set at operating temperature.
4. Motor starting capability shall as indicated on drawings. The generator set shall be capable of sustaining a minimum of 90% of rated no load voltage with the specified kVA load at near zero power factor applied to the generator set.
5. The alternator shall produce a clean AC voltage waveform, with not more than 5% total harmonic distortion at full linear load, when measured from line to neutral, and with not more than 3% in any single harmonic. Telephone influence factor shall be less than 40.
6. The time required to automatically start, accelerate to rated speed and voltage, and synchronize the generator set to the system bus on a normal power failure shall not exceed 10 seconds under normal power failure conditions, assuming that the generator set is in an ambient temperature of 20F or greater, and water jacket heaters are operating properly.
7. Engine performance shall be based on the incoming gas pressure at the skid as required by engine manufacturer.

C. Construction

1. The engine-generator set shall be mounted on a heavy-duty steel base to maintain alignment between components. The base shall incorporate a battery tray with hold-down clamps within the rails
2. All switches, lamps, and meters in the control system shall be oil-tight and dust-tight, and the enclosure door shall be gasketed. There shall be no exposed points in the control (with the door open) that operate in excess of 50 volts.

D. Connections

1. The generator set load connections shall be composed of silver or tin plated copper bus bars, drilled to accept mechanical or compression terminations of the number and type as shown on the drawings. Sufficient lug space shall be provided for use with cables of the number and size as shown on the drawings.
2. Power connections to auxiliary devices shall be made at the devices, with required protection located at a wall-mounted common distribution panel.
3. Generator set control interfaces to other system components shall be made on a common, permanently labeled terminal block assembly.

2.2 ENGINE AND ENGINE EQUIPMENT

- A. The engine shall be diesel fueled, radiator and fan cooled. The horsepower rating of the engine at its minimum tolerance level shall be sufficient to drive the alternator and all connected accessories
- B. Complete engine fuel system, including all pressure regulators, strainers, and control valves.
- C. An electronic governor system shall provide automatic isochronous frequency regulation. The governing system dynamic capabilities shall be controlled as a function of engine coolant temperature to provide fast, stable operation at varying engine operating temperature conditions. The control system shall actively control the fuel rate and excitation as appropriate to the state of the generator set. Fuel rate shall be regulated as a function of starting, accelerating to start disconnect speed, accelerating to rated speed, and operating in various isochronous or parallel states.
- D. Skid-mounted radiator and cooling system rated for full load operation in 104 degrees F (40 degrees C) ambient as measured at the generator air inlet, based on 0.5 in H₂O external static head. Radiator shall be sized based on a core temperature which is 20F higher than the rated operation temperature, or prototype tested to verify cooling performance of the engine/radiator/fan operation in a controlled environment. Radiator shall be provided with a duct adapter flange. The equipment manufacturer shall fill the cooling system with a 50/50-ethylene glycol/water mixture. Rotating parts shall be guarded against accidental contact.
- E. Electric starter(s) capable of three complete cranking cycles without overheating.
- F. Positive displacement, mechanical, full pressure, lubrication oil pump.
- G. Full flow lubrication oil filters with replaceable spin-on canister elements and dipstick oil level indicator.
- H. Replaceable dry element air cleaner with restriction indicator.
- I. Flexible fuel lines.
- J. Engine mounted battery charging alternator, 40-ampere minimum and solid-state voltage regulator.
- K. Coolant heater
 1. Engine mounted, thermostatically controlled, coolant heater. Heater voltage shall be as shown on the project drawings. The coolant heater shall be UL 499(2005) listed and labeled.
 2. The coolant heater shall be installed on the engine with silicone hose connections. Steel tubing shall be used for connections into the engine coolant system wherever the length of pipe run exceeds 12 inches. The coolant heater installation shall be specifically designed to provide

proper venting of the system. The coolant heaters shall be installed using quick disconnect couplers to isolate the heater for replacement of the heater element. The quick disconnect/automatic sealing couplers shall allow the heater element to be replaced without draining the engine cooling system or significant coolant loss.

3. The coolant heater shall be provided with a 24V DC thermostat, installed at the engine thermostat housing. An AC power connection box shall be provided for a single AC power connection to the coolant heater system.
 4. The coolant heater(s) shall be sized as recommended by the engine manufacturer to warm the engine to a minimum of 100F (40°C) in a 40°F ambient, in compliance with NFPA110 requirements, or the temperature required for starting and load pickup requirements of this specification.
- L. Provide vibration isolators, spring/pad type, quantity as recommended by the generator set manufacturer. Isolators shall include seismic restraints if required by site location. Refer to Structural plans for site specific seismic/geotechnical requirements.
- M. Starting and Control Batteries shall be calcium/lead antimony type, 24 volt DC, sized as recommended by the engine manufacturer, complete with battery cables and connectors.
- N. Provide a complete exhaust system including exhaust silencer for the engine of size and type as recommended by the generator set manufacturer and approved by the engine manufacturer. The mufflers shall be critical grade. Exhaust system shall be installed according to the engine manufacturer's recommendations and applicable codes and standards. Engine exhaust design shall be submitted with generator package. Skin temperature of the assembly with aluminum jacket shall be approximately 140 °F. for personnel protection.
- O. A UL listed certified 10 amp voltage regulated battery charger shall be provided for each engine-generator set. Input AC voltage and DC output voltage shall be as required. Chargers shall be equipped with float, taper and equalize charge settings. Operational monitors shall provide visual output along with individual form C contacts rated at 4 amps, 120V AC, 30V DC for remote indication of:
1. Loss of AC power - red light
 2. Low battery voltage - red light
 3. High battery voltage - red light
 4. Power ON - green light (normally open relay contact)
 5. Charger shall include an Analog DC voltmeter and ammeter, 12 hour equalize charge timer, and AC and DC fuses.
- P. A fixed resistive test load rated at a minimum of 50% of generator rating shall be provided in the exhaust.

2.3 AC GENERATOR

- A. The AC generator shall be; synchronous, four pole, 2/3 pitch, revolving field, drip-proof construction, single pre-lubricated sealed bearing, air cooled by a direct drive centrifugal blower fan, and directly connected to the engine with flexible drive disc. All insulation system components shall meet NEMA MG1 temperature limits for Class H insulation system. Actual temperature rise measured by resistance method at full load shall not exceed 125 °C.
- B. The generator shall be capable of delivering rated output (kVA) at rated frequency and power factor, at any voltage not more than 5% above or below rated voltage.

- C. A permanent magnet generator (PMG) shall be included to provide a reliable source of excitation power for optimum motor starting and short circuit performance. The PMG and controls shall be capable of sustaining and regulating current supplied to a single phase or three phase fault at approximately 300% of rated current for not more than 10 seconds.
- D. The sub-transient reactance of the alternator shall not exceed 12 percent, based on the standby rating of the generator set.

2.4 GENERATOR SET CONTROL

- A. The generator set shall be provided with a microprocessor-based control system that is designed to provide automatic starting, monitoring, and control functions for the generator set. The control system shall also be designed to allow local monitoring and control of the generator set, and remote monitoring and control as described in this specification. The control shall be mounted on the generator set. The control shall be vibration isolated and prototype tested to verify the durability of all components in the system under the vibration conditions encountered. The generator set mounted control shall include the following features and functions:
 - 1. Mode Select Switch - The mode select switch shall initiate the following control modes. When in the RUN or Manual position the generator set shall start, and accelerate to rated speed and voltage as directed by the operator. In the OFF position the generator set shall immediately stop, bypassing all time delays. In the AUTO position the generator set shall be ready to accept a signal from a remote device to start and accelerate to rated speed and voltage.
 - 2. EMERGENCY STOP - Switch shall be Red "mushroom-head" push-button. Depressing the emergency stop switch shall cause the generator set to immediately shut down, and be locked out from automatic restarting.
 - 3. RESET - The RESET switch shall be used to clear a fault and allow restarting the generator set after it has shut down for any fault condition.
 - 4. PANEL LAMP - Depressing the panel lamp switch shall cause the entire panel to be lighted with DC control power. The panel lamps shall automatically be switched off 10 minutes after the switch is depressed, or after the switch is depressed a second time.
- B. Generator Set AC Output Metering. The generator set shall be provided with a metering set including the following features and functions:
 - 1. Analog voltmeter, ammeter, frequency meter, and kilowatt (KW) meter. Voltmeter and ammeter shall display all three phases. Ammeter and KW meter scales shall be color coded in the following fashion: readings from 0-90% of generator set standby rating: green; readings from 90-100% of standby rating: amber; readings in excess of 100%: red.
 - 2. Digital metering set, 0.5% accuracy, to indicate generator RMS voltage and current, frequency, output current, output KW, KW-hours, and power factor. Generator output voltage shall be available in line-to-line and line-to-neutral voltages, and shall display all three phase voltages (line to neutral or line to line) simultaneously.
 - 3. Both analog and digital metering is required. The analog and digital metering equipment shall be driven by a single microprocessor, to provide consistent readings and performance.
- C. Generator Set Alarm and Status Display.
 - 1. The generator set shall be provided with alarm and status indicating lamps to indicate non-automatic generator status, and existing warning and shutdown conditions. The lamps shall be high-intensity LED type. The lamp condition shall be clearly apparent under bright room lighting conditions. The generator set control shall indicate the existence of the following alarm

and shutdown conditions on an alphanumeric digital display panel and include a digital output for use in remote monitoring at the Assembly Square Station Communication Programmable Logic Controller for each condition including the four customer specified alarm or shutdown conditions:

- a. low fuel gas pressure (alarm)
 - b. low fuel gas pressure (alarm)
 - c. fuel gas pressure sender failure (alarm)
 - d. low coolant temperature (alarm)
 - e. high coolant temperature (alarm)
 - f. high coolant temperature (alarm)
 - g. engine temperature sender failure (alarm)
 - h. low coolant level (alarm)
 - i. fail to crank (alarm)
 - j. fail to start/overcrank (alarm)
 - k. overspeed (alarm)
 - l. low DC voltage (alarm)
 - m. high DC voltage (alarm)
 - n. weak battery (alarm)
 - o. high AC voltage (alarm)
 - p. low AC voltage (alarm)
 - q. under frequency (alarm)
 - r. over current (warning)
 - s. over current (alarm)
 - t. short circuit (alarm)
 - u. ground fault (alarm) (optional--when required by code or specified)
 - v. over load (alarm)
 - w. emergency stop (alarm)
2. Provisions shall be made for indication of four customer-specified alarm or shutdown conditions with one digital output for remote monitoring for each condition listed. Labeling of the customer-specified alarm or shutdown conditions shall be of the same type and quality as the above specified conditions. The non-automatic indicating lamp shall be red, and shall flash to indicate that the generator set is not able to automatically respond to a command to start from a remote location.

The Gas Detector inside weather enclosure shall indicate:

- a. Gas Vapor Warning (alarm)
- b. Gas Vapor High Level Alarm (alarm)
- c. Gas Vapor Trouble (alarm)

D. Engine Status Monitoring.

1. The following information shall be available from a digital status panel on the generator set control:

Engine oil pressure (psi or kPA)
Engine coolant temperature (°F or °C)
Engine oil temperature (°F or °C)
Engine speed (rpm)
Number of hours of operation (hours)

Number of start attempts
Battery voltage (DC volts)

2. The control system shall also incorporate a data logging and display provision to allow logging of the last 10 warning or shutdown indications on the generator set, as well as total time of operation at various loads, as a percent of the standby rating of the generator set.

E. Engine Control Functions.

1. The control system provided shall include a cycle cranking system, which allows for user selected crank time, rest time, and # of cycles. Initial settings shall be for 3 cranking periods of 15 seconds each, with 15 second rest period between cranking periods.
2. The control system shall include an idle mode control, which allows the engine to run in idle mode in the RUN position only. In this mode, the alternator excitation system shall be disabled.
3. The control system shall include an engine governor control, which functions to provide steady state frequency regulation as noted elsewhere in this specification. The governor control shall include adjustments for gain, damping, and a ramping function to control engine speed and limit exhaust smoke while the unit is starting.
4. The control system shall include time delay start (adjustable 0-300 seconds) and time delay stop (adjustable 0-600 seconds) functions.
5. The control system shall include sender failure monitoring logic for speed sensing, oil pressure, and engine temperature which is capable of discriminating between failed senders or wiring components, and an actual failure conditions.

F. Alternator Control Functions:

1. The generator set shall include an automatic digital voltage regulation system that is matched and prototype tested with the governing system provided. It shall be immune from misoperation due to load-induced voltage waveform distortion and provide a pulse width modulated output to the alternator exciter. The voltage regulation system shall be equipped with three-phase RMS sensing and shall control buildup of AC generator voltage to provide a linear rise and limit overshoot. The system shall include a torque-matching characteristic, which shall reduce output voltage in proportion to frequency below a threshold of [58-59] HZ. The voltage regulator shall include adjustments for gain, damping, and frequency roll-off. Adjustments shall be broad range, and made via digital raise-lower switches, with an alphanumeric LED readout to indicate setting level. Rotary potentiometers for system adjustments are not acceptable.
2. Controls shall be provided to monitor the output current of the generator set and initiate an alarm (over current warning) when load current exceeds 110% of the rated current of the generator set on any phase for more than 60 seconds. The controls shall shut down and lock out the generator set when output current level approaches the thermal damage point of the alternator. The protective functions provided shall be in compliance to the requirements of NFPA70 article 445.
3. Controls shall be provided to individually monitor all three phases of the output current for short circuit conditions. The control/protection system shall monitor the current level and voltage. The controls shall shut down and lock out the generator set when output current level approaches the thermal damage point of the alternator (short circuit shutdown). The protective functions provided shall be in compliance to the requirements of NFPA 70, article 445.
4. Controls shall be provided to monitor the KW load on the generator set, and initiate an alarm condition (over load) when total load on the generator set exceeds the generator set rating for in excess of 5 seconds. Controls shall include a load shed control, to operate a set of dry contacts (for use in shedding customer load devices) when the generator set is overloaded.

5. An AC over/under voltage monitoring system that responds only to true RMS voltage conditions shall be provided. The system shall initiate shutdown of the generator set when alternator output voltage exceeds 110% of the operator-set voltage level for more than 10 seconds, or with no intentional delay when voltage exceeds 130%. Under voltage shutdown shall occur when the output voltage of the alternator is less than 85% for more than 10 seconds.
 6. A battery monitoring system shall be provided which initiates alarms when the DC control and starting voltage is less than 25V DC or more than 32V DC. During engine starting, the low voltage limit shall be disabled, and if DC voltage drops to less than 14.4 volts for more than two seconds a "weak battery" alarm shall be initiated.
 7. When required by National Electrical Code or indicated on project drawings, the control System shall include a ground fault monitoring relay. The relay shall be adjustable from 3.8-1200 amps, and include adjustable time delay of 0-10.0 seconds. The relay shall be for indication only and not trip or shut down the generator set. Note bonding and grounding requirements for the generator set, and provide relay that will function correctly in system as installed.
- G. The generator set shall be provided with a network communication module to allow LonMark compliant communication with the generator set control by remote devices. The control shall communicate all engine and alternator data, and allow starting and stopping of the generator set via the network in both test and emergency modes.
- H. Provide and install a 20-light LED type remote alarm annunciator with horn, located in a location that can be conveniently monitored by facility personnel. The remote annunciator shall provide all the audible and visual alarms called for by NFPA Standard 110 for level 1 systems; and in addition shall provide indications for high battery voltage, low battery voltage, loss of normal power to the charger. Spare lamps shall be provided to allow future addition of other alarm and status functions to the annunciator. Provisions for labeling of the annunciator in a fashion consistent with the specified functions shall be provided. Alarm silence and lamp test switch(es) shall be provided. LED lamps shall be replaceable, and indicating lamp color shall be capable of changes needed for specific application requirements. Alarm horn shall be switchable for all annunciation points. Alarm horn (when switched on) shall sound for first fault, and all subsequent faults, regardless of whether first fault has been cleared, in compliance with NFPA110 3-5.6.2.
- I. The generator set shall be provided with a mounted main line circuit breaker, sized to carry the rated output current of the generator set on a continuous basis. The circuit breaker shall incorporate an electronic trip unit that operates to protect the alternator under all over-current conditions, or a thermal-magnetic trip with other over-current protection devices that positively protect the alternator under over-current conditions. The supplier shall submit time over-current characteristic curves and thermal damage curve for the alternator, demonstrating the effectiveness of the protection provided.
- J. Control Interfaces for Remote Monitoring:
1. All control and interconnection points from the generator set to remote components shall be brought to a separate connection box. No field connections shall be made in the control enclosure or in the AC power output enclosure. Provide the following features in the control system:
 - a. Form "C" dry common alarm contact set rated 2A @ 30V DC to indicate existence of any alarm or shutdown condition on the generator set.
 - b. One set of contacts rated 2A @ 30V DC to indicate generator set is ready to load. The contacts shall operate when voltage and frequency are greater than 90% of rated condition.
 - c. A fused 10 amp switched 24V DC power supply circuit shall be provided for customer use. DC power shall be available from this circuit whenever the generator set is running.

- d. A fused 20 amp 24V DC power supply circuit shall be provided for customer use. DC power shall be available from this circuit at all times from the engine starting/control batteries.
- e. The control shall be provided with a direct serial communication link for the LonWorks communication network interface as described elsewhere in this specification and shown on the drawings.

2.5 OUTDOOR WEATHER-PROTECTION SOUND ATTENUATING HOUSING

- A. The generator set shall be provided with a sound-attenuated housing which allows the generator set to operate at full rated load in the ambient conditions previously specified. The enclosure shall reduce the sound level of the generator set while operating at full rated load to a maximum of 80 dBA at any location 1 meter from the generator set in a free field environment. Housing configuration and materials used may be of any suitable design which meets application needs, except that acoustical materials used shall be oil and water resistant. No foam materials shall be used unless they can be demonstrated to have the same durability and life as fiberglass.
- B. The enclosure shall include hinged doors for access to both sides of the engine and alternator, and the control equipment. Key-locking and padlockable door latches shall be provided for all doors. Door hinges shall be stainless steel.
- C. The enclosure shall be provided with an exhaust silencer which is mounted inside of the enclosure, and allows the generator set package to meet specified sound level requirements. Silencer and exhaust shall extend to an external stack routed approximately 30-feet above grade/10-feet minimum above enclosure. Reference Mechanical (P2.01) plans for routing.
- D. All sheet metal shall be primed for corrosion protection and finish painted with the manufacturer's standard color. All surfaces of all metal parts shall be primed and painted.
- E. Painting of hoses, clamps, wiring harnesses, and other non-metallic service parts shall not be acceptable. Fasteners used shall be corrosion resistant, and designed to minimize marring of the painted surface when removed for normal installation or service work.
- F. The enclosure compartment shall be equipped with heat to maintain the interior above freezing conditions. Heating shall be an integral part of the enclosure. Nominal capacity 5-Kw (determined by mfg.) 208 volt/3-phase.

2.6 AUTOMATIC TRANSFER SWITCH

- A. See Specification Section 16640 – LOW VOLTAGE AUTOMATIC AND MANUAL TRANSFER SWITCHES for details.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Equipment shall be installed by the Design-Builder in accordance with final submittals and contract documents. Installation shall comply with applicable state and local codes as required by the authority

having jurisdiction. Install equipment in accordance with manufacturer's instructions and instructions included in the listing or labeling of UL listed products.

- B. Installation of equipment shall include furnishing and installing all interconnecting wiring between all major equipment provided for the on-site power system. The Design-Builder shall also perform interconnecting wiring between equipment sections (when required), under the supervision of the equipment supplier.
- C. Equipment shall be installed on concrete housekeeping pads. Equipment shall be permanently fastened to the pad in accordance with manufacturer's instructions and seismic requirements of the site. Refer to the structural plans for site specific seismic/geotechnical information.
- D. Equipment shall be initially started and operated by representatives of the manufacturer.
- E. All equipment shall be physically inspected for damage. Scratches and other installation damage shall be repaired prior to final system testing. Equipment shall be thoroughly cleaned to remove all dirt and construction debris prior to final testing of the system.
- F. All gas piping and generator exhaust piping shall be performed by a Massachusetts licensed plumber or gas fitter.

3.2 SEQUENCE OF OPERATION

- A. Generator set shall start on receipt of a start signal from remote equipment. The start signal shall be via hardwired connection to the generator set control.
- B. The generator set shall complete a time delay [10 sec] start period as programmed into the control.
- C. The generator set control shall initiate the starting sequence for the generator set. The starting sequence shall include the following functions:
 - 1. The control system shall verify that the engine is rotating when the starter is signaled to operate. If the engine does not rotate after two attempts, the control system shall shut down and lock out the generator set, and indicate "fail to crank" shutdown.
 - 2. The engine shall fire and accelerate as quickly as practical to start disconnect speed. If the engine does not start, it shall complete a cycle cranking process as described elsewhere in this specification. If the engine has not started by the completion of the cycle cranking sequence, it shall be shut down and locked out, and the control system shall indicate "fail to start".
 - 3. The engine shall accelerate to rated speed and the alternator to rated voltage. Excitation shall be disabled until the engine has exceeded programmed idle speed, and regulated to prevent over voltage conditions and oscillation as the engine accelerates and the alternator builds to rated voltage.
- D. On reaching rated speed and voltage, the generator set shall operate as dictated by the control system in isochronous, synchronize, load share, load demand, or load govern state.
- E. When all start signals have been removed from the generator set, it shall complete a time delay stop sequence. The duration of the time delay stop period shall be adjustable by the operator.
- F. On completion of the time delay stop period, the generator set control shall switch off the excitation system and shall shut down.

1. Any start signal received after the time stop sequence has begun shall immediately terminate the stopping sequence and return the generator set to isochronous operation.

3.3 FACTORY TESTING

- A. The generator set supplier shall perform a complete operational test on the generator set and provide a Certified Test Report to the MBTA and Engineer prior to shipping from the factory. Equipment supplied shall be fully tested at the factory for function and performance.
- B. Factory testing may be witnessed by the owner and consulting engineer. Costs for travel expenses will be the responsibility of the owner and consulting engineer. Supplier is responsible to provide a two week notice to the MBTA for testing.
- C. Generator set factory tests on the equipment shall be performed at rated load and rated power factor. Generator sets that have not been factory tested at rated power factor will not be acceptable. Tests shall include:
 1. Run at full load
 2. Maximum power
 3. Voltage regulation
 4. Transient and steady-state governing
 5. Single step load pickup
 6. Emergency Shut-down
 7. And function of safety shutdowns.

3.4 ON-SITE ACCEPTANCE TEST

- A. The complete installation shall be tested for compliance with the specification following the completion of all site work. The Design-Builder shall obtain the necessary temporary plumbing tag to complete the gas service to the generator set for start-up. Initial startup testing must be conducted by representatives of the manufacturer in the presence of the National Grid, Plumbing Design-Builder, MBTA, and State Plumbing/Gas Inspector, with required fuel service ready and inspected. The Engineer shall be notified in advance and shall have the option to witness the tests.
- B. Installation acceptance tests to be conducted on-site shall include a "cold start" test, a two hour full load test, and a one step rated load pickup test in accordance with NFPA 110. The Design-Builder must provide a portable resistive load bank rated for the generators full load and make all temporary connections and disconnections for the full load test.
- C. Perform a power failure test on the entire installed system. This test shall be conducted by opening the power supply from the utility service, and observing proper operation of the system for at least 2 hours. Coordinate timing and obtain approval for start of test with site personnel, the MBTA representative and the Engineer.
- D. Provide Written and Signed Test Results
- E. Provide Operating and Maintenance Manual with recommended Spare Parts List

3.5 TRAINING

- A. The equipment supplier shall provide training for the facility operating personnel covering operation and maintenance of the equipment provided. The training program shall be not less than 4 hours in

duration and the class size shall be limited to 5 persons. Training date shall be coordinated with the facility owner.

3.6 SERVICE AND SUPPORT

- A. The manufacturer of the generator set shall maintain service parts inventory at a central location which is accessible to the service location 24 hours per day, 365 days per year. The generator set shall be serviced by a local service organization that is trained and factory certified in generator set service. The supplier shall maintain an inventory of critical replacement parts at the local service organization, and in service vehicles.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16670

LIGHTNING PROTECTION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section includes lightning protection for structures.

1.3 ACTION SUBMITTALS

- A. Product Data: For each type of product indicated.
- B. Shop Drawings: For air terminals and mounting accessories.
 - 1. Layout of the lightning protection system, along with details of the components to be used in the installation.
 - 2. Include indications for use of raceway, data on how concealment requirements will be met, and calculations required by NFPA 780 for bonding of grounded and isolated metal bodies.

1.4 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For qualified Installer and manufacturer. Include data on listing or certification by UL.
- B. Certification, signed by Design-Builder, that roof adhesive is approved by manufacturer of roofing material.
- C. Field quality-control reports.
- D. Comply with recommendations in NFPA 780, Annex D, "Inspection and Maintenance of Lightning Protection Systems," for maintenance of the lightning protection system.
- E. Other Informational Submittals: Plans showing dimensioned as-built locations of grounding features, including the following:
 - 1. Ground rods.
 - 2. Ground loop conductor.

1.5 QUALITY ASSURANCE

- A. Installer Qualifications: Certified by UL, trained and approved for installation of units required for this Project.
- B. System Certificate:
 - 1. UL Master Label.
- C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 780, "Definitions" Article.

1.6 COORDINATION

- A. Coordinate installation of lightning protection with installation of other building systems and components, including electrical wiring, supporting structures and building materials, metal bodies requiring bonding to lightning protection components, and building finishes.
- B. Coordinate installation of air terminals attached to roof systems with roofing manufacturer and Installer.
- C. Flashings of through-roof assemblies shall comply with roofing manufacturers' specifications.

PART 2 - PRODUCTS

2.1 LIGHTNING PROTECTION SYSTEM COMPONENTS

- A. Comply with UL 96 and NFPA 780.
- B. Roof-Mounted Air Terminals: NFPA 780, Class I, copper unless otherwise indicated.
 - 1. Air Terminals More than 24 Inches Long: With brace attached to the terminal at not less than half the height of the terminal.
 - 2. Single-Membrane, Roof-Mounted Air Terminals: Designed specifically for single-membrane roof system materials. Comply with requirements in roofing Sections.
- C. Main and Bonding Conductors: Copper.
- D. Ground Loop Conductor: The same size and type as the main conductor except tinned.
- E. Ground Rods: Copper-clad steel; 3/4 inch in diameter by 10 feet long.
- F. Heavy-Duty, Stack-Mounted, Lightning Protection Components: Stainless steel.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install lightning protection components and systems per UL 96A and NFPA 780.
- B. Install conductors with direct paths from air terminals to ground connections. Avoid sharp bends.

- C. Conceal the following conductors:
 - 1. System conductors.
 - 2. Down conductors.
 - 3. Interior conductors.
 - 4. Conductors within normal view of exterior locations at grade within 200 feet of building.
- D. Cable Connections: Use exothermic-welded connections for all conductor splices and connections between conductors and other components.
 - 1. Exception: In single-ply membrane roofing, exothermic-welded connections may be used only below the roof level.
- E. Air Terminals on Single-Ply Membrane Roofing: Comply with roofing membrane and adhesive manufacturer's written instructions.
- F. Bond extremities of vertical metal bodies exceeding 60 feet in length to lightning protection components.
- G. Ground Loop: Install ground-level, potential equalization conductor and extend around the perimeter of structure.
 - 1. Bury ground ring not less than 24 inches from building foundation.
 - 2. Bond ground terminals to the ground loop.
 - 3. Bond grounded building systems to the ground loop conductor within 12 feet of grade level.
- H. Bond lightning protection components with intermediate-level interconnection loop conductors to grounded metal bodies of building at 60-foot intervals.

3.2 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

- A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 16050 "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK."

3.3 CORROSION PROTECTION

- A. Do not combine materials that can form an electrolytic couple that will accelerate corrosion in the presence of moisture unless moisture is permanently excluded from junction of such materials.
- B. Use conductors with protective coatings where conditions cause deterioration or corrosion of conductors.

3.4 FIELD QUALITY CONTROL

- A. Notify MBTA at least 48 hours in advance of inspection before concealing lightning protection components.
- B. UL Inspection: Meet requirements to obtain a UL Master Label for system.
- C. LPI System Inspection: Meet requirements to obtain an LPI System Certificate.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A.** Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION

SECTION 16705

FIRE-ALARM SYSTEM

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Volume 1 DB Contract Terms and Conditions and Volume 2 Technical Provisions.

1.2 SUMMARY

- A. Section Includes:
 - 1. Fire-alarm control unit.
 - 2. Manual fire-alarm boxes.
 - 3. System smoke detectors.
 - 4. Heat detectors.
 - 5. Notification appliances.
 - 6. Device guards.
 - 7. Magnetic door holders.
 - 8. Graphic annunciator.
 - 9. Addressable interface device.
 - 10. Digital alarm communicator transmitter.
 - 11. Network communications.

1.3 DEFINITIONS

- A. EMT: Electrical Metallic Tubing.
- B. FACP: Fire Alarm Control Panel.
- C. HLI: High Level Interface.
- D. NICET: National Institute for Certification in Engineering Technologies.
- E. PC: Personal computer.

1.4 REQUIREMENTS

- A. System shall be Class A, 4-wire system.
- B. System, all components and operating sequence shall be as approved by the local AHJ and MBTA.
- C. System and all components shall be compliant with Massachusetts Electrical Code (MEC).

1.5 SUBMITTALS

- A. Product Data: For each type of product, including furnished options and accessories.
1. Include construction details, material descriptions, dimensions, profiles, and finishes.
 2. Include rated capacities, operating characteristics, and electrical characteristics.
- B. Shop Drawings: For fire-alarm system.
1. Comply with recommendations and requirements in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
 2. Include plans, elevations, sections, details, and attachments to other work.
 3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and locations. Indicate conductor sizes, indicate termination locations and requirements, and distinguish between factory and field wiring.
 4. Detail assembly and support requirements.
 5. Include voltage drop calculations for notification-appliance circuits.
 6. Include battery-size calculations.
 7. Include input/output matrix.
 8. Include statement from manufacturer that all equipment and components have been tested as a system and meet all requirements in this Specification and in NFPA 72.
 9. Include performance parameters and installation details for each detector.
 10. Verify that each duct detector is listed for complete range of air velocity, temperature, and humidity possible when air-handling system is operating.
 11. Coordinate location of duct detectors and access to them.
 - a. Show critical dimensions that relate to placement and support of sampling tubes, detector housing, and remote status and alarm indicators.
 - b. Show field wiring required for HVAC unit shutdown on alarm.
 - c. Show field wiring and equipment required for HVAC unit shutdown on alarm and override by firefighters' control system.
 - d. Show field wiring and equipment required for HVAC unit shutdown on alarm and override by firefighters' smoke-evacuation system.
 - e. Locate detectors per manufacturer's written recommendations.
 12. Include voice/alarm signaling-service equipment rack or console layout, grounding schematic, amplifier power calculation, and single-line connection diagram.
 13. Include floor plans to indicate final outlet locations showing address of each addressable device. Show size and route of cable and conduits and point-to-point wiring diagrams.
- C. General Submittal Requirements:
1. Submittals shall be approved by authorities having jurisdiction (AHJ) prior to submitting them to MBTA.
- D. Delegated-Design Submittal: For notification appliances and smoke and heat detectors, in addition to submittals listed above, indicate compliance with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Drawings showing the location of each notification appliance and smoke and heat detector, ratings of each, and installation details as needed to comply with listing conditions of the device.
2. Design Calculations: Calculate requirements for selecting the spacing and sensitivity of detection, complying with NFPA 72. Calculate spacing and intensities for strobe signals and sound-pressure levels for audible appliances.
3. Indicate audible appliances required to produce square wave signal per NFPA 72.

1.6 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fire-alarm systems and components to include in emergency, operation, and maintenance manuals.
 1. Include the following:
 - a. Comply with the "Records" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
 - b. Provide "Fire Alarm and Emergency Communications System Record of Completion Documents" per the "Completion Documents" Article in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
 - c. Complete wiring diagrams showing connections between all devices and equipment. Each conductor shall be numbered at every junction point with indication of origination and termination points.
 - d. Riser diagram.
 - e. Device addresses.
 - f. Record copy of site-specific software.
 - g. Provide "Inspection and Testing Form" per the "Inspection, Testing and Maintenance" chapter in NFPA 72, and include the following:
 1. Equipment tested.
 2. Frequency of testing of installed components.
 3. Frequency of inspection of installed components.
 4. Requirements and recommendations related to results of maintenance.
 5. Manufacturer's user training manuals.
 - h. Manufacturer's required maintenance related to system warranty requirements.
 - i. Abbreviated operating instructions for mounting at fire-alarm control unit and each annunciator unit.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
 1. Lamps for Remote Indicating Lamp Units: Quantity equal to 10 % of amount installed, but no fewer than one unit.
 2. Lamps for Strobe Units: Quantity equal to 10 % of amount installed, but no fewer than one unit.
 3. Smoke Detectors, Fire Detectors: Quantity equal to 10 % of amount of each type installed, but no fewer than one unit of each type.
 4. Detector Bases: Quantity equal to 10 % of amount of each type installed, but no fewer than one unit of each type.

5. Keys and Tools: One extra set for access to locked or tamper-proofed components.
6. Audible and Visual Notification Appliances: 10 of each type installed.
7. Fuses: 10 of each type installed in the system. Provide in a box or cabinet with compartments marked with fuse types and sizes.

1.8 QUALITY ASSURANCE

- A. Installer Qualifications: Personnel shall be trained and certified by manufacturer for installation of units required for this Project.
- B. NFPA Certification: Obtain certification per NFPA 72 by a UL-listed alarm company.

1.9 PROJECT CONDITIONS

- A. Perform a full test of the existing system prior to starting work. Document any equipment or components not functioning as designed.
- B. Interruption of Existing Fire-Alarm Service: Do not interrupt fire-alarm service to facilities occupied by MBTA or others unless permitted under the following conditions and then only after arranging to provide temporary guard service per requirements indicated:
 1. Notify MBTA no fewer than seven days in advance of proposed interruption of fire-alarm service.
 2. Do not proceed with interruption of fire-alarm service without Construction Manager's, MBTA's written permission.
- C. Use of Devices during Construction: Protect devices during construction unless devices are placed in service to protect the facility during construction.

1.10 SEQUENCING AND SCHEDULING

- A. Existing Fire-Alarm Equipment: Maintain existing equipment fully operational until new equipment has been tested and accepted. As new equipment is installed, label it "NOT IN SERVICE" until it is accepted. Remove labels from new equipment when put into service, and label existing fire-alarm equipment "NOT IN SERVICE" until removed from the building.
- B. Equipment Removal: After acceptance by MBTA of new fire-alarm system, remove existing disconnected fire-alarm equipment and wiring.

1.11 WARRANTY

- A. Warranty: Design Builder agrees to repair or replace fire-alarm system equipment and components that fail in materials or workmanship within manufacturer's specified warranty period.
 1. Warranty shall include all materials and labor.
 2. Warranty Period: 1 year from date of acceptance by MBTA.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

- A. Source Limitations for Fire-Alarm System and Components: Components shall be compatible with, and operate as an extension of existing system. Provide system manufacturer's certification that all components provided have been tested as, and will operate as, a system.
- B. Noncoded, addressable system, with multiplexed signal transmission and voice/strobe evacuation.
- C. Automatic sensitivity control of certain smoke detectors.
- D. All components provided shall be listed for use with the selected system.
- E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in MEC, by a qualified testing agency, and marked for intended location and application.

2.2 SYSTEMS OPERATIONAL DESCRIPTION

- A. Fire-alarm signal initiation shall be by one or more of the following devices where applicable:
 - 1. Manual stations.
 - 2. Heat detectors.
 - 3. Smoke detectors.
 - 4. Duct smoke detectors.
 - 5. Carbon monoxide detectors.
 - 6. Automatic sprinkler system water flow.
 - 7. Pre-action system.
 - 8. Fire-extinguishing system operation.
 - 9. Fire standpipe system.
 - 10. Dry system pressure flow switch.
 - 11. Fire pump running.
- B. Fire-alarm signal shall initiate the following actions:
 - 1. Continuously operate alarm notification appliances, including voice evacuation notices.
 - 2. Identify alarm and specific initiating device at fire-alarm control unit, connected network control panels, and remote annunciators.
 - 3. Transmit an alarm signal to the remote alarm receiving station.
 - 4. Transmit alarm signal via the Master Box
 - 5. Unlock electric door locks in designated egress paths.
 - 6. Release fire and smoke doors held open by magnetic door holders.
 - 7. Activate voice/alarm communication system.
 - 8. Switch heating, ventilating, and air-conditioning equipment controls to fire-alarm mode.
 - 9. Close smoke dampers in air ducts of designated air-conditioning duct systems.
 - 10. Recall elevators to primary or alternate recall floors.
 - 11. Activate elevator power shunt trip.
 - 12. Activate emergency lighting control.
 - 13. Activate emergency shutoffs for gas and fuel supplies.
 - 14. Record events in the system memory.
 - 15. Record events by the system printer.

16. Indicate device in alarm on the graphic annunciator.
 17. Activate exterior alarm beacon.
- C. Supervisory signal initiation shall be by one or more of the following devices and actions:
1. Valve supervisory switch.
 2. High- or low-air-pressure switch of a dry-pipe or pre-action sprinkler system.
 3. Elevator shunt-trip supervision.
 4. Fire pump running.
 5. Fire-pump loss of power.
 6. Fire-pump power phase reversal.
 7. Independent fire-detection and -suppression systems.
 8. User disabling of zones or individual devices.
 9. Loss of communication with any panel on the network.
- D. System trouble signal initiation shall be by one or more of the following devices and actions:
1. Open circuits, shorts, and grounds in designated circuits.
 2. Opening, tampering with, or removing alarm-initiating and supervisory signal-initiating devices.
 3. Loss of communication with any addressable sensor, input module, relay, control module, remote annunciator, printer interface, or Ethernet module.
 4. Loss of primary power at fire-alarm control unit.
 5. Ground or a single break in internal circuits of fire-alarm control unit.
 6. Abnormal ac voltage at fire-alarm control unit.
 7. Break in standby battery circuitry.
 8. Failure of battery charging.
 9. Abnormal position of any switch at fire-alarm control unit or annunciator.
 10. Voice signal amplifier failure.
- E. System Supervisory Signal Actions:
1. Initiate notification appliances.
 2. Identify specific device initiating the event at fire-alarm control unit, connected network control panels, and remote annunciators.
 3. After a time, delay of 200 seconds (adjustable), transmit a trouble or supervisory signal to the remote alarm receiving station.
 4. Transmit system status to building management system.
 5. Display system status on graphic annunciator.

2.3 PERFORMANCE REQUIREMENTS

- A. Seismic Performance: Fire-alarm control unit and raceways shall withstand the effects of earthquake motions determined per ASCE/SEI 7.
1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2.4 FIRE-ALARM CONTROL PANEL

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. GE UTC Fire & Security; A United Technologies Company.
 2. Mircom Technologies, Ltd.
 3. Notifier.
 4. Siemens Industry, Inc.; Fire Safety Division.
 5. Simplex Grinnell LP.
 - a. System software and programs shall be held in nonvolatile flash, electrically erasable, programmable, read-only memory, retaining the information through failure of primary and secondary power supplies.
 - b. Include a real-time clock for time annotation of events on the event recorder.
 - c. Provide communication between the FACP and remote circuit interface panels, annunciators, and displays.
 - d. The FACP shall be listed for connection to a remote-station signaling system service.
 - e. Provide nonvolatile memory for system database, logic, and operating system and event history. The system shall require no manual input to initialize in the event of a complete power down condition. The FACP shall provide a minimum 500-event history log.
 6. Addressable Initiation Device Circuits: The FACP shall indicate which communication zones have been silenced and shall provide selective silencing of alarm notification appliance by building communication zone.
 7. Addressable Control Circuits for Operation of Notification Appliances and Mechanical Equipment: The FACP shall be listed for releasing service.
- B. Alphanumeric Display and System Controls: Arranged for interface between human operator at fire-alarm control unit and addressable system components including annunciation and supervision. Display alarm, supervisory, and component status messages and the programming and control menu.
1. Annunciator and Display: Liquid-crystal type, 80 characters, minimum.
 2. Keypad: Arranged to permit entry and execution of programming, display, and control commands.
- C. Initiating-Device, Notification-Appliance, and Signaling-Line Circuits:
1. Pathway Class Designations: NFPA 72, Class A.
 2. Pathway Survivability: Level 0.
 3. Install no more than 100 addressable devices on each signaling-line circuit.
 4. Serial Interfaces:
 - a. One dedicated RS 485 port for remote station operation using point ID DACT.
 - b. One RS 485 port for remote annunciators, Ethernet module, or multi-interface module (printer port).
 - c. One USB port for PC configuration.
 - d. One RS 232 port for VESDA HLI connection.
 - e. One RS 232 port for voice evacuation interface.
- D. Smoke-Alarm Verification:
1. Initiate audible and visible indication of an "alarm-verification" signal at fire-alarm control unit.
 2. Activate an approved "alarm-verification" sequence at fire-alarm control unit and detector.
 3. Record events.
 4. Sound general alarm if the alarm is verified.
 5. Cancel fire-alarm control unit indication and system reset if the alarm is not verified.

E. Notification-Appliance Circuit:

1. Audible appliances shall sound in a three-pulse temporal pattern, as defined in NFPA 72 or as approved by the AHJ in the respective city and MBTA.
2. Where notification appliances provide signals to sleeping areas, the alarm signal shall be a 520-Hz square wave with an intensity 15 dB above the average ambient sound level or 5 dB above the maximum sound level, or at least 75 dBA, whichever is greater, measured at the pillow.
3. Visual alarm appliances shall flash in synchronization where multiple appliances are in the same field of view, as defined in NFPA 72.

F. Elevator Recall:

1. Elevator recall shall be initiated only by one of the following alarm-initiating devices:
 - a. Elevator lobby detectors except the lobby detector on the designated floor.
 - b. Smoke detector in elevator machine room.
 - c. Smoke detectors in elevator hoistway.
2. Elevator controller shall be programmed to move the cars to the alternate recall floor if lobby detectors located on the designated recall floors are activated.
3. Water-flow alarm connected to sprinkler in an elevator shaft and elevator machine room shall shut down elevators associated with the location without time delay.
 - a. Water-flow switch associated with the sprinkler in the elevator pit may have a delay to allow elevators to move to the designated floor.

G. Door Controls: Door hold-open devices that are controlled by smoke detectors at doors in smoke-barrier walls shall be connected to fire-alarm system.

H. Transmission to Remote Alarm Receiving Station: Automatically transmit alarm, supervisory, and trouble signals to a remote alarm station.

I. Voice/Alarm Signaling Service: Central emergency communication system with redundant microphones, preamplifiers, amplifiers, and tone generators provided in a separate cabinet located in the fire command center or as a special module that is part of fire-alarm control unit.

1. Indicate number of alarm channels for automatic, simultaneous transmission of different announcements to different zones or for manual transmission of announcements by use of the central-control microphone. Amplifiers shall comply with UL 1711.
 - a. Allow the application of, and evacuation signal to, indicated number of zones and, at the same time, allow voice paging to the other zones selectively or in any combination.
 - b. Programmable tone and message sequence selection.
 - c. Standard digitally recorded messages for "Evacuation" and "All Clear."
 - d. Generate tones to be sequenced with audio messages of type recommended by NFPA 72 and that are compatible with tone patterns of notification-appliance circuits of fire-alarm control unit.
2. Status Annunciator: Indicate the status of various voice/alarm speaker zones and the status of firefighters' two-way telephone communication zones.
3. Preamplifiers, amplifiers, and tone generators shall automatically transfer to backup units, on primary equipment failure.

- J. Printout of Events: On receipt of signal, print alarm, supervisory, and trouble events. Identify zone, device, and function. Include type of signal (alarm, supervisory, or trouble) and date and time of occurrence. Differentiate alarm signals from all other printed indications. Also print system reset event, including same information for device, location, date, and time. Commands initiate the printing of a list of existing alarm, supervisory, and trouble conditions in the system and a historical log of events.
- K. Primary Power: 24-V dc obtained from 120-V ac emergency power source and a power-supply module. Initiating devices, notification appliances, signaling lines, trouble signals, supervisory signals supervisory and digital alarm communicator transmitters and digital alarm radio transmitters shall be powered by 24-V dc source.
 - 1. Alarm current draw of entire fire-alarm system shall not exceed 80 % of the power-supply module rating.
- L. Secondary Power: 24-V dc supply system with batteries, automatic battery charger, and automatic transfer switch.
 - 1. Batteries: Sealed lead calcium.
- M. Instructions: Computer printout or typewritten instruction card mounted behind a plastic or glass cover in a stainless-steel or aluminum frame. Include interpretation and describe appropriate response for displays and signals. Briefly describe the functional operation of the system under normal, alarm, and trouble conditions.

2.5 PREACTION SYSTEM

- A. Initiate Pre-signal Alarm: This function shall cause an audible and visual alarm and indication to be provided at the FACP. Activation of an initiation device connected as part of a preaction system shall be annunciated at the FACP only, without activation of the general evacuation alarm.

2.6 MANUAL FIRE-ALARM PULL STATIONS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. GE UTC Fire & Security; A United Technologies Company.
 - 2. Mircom Technologies, Ltd.
 - 3. Notifier.
 - 4. Siemens Industry, Inc.; Fire Safety Division.
 - 5. SimplexGrinnell LP.
- B. General Requirements for Manual Fire-Alarm Boxes: Comply with UL 38. Boxes shall be finished in red with molded, raised-letter operating instructions in contrasting color; shall show visible indication of operation; and shall be mounted on recessed outlet box where practical. If surface mounted, provide manufacturer's surface back box.
 - 1. Double-action mechanism requiring two actions to initiate an alarm, pull-lever type; with integral, attached addressable module arranged to communicate manual-station status (normal, alarm, or trouble) to fire-alarm control unit.
 - 2. Station Reset: Key- or wrench-operated switch.

3. Protective Shield: Factory-fabricated, clear polycarbonate enclosure hinged at the top to permit lifting for access to initiate an alarm. Lifting the cover actuates an integral battery-powered audible horn intended to discourage false-alarm operation.

2.7 SYSTEM SMOKE DETECTORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 1. GE UTC Fire & Security; A United Technologies Company.
 2. Mircom Technologies, Ltd.
 3. Notifier.
 4. Siemens Industry, Inc.; Fire Safety Division.
 5. SimplexGrinnell LP.
- B. General Requirements for System Smoke Detectors:
 1. Comply with UL 268; operating at 24-V dc, nominal.
 2. Detectors shall be four-wire type.
 3. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to fire-alarm control unit.
 4. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. Provide terminals in the fixed base for connection to building wiring.
 5. Self-Restoring: Detectors do not require resetting or readjustment after actuation to restore them to normal operation.
 6. Integral Visual-Indicating Light: LED type, indicating detector has operated and power-on status.
 7. Remote Control: If required by MBTA, detectors shall be digital-addressable type, individually monitored at fire-alarm control unit for calibration, sensitivity, and alarm condition and individually adjustable for sensitivity by fire-alarm control unit.
 - a. Rate-of-rise temperature characteristic of combination smoke- and heat-detection units shall be selectable at fire-alarm control unit for 15 or 20 deg F per minute.
 - b. Fixed-temperature sensing characteristic of combination smoke- and heat-detection units shall be independent of rate-of-rise sensing and shall be settable at fire-alarm control unit to operate at 135 or 155 deg F.
 - c. Multiple levels of detection sensitivity for each sensor.
- C. Photoelectric Smoke Detectors:
 1. Detector address shall be accessible from fire-alarm control unit and shall be able to identify the detector's location within the system and its sensitivity setting.
 2. An operator at fire-alarm control unit, having the designated access level, shall be able to manually access the following for each detector:
 - a. Primary status.
 - b. Device type.
 - c. Present average value.
 - d. Present sensitivity selected.
 - e. Sensor range (normal, dirty, etc.).

D. Ionization Smoke Detector:

1. Detector address shall be accessible from fire-alarm control unit and shall be able to identify the detector's location within the system and its sensitivity setting.
2. An operator at fire-alarm control unit, having the designated access level, shall be able to manually access the following for each detector:
 - a. Primary status.
 - b. Device type.
 - c. Present average value.
 - d. Present sensitivity selected.
 - e. Sensor range (normal, dirty, etc.).

E. Duct Smoke Detectors:

1. Duct smoke detectors will be provided by Division 15. Wiring to fire alarm system under this section.
2. Relay Fan Shutdown: Fully programmable relay rated to interrupt fan motor-control circuit.

2.8 CARBON MONOXIDE DETECTORS

A. General: Carbon monoxide detector listed for connection to fire-alarm system.

1. Mounting: Adapter plate for outlet box mounting.
2. Testable by introducing test carbon monoxide into the sensing cell.
3. Detector shall provide alarm contacts and trouble contacts.
4. Detector shall send trouble alarm when nearing end-of-life, power supply problems, or internal faults.
5. Comply with UL 2075.
6. Locate, mount, and wire per manufacturer's written instructions.
7. Provide means for addressable connection to fire-alarm system.
8. Test button simulates an alarm condition.

2.9 MULTICRITERIA DETECTORS

- A. Mounting: Twist-lock base interchangeable with smoke-detector bases.
- B. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to fire-alarm control unit.
- C. Automatically adjusts its sensitivity by means of drift compensation and smoothing algorithms. The detector shall send trouble alarm if it is incapable of compensating for existing conditions.
- D. Test button tests all sensors in the detector.
- E. An operator at fire-alarm control unit, having the designated access level, shall be able to manually access the following for each detector:
 1. Primary status.
 2. Device type.
 3. Present sensitivity selected.

4. Sensor range (normal, dirty, etc.).
- F. Sensors: The detector shall be comprised of four sensing elements including a smoke sensor, a carbon monoxide sensor, an infrared sensor, and a heat sensor.
1. Smoke sensor shall be photoelectric type as described in "System Smoke Detectors" Article.
 2. Carbon monoxide sensor shall be as described in "Carbon Monoxide Detectors" Article.
 3. Heat sensor shall be as described in "Heat Detectors" Article.
 4. Each sensor shall be separately listed per requirements for its detector type.

2.10 HEAT DETECTORS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. GE UTC Fire & Security; A United Technologies Company.
 2. Mircom Technologies, Ltd.
 3. Notifier.
 4. Siemens Industry, Inc.; Fire Safety Division.
 5. SimplexGrinnell LP.
- B. General Requirements for Heat Detectors: Comply with UL 521.
1. Temperature sensors shall test for and communicate the sensitivity range of the device.
- C. Heat Detector, Combination Type: Actuated by either a fixed temperature of 135 deg F or a rate of rise that exceeds 15 deg F per minute unless otherwise indicated.
1. Mounting: Twist-lock base interchangeable with smoke-detector bases.
 2. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to fire-alarm control unit.
- D. Heat Detector, Fixed-Temperature Type: Actuated by temperature that exceeds a fixed temperature of 190 deg F.
1. Mounting: Twist-lock base interchangeable with smoke-detector bases.
 2. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to fire-alarm control unit.

2.11 NOTIFICATION APPLIANCES

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. GE UTC Fire & Security; A United Technologies Company.
 2. Mircom Technologies, Ltd.
 3. Siemens Industry, Inc.; Fire Safety Division.
 4. SimplexGrinnell LP.
- B. General Requirements for Notification Appliances: Individually addressed, connected to a signaling-line circuit, equipped for mounting as required, and with screw terminals for system connections.

1. Combination Devices: Factory-integrated audible and visible devices in a single-mounting assembly, equipped for mounting as indicated, and with screw terminals for system connections.
- C. Chimes, Low-Level Output: Vibrating type, 75-dBA minimum rated output.
- D. Chimes, High-Level Output: Vibrating type, 81-dBA minimum rated output.
- E. Horns: Electric-vibrating-polarized type, 24-V dc; with provision for housing the operating mechanism behind a grille. Comply with UL 464. Horns shall produce a sound-pressure level of 90 dBA, measured 10 feet from the horn, using the coded signal prescribed in UL 464 test protocol.
- F. Visible Notification Appliances: Xenon strobe lights complying with UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate. The word "FIRE" green, engraved in minimum 1-inch- high letters on the lens.
1. Rated Light Output:
 - a. 15, 30, 75, 110, 177 cd.
 - b. 15/30/75/110 cd, selectable in the field.
 2. Mounting: Wall mounted unless otherwise required.
 3. For units with guards to prevent physical damage, light output ratings shall be determined with guards in place.
 4. Flashing shall be in a temporal pattern, synchronized with other units.
 5. Strobe Leads: Factory connected to screw terminals.
 6. Mounting Faceplate: Factory finished, red.
- G. Voice/Tone Notification Appliances:
1. Comply with UL 1480.
 2. Speakers for Voice Notification: Locate speakers for voice notification to provide the intelligibility requirements of the "Notification Appliances" and "Emergency Communications Systems" chapters in NFPA 72.
 3. High-Range Units: Rated 2 to 15 W.
 4. Low-Range Units: Rated 1 to 2 W.
 5. Mounting: Flush or surface mounted and bidirectional.
 6. Matching Transformers: Tap range matched to acoustical environment of speaker location.

2.12 MAGNETIC DOOR HOLDERS

- A. Description: Units are equipped for wall or floor mounting as indicated and are complete with matching doorplate.
1. Electromagnets: Require no more than 3 W to develop 25-lbf holding force.
 2. Wall-Mounted Units: Flush mounted unless otherwise indicated.
 3. Rating: 24-V dc.
- B. Material and Finish: Match door hardware.

2.13 GRAPHIC ANNUNCIATOR

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
 - 1. GE UTC Fire & Security; A United Technologies Company.
 - 2. Mircom Technologies, Ltd.
 - 3. Siemens Industry, Inc.; Fire Safety Division.
 - 4. SimplexGrinnell LP.
 - 5. H. R. Kirkland, Inc.
 - 6. Space Age Electronics.
 - 7. Light Engineered Displays, Inc.

- B. Graphic Annunciator Workstation: PC-based, with fire-alarm annunciator software with historical logging, report generation, and a graphic interface showing all alarm points in the system. PC with operating system software, minimum 500GB hard drive, 20" digital display monitor, with wireless keyboard and mouse.

2.14 ADDRESSABLE INTERFACE DEVICE

- A. General:
 - 1. Include address-setting means on the module.
 - 2. Store an internal identifying code for control panel use to identify the module type.
 - 3. Listed for controlling HVAC fan motor controllers.

- B. Monitor Module: Microelectronic module providing a system address for alarm-initiating devices for wired applications with normally open contacts.

- C. Integral Relay: Capable of providing a direct signal to elevator controller to initiate elevator recall.
 - 1. Allow the control panel to switch the relay contacts on command.
 - 2. Have a minimum of two normally open and two normally closed contacts available for field wiring.

- D. Control Module:
 - 1. Operate notification devices.
 - 2. Operate solenoids for use in sprinkler service.
 - 3. Operate necessary interface equipment.

2.15 DIGITAL ALARM COMMUNICATOR TRANSMITTER

- A. Digital alarm communicator transmitter shall be acceptable to the remote central station and shall comply with UL 632.

- B. Functional Performance: Unit shall receive an alarm, supervisory, or trouble signal from fire-alarm control unit and automatically capture one telephone line(s) and dial a preset number for a remote central station. When contact is made with central station(s), signals shall be transmitted. If service on either line is interrupted for longer than 45 seconds, transmitter shall initiate a local trouble signal and transmit the signal indicating loss of telephone line to the remote alarm receiving station over the

remaining line. Transmitter shall automatically report telephone service restoration to the central station. If service is lost on both telephone lines, transmitter shall initiate the local trouble signal.

- C. Local functions and display at the digital alarm communicator transmitter shall include the following:
 - 1. Verification that both telephone lines are available.
 - 2. Programming device.
 - 3. LED display.
 - 4. Manual test report function and manual transmission clear indication.
 - 5. Communications failure with the central station or fire-alarm control unit.

- D. Digital data transmission shall include the following:
 - 1. Address of the alarm-initiating device.
 - 2. Address of the supervisory signal.
 - 3. Address of the trouble-initiating device.
 - 4. Loss of ac supply.
 - 5. Loss of power.
 - 6. Low battery.
 - 7. Abnormal test signal.
 - 8. Communication bus failure.

- E. Secondary Power: Integral rechargeable battery and automatic charger.

- F. Self-Test: Conducted automatically every 24 hours with report transmitted to central station.

2.16 NETWORK COMMUNICATIONS

- A. Provide network communications for fire-alarm system per fire-alarm manufacturer's written requirements.

- B. Provide network communications pathway per manufacturer's written requirements and requirements in NFPA 72 and MEC.

- C. Provide integration gateway using BACnet, Modbus or as "specified by others" for connection to building automation system.

2.17 SYSTEM PRINTER

- A. Printer shall be listed and labeled as an integral part of fire-alarm system.

2.18 DEVICE GUARDS

- A. Description: Polycarbonate of size and shape for the manual station, smoke detector, gong, or other device requiring protection.
 - 1. Factory fabricated and furnished by device manufacturer.
 - 2. Finish: Paint of color to match the protected device.

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine areas and conditions for compliance with requirements for ventilation, temperature, humidity, and other conditions affecting performance of the Work.
 - 1. Verify that manufacturer's written instructions for environmental conditions have been permanently established in spaces where equipment and wiring are installed, before installation begins.
- B. Examine roughing-in for electrical connections to verify actual locations of connections before installation.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EQUIPMENT INSTALLATION

- A. Comply with NFPA 72, NFPA 101, and requirements of authorities having jurisdiction for installation and testing of fire-alarm equipment. Install all electrical wiring to comply with requirements in Massachusetts Electrical Code, including, but not limited to, Article 760, "Fire Alarm Systems."
 - 1. Devices placed in service before all other trades have completed cleanup shall be replaced.
 - 2. Devices installed but not yet placed in service shall be protected from construction dust, debris, dirt, moisture, and damage per manufacturer's written storage instructions.
- B. Install wall-mounted equipment, with tops of cabinets not more than 78 inches above the finished floor.
 - 1. Comply with requirements for seismic-restraint devices specified in Section 16074 "Seismic Controls for Electrical Systems."
- C. Manual Fire-Alarm Pull Stations:
 - 1. Install manual fire-alarm box in the normal path of egress within 60 inches of the exit doorway.
 - 2. Mount manual fire-alarm box on a background of a contrasting color.
 - 3. The operable part of manual fire-alarm box shall be between 42 inches and 48 inches above floor level. All devices shall be mounted at the same height unless otherwise indicated.
- D. Smoke- or Heat-Detector Spacing:
 - 1. Comply with the "Smoke-Sensing Fire Detectors" section in the "Initiating Devices" chapter in NFPA 72, for smoke-detector spacing.
 - 2. Comply with the "Heat-Sensing Fire Detectors" section in the "Initiating Devices" chapter in NFPA 72, for heat-detector spacing.
 - 3. Smooth ceiling spacing shall not exceed 30 feet.
 - 4. Spacing of detectors for irregular areas, for irregular ceiling construction, and for high ceiling areas shall be determined per Annex A or Annex B in NFPA 72.
 - 5. HVAC: Locate detectors not closer than 36 inches from air-supply diffuser or return-air opening.

6. Lighting Fixtures: Locate detectors not closer than 12 inches from any part of a lighting fixture and not directly above pendant mounted or indirect lighting.
- E. Install a cover on each smoke detector that is not placed in service during construction. Cover shall remain in place except during system testing. Remove cover prior to system turnover.
- F. Duct Smoke Detectors: Comply with NFPA 72 and NFPA 90A. Install sampling tubes so they extend the full width of duct. Tubes more than 36 inches long shall be supported at both ends.
 1. Do not install smoke detector in duct smoke-detector housing during construction. Install detector only during system testing and prior to system turnover.
- G. Elevator Shafts: Coordinate temperature rating and location with sprinkler rating and location. Do not install smoke detectors in sprinklered elevator shafts.
- H. Single-Station Smoke Detectors: Where more than one smoke alarm is installed within a dwelling or suite, they shall be connected so that the operation of any smoke alarm causes the alarm in all smoke alarms to sound.
- I. Remote Status and Alarm Indicators: Install in a visible location near each smoke detector, sprinkler water-flow switch, and valve-tamper switch that is not readily visible from normal viewing position.
- J. Audible Alarm-Indicating Devices: Install not less than 6 inches below the ceiling. Install bells and horns on flush-mounted back boxes with the device-operating mechanism concealed behind a grille. Install all devices at the same height unless otherwise indicated.
- K. Visible Alarm-Indicating Devices: Install adjacent to each alarm bell or alarm horn and at least 6 inches below the ceiling. Install all devices at the same height unless otherwise indicated.
- L. Device Location-Indicating Lights: Locate in public space near the device they monitor.

3.3 PATHWAYS

- A. Pathways above recessed ceilings and in non-accessible locations may be routed exposed.
 1. Exposed pathways located more than 96 inches above the floor shall be installed in EMT
 2. Exposed pathways located less than 96 inches above the floor shall be installed in Rigid galvanized steel conduit.
- B. Exposed EMT shall be painted as required by MBTA.

3.4 CONNECTIONS

- A. For fire-protection systems related to doors in fire-rated walls and partitions and to doors in smoke partitions, comply with requirements in Section 08711 "Door Hardware." Connect hardware and devices to fire-alarm system.
 1. Verify that hardware and devices are listed for use with installed fire-alarm system before making connections.

- B. Make addressable connections with a supervised interface device to the following devices and systems. Install the interface device less than 36 inches from the device controlled. Make an addressable confirmation connection when such feedback is available at the device or system being controlled.
1. Alarm-initiating connection to smoke-control system (smoke management) at firefighters' smoke-control system panel.
 2. Alarm-initiating connection to stairwell and elevator-shaft pressurization systems.
 3. Smoke dampers in air ducts of designated HVAC duct systems.
 4. Magnetically held-open doors.
 5. Electronically locked doors and access gates.
 6. Alarm-initiating connection to elevator recall system and components.
 7. Alarm-initiating connection to activate emergency lighting control.
 8. Alarm-initiating connection to activate emergency shutoffs for gas and fuel supplies.
 9. Supervisory connections at valve supervisory switches.
 10. Supervisory connections at low-air-pressure switch of each dry-pipe sprinkler system.
 11. Supervisory connections at elevator shunt-trip breaker.
 12. Data communication circuits for connection to building management system.
 13. Data communication circuits for connection to mass notification system.
 14. Supervisory connections at fire-extinguisher locations.
 15. Supervisory connections at fire-pump power failure including a dead-phase or phase-reversal condition.
 16. Supervisory connections at fire-pump engine control panel.

3.5 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 16195 "Electrical Identification."
- B. Install framed instructions in a location visible from fire-alarm control unit.

3.6 GROUNDING

- A. Ground fire-alarm control unit and associated circuits; comply with IEEE 1100. Install a ground wire from main service ground to fire-alarm control unit.
- B. Ground shielded cables at the control panel location only. Insulate shield at device location.

3.7 FIELD QUALITY CONTROL

- A. Field tests shall be witnessed by authorities having jurisdiction and MBTA representative.
- B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
- C. Perform tests and inspections.
- D. Perform the following tests and inspections with the assistance of a factory-authorized service representative:

1. Visual Inspection: Conduct visual inspection prior to testing.
 - a. Inspection shall be based on completed record Drawings and system documentation that is required by the "Completion Documents, Preparation" table in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
 - b. Comply with the "Visual Inspection Frequencies" table in the "Inspection" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72; retain the "Initial/Reacceptance" column and list only the installed components.
 2. System Testing: Comply with the "Test Methods" table in the "Testing" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
 3. Test audible appliances for the public operating mode per manufacturer's written instructions. Perform the test using a portable sound-level meter complying with Type 2 requirements in ANSI S1.4.
 4. Test audible appliances for the private operating mode per manufacturer's written instructions.
 5. Test visible appliances for the public operating mode per manufacturer's written instructions.
 6. Factory-authorized service representative shall prepare the "Fire Alarm System Record of Completion" in the "Documentation" section of the "Fundamentals" chapter in NFPA 72 and the "Inspection and Testing Form" in the "Records" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
- E. Reacceptance Testing: Perform reacceptance testing to verify the proper operation of added or replaced devices and appliances.
- F. Fire-alarm system will be considered defective if it does not pass tests and inspections.
- G. Prepare test and inspection reports.
- H. Maintenance Test and Inspection: Perform tests and inspections listed for weekly, monthly, quarterly, and semiannual periods. Use forms developed for initial tests and inspections.
- I. Annual Test and Inspection: One year after date of Substantial Completion, test fire-alarm system complying with visual and testing inspection requirements in NFPA 72. Use forms developed for initial tests and inspections.

3.8 MAINTENANCE SERVICE

- A. Initial Maintenance Service: Beginning at Substantial Completion, maintenance service shall include 12 months' full maintenance by skilled employees of manufacturer's designated service organization. Include preventive maintenance, repair or replacement of worn or defective components, lubrication, cleaning, and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.
1. Include visual inspections per the "Visual Inspection Frequencies" table in the "Testing" paragraph of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
 2. Perform tests in the "Test Methods" table in the "Testing" paragraph of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
 3. Perform tests per the "Testing Frequencies" table in the "Testing" paragraph of the "Inspection, Testing and Maintenance" chapter in NFPA 72.

3.9 SOFTWARE SERVICE AGREEMENT

- A. Comply with UL 864.
- B. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for two years.
- C. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
 - 1. Upgrade Notice: At least 30 days to allow MBTA to schedule access to system and to upgrade computer equipment if necessary.

3.10 DEMONSTRATION

- A. Engage a factory-authorized service representative to train MBTA's maintenance personnel to adjust, operate, and maintain fire-alarm system.

PART 4 - MEASUREMENT AND PAYMENT

4.1 GENERAL

- A. Separate measurement and payment will not be made for the work of this section, but all costs in connection therewith are included in the contract price as identified in Volume 1 DB Contract Terms and Conditions Section 14 "Payment".

END OF SECTION